CHAPTER 4

TOOLS FOR DEVELOPING EMISSION INVENTORIES

Chapter 4 Objective: ***To present an overview of the tools available for the development of emission inventories.***

As summarized in Figure 2.1, the emission inventory development process begins with emission measurements, compilation of activity data, development of emission factors and models, and collection of data from individual sources. Emission inventories are then compiled at the local, state or provincial, regional, or national level, subjected to quality assurance checks and reviews, and enhanced as necessary for their particular use.

Extensive guidance on preparing emission inventories is available from several sources:

Canada: http://www.ec.gc.ca/pdb/npri/2002guidance/cac2002/CACs_2002_p6_e.cfm

United States: http://www.epa.gov/ttn/chief/eidocs/eiguid/; http://www.epa.gov/ttn/chief/eiip/

Mexico: http://www.epa.gov/ttn/catc/dir1/volume.pdf

International global climate: http://www.ipcc-nggip.iges.or.jp/public/gp/english.

This chapter discusses the ensemble of inventory development tools and associated programs, focusing primarily on methods applied by Canada, the United States, and Mexico. The reader is introduced to emission inventory methods and guidance, emission factors and speciation profiles, emission-related activity data, emission inventory models, emission processors, emission projections, emission test methods, data management, and QA/QC methods. In addition to the excellent guidance provided by the websites listed above, references are provided for each tool. The strengths and weaknesses of the tools introduced here are addressed in Chapter 5.

4.1 EMISSION INVENTORY METHODS AND GUIDANCE

4.1.1 U.S. Emission Inventory Improvement Program (EIIP)

The EIIP began in 1993 as a jointly sponsored effort of STAPPA/ALAPCO and the U.S. EPA. It was funded and spearheaded by state and local agencies, but also involved resources from the U.S. EPA and in-kind contributions from industries. EIIP products were produced by those actually doing emission inventories. EIIP and its many committees are no longer in existence. However, the communications, relationships, and interactions among participants were invaluable to the emission inventory community and continue to provide positive results. The program produced documents that continue to help emission inventory developers.

The EIIP was developed to complement the emission inventory work done by the U.S. EPA. Although emission factors were available and a data reporting system was in place at the U.S. EPA in the early 1990s, no standardized procedures or recent guidance manuals on how to calculate and assemble emission inventories existed. The EIIP responded to this obvious need by producing documents to provide detailed guidance and procedures on estimating emissions. These documents are considered as the equivalent of non-binding federal guidance. The U.S. EPA, state, local, and tribal agencies, and others retain the discretion to employ or to require other approaches that meet the requirements of the applicable statutory or regulatory requirements in individual circumstances.

The EIIP sought to improve and refine the emission inventory preparation process by assembling and developing:

- Hierarchies of methods for estimating emissions
- Preferred methods for collecting data and calculating emissions
- Guidance on locating activity data
- Improved reporting systems
- Procedures for quality control
- More consistent documentation.

EIIP guidance includes sets of "preferred and alternative methods" for most inventory-associated tasks. This standardization improves the consistency of collected data, provides better quality control and documentation, and results in increased usefulness of emission information. Later in the program, the EIIP updated some emission factors.

EIIP documents, consisting of the 10 volumes described in Table 4.1, are available at http://www.epa.gov/ttn/chief/eiip/techreport/index.html.

New funding for EIIP was discontinued after FY 2003. However, a suite of projects underway will be completed during FY 2005 using existing program funds. Although new funding for the EIIP

Table 4.1. EIIP Document Descriptions. The 10 volumes cover emission estimating, data management, QA/QC, and emission projections.

Volume	Title	Description
I	Introduction	Introduction
II	Point Sources	16 chapters describing methodologies for estimating emissions from point sources
III	Area Sources	24 chapters, some of which have not been completed, on methodologies for estimating area sources.
IV	Mobile Sources	3 chapters on methodologies for estimating emissions from mobile sources.
V	Biogenic Sources	Preferred methods for estimating emissions from biogenic sources.
VI	Quality Assurance/Quality Control	5 chapters and 6 appendices for ensuring quality assurance and quality control in emission inventories. Also contains a chapter on evaluating uncertainty in emission inventories.
VII	Data Management Procedures	2 chapters on a conceptual data model and an implementation guideline.
VIII	Greenhouse Gases	16 chapters on methodologies for estimating greenhouse gas emission from various sources.
IX	Particulate Emissions	A chapter on conducting $PM_{2.5}$ emission inventories, and 22 documents that provide NEI methodology for estimating PM emissions from various source categories.
X	Emission Projections	Information and procedures to assist state and local agencies in projecting future air pollution emissions.

is not expected, the U.S. EPA intends to update EIIP guidance materials as resources permit, or remove them from the EIIP website as more current U.S. EPA guidance materials become available.

4.1.2 Canadian Emissions and Projections Working Group

Canada has established the Emissions and Projections Working Group (EPWG) under the National Air Issues Coordinating Committee. Operating jointly on behalf of the Canadian Ministers of Energy and Environment, the mandate of the EPWG is to support development of coordinated air quality management plans and strategies, track progress in achieving targets to reduce air pollutants, facilitate national shareholder consultations, and advise the federal government regarding negotiations on international air quality programs. To implement this mandate, the EPWG has developed methodologies, processes, and procedures for the timely and accurate preparation of emission inventories and projections of Canada's CACs. In addition to supporting federal activities, the emission information developed by the EPWG supports various international, provincial/territorial, and local air management initiatives.

The EPWG has four primary responsibilities:

1. Develop emission inventory, forecast, backcast, and trend information on Canada's CACs which consist of NO_x, SO_x, VOCs, CO, PM_{10}, and $PM_{2.5}$.
2. Improve the coordination of federal, provincial, and territorial inventory schedules for compiling emission inventories, trends, and projections.
3. Evaluate, and where necessary, develop standardized methodologies for compiling emission inventories, and for performing projections and backcasts which are to be used by jurisdictions throughout Canada.
4. Consult with stakeholders to inform them of emission inventory activities, and to solicit their input on these activities.

The EPWG also assumes a consultative role. There are various emission inventory products (e.g., GHGs, toxic air pollutants) that are completed on an ad-hoc basis in Canada or are developed by other organizations. These are not always regularly scheduled products, and are often completed within a larger process such as that for the Canada-Wide Standards. The EPWG is available to serve as a venue to review and provide comments on the emission estimates that are contained in these inventories. The EPWG's website can be accessed at http://ccme.miupdate.com/initiatives/climate.html?category_id=34.

4.1.3 Mexican Emission Inventory Development Program

Since 1994, the WGA, U.S. EPA, and INE have led a comprehensive emission inventory development program for Mexico. A primary goal of this program is to increase capacity within Mexico among government, academic, and other emission inventory stakeholders for the development of emission inventories. A major objective of the emission inventory capacity-building work is the development of a set of 10 manuals. These manuals, some of which contain Mexico-specific emission factors and emission estimation methodologies, are designed to help guide the emission inventory development process throughout the country. INE has provided access to these manuals in Spanish on its website. Table 4.2 provides a list of the completed manuals and a description of each. The 11 volumes cover planning, emission estimating, data management, QA/QC, uncertainty analysis, and emission verification. Also, an Advanced Training Workbook provides sample calculations and case studies involving the use of emission factors and activity data especially for sources found in Mexico. The manuals are being revised and updated and will be compiled in a series of three books to be distributed among national officials in charge of emission inventory development.

A series of workshops and capacity building activities are programmed for the 2005-2006 period to support the update and continuity of the Mexican NEI.

The methodology detailed in the manuals has been used since 1998 for emission inventory development. Mexico City emission inventories utilize specific

Table 4.2. Mexican Manuals for Emission Inventory Development.		
Volume	**Title**	**Description**
I	Emission Inventory Program Planning	Provides planning issues that must be considered in an air emission inventory program.
II	Emission Inventory Fundamentals	Presents the fundamentals of emission inventory development and discusses inventory elements that apply to multiple source types.
III	Basic Emission Estimating Techniques	Presents methodologies used to develop emission estimates.
IV	Point Sources	Provides guidance for developing the point source emission inventory.
V	Area Sources	Provides guidance for developing the area source emission inventory.
VI	Motor Vehicles	Provides methodologies for estimating emissions from mobile sources.
VII	Natural Sources	Provides guidance for developing natural source emission inventories (i.e., biogenic VOCs and soil NO_x).
VIII	Modeling Inventory Development	Provides guidance for developing inventory data for use in air quality.
IX	Emission Inventory Program Evaluation	This manual consists of three parts: QA/QC, uncertainty analysis, and emission verification.
X	Data Management	Addresses the needs associated with the data management element of the Mexico National Emission Inventory Program.
XI	References	This manual is a compendium of tools that can be used in emission inventory program development.

emission factors when available. In cases where Mexico City-specific emission factors have not been developed, international emission factors are used. The Mexican emission data (i.e., emission factors and activity data) for point, nonpoint, and nonroad mobile sources were assigned confidence ratings according to the approach shown in Table 4.3. The confidence ratings will be used to identify the priorities for future improvements to the inventory.

4.2 EMISSION FACTORS AND SPECIATION PROFILES

4.2.1 Compilation of Air Pollutant Emission Factors (AP-42)

An emission factor is a representative value that relates the quantity of a pollutant released to the atmosphere to an activity associated with the release of that pollutant. Designed for use in compiling contributions from various sources into overall inventories, emission factors are usually expressed as the weight of the pollutant divided by a unit weight, volume, distance, or duration of the activity (e.g., pounds of SO_2 per ton of coal burned). These factors are usually simple averages of all available data that are of acceptable quality, and are generally assumed to be representative of long-term averages for all facilities in a given source category.

The principal repository of emission factors is the U.S. EPA's Compilation of Air Pollutant Emission Factors, commonly referred to as AP-42. AP-42, available at http://www.epa.gov/ttn/chief/ap42/index.html, contains 14 major categories of emission sources and over 150 subcategories. The major source categories are listed in Table 4.4.

AP-42 emission factors are developed from emission tests, mass balances, control-equipment vendor

Table 4.3. Confidence Rating Approach for the Mexican NEI.			
Rating		**Activity Data**	**Emission Factor**
A	High	Based on comprehensive Mexico-specific data	Based on comprehensive Mexico-specific data
B	Medium	Based on limited/extrapolated Mexico-specific data	Based on limited Mexico-specific data
C	Low	Based on expert judgment	Based on expert judgment
D	Preliminary Estimate	Based on extrapolated U.S. data	Based on U.S. factors
E	Not Quantifiable	Insufficient data	No emission factors exist

specifications, and emission models. Factors are assigned a rating from A through E, reflecting the robustness of the factor. The assignment of factor ratings involves a two-step process. The first step involves an appraisal of the test data quality used to calculate an emission factor. The second step involves an assessment of the representativeness of the factor as a national annual average for the source category. Test-data quality is rated from A through D as shown in Box 4.1.

It must be emphasized that AP-42 emission factors are default values to be used when source-specific emission information is not available. Because AP-42 factors are source-category-wide averages they should not be used to calculate emissions from specific sources. Where test data or source specific data are available, these data should be used in lieu of AP-42 factors.

AP-42 emission factors and support documents are available at http://www.epa.gov/ttn/chief/efinformation.html. AP-42 factors are also retrievable from a searchable FoxPro database: the Factor Information and Retrieval (FIRE) system (see Section 4.2.3), available at http://www.epa.gov/ttn/chief/software/fire/.

Many of the existing emission factors in versions of AP-42 (U.S. EPA, 2005) are old and outdated, and not always used appropriately. In addition, the current emission factor development program is both expensive and cumbersome. Increased emphasis needs to be given to key sources that

Table 4.4. Major Source Categories Contained in AP-42. Emission factors are grouped into 12 stationary source categories.

Chapter	**Title**
1	External Combustion Sources
2	Solid Waste Disposal
3	Stationary Internal Combustion Sources
4	Evaporation Loss Source
5	Petroleum Industry
6	Organic Chemical Process Industry
7	Liquid Storage Tanks
8	Inorganic Chemical Industry
9	Food and Agricultural Industries
10	Wood Products Industry
11	Mineral Products Industry
12	Metallurgical Industry
13	Miscellaneous Sources
14	Greenhouse Gas Biogenic Sources

Box 4.1. U.S. EPA Emission Factor Quality Rating System

AP-42 emission factors also have qualitative data ratings. AP-42 emission factors are developed from emission tests, mass balances, control-equipment vendor specifications, and emission models. Emission test data are assigned ratings of A-D. Emission factors are assigned a rating from A through E, reflecting the robustness of the factor. The following tables explain the emission test data quality and emission factor ratings.

Emission Test Data Quality Ratings

Rating	Explanation
A	Tests are performed by a sound methodology and are reported in enough detail for adequate validation.
B	Tests are performed by a generally sound methodology, but lacking enough detail for adequate validation.
C	Tests are based on an unproven or new methodology, or are lacking a significant amount of background information.
D	Tests are based on a generally unacceptable method, but the method may provide an order-of-magnitude value for the source.

Emission Factor Ratings

Rating	Explanation
A (Excellent)	Factor is developed from A or B rated source test data taken from many randomly chosen facilities in the industry population. The source category population is sufficiently specific to minimize variability.
B (Above Average)	Factor is developed from A or B rated test data from a reasonable number of facilities. Although no specific bias is evident, it is not clear if the facilities tested represent a random sample of the industry. As with an A rating, the source category population is sufficiently specific to minimize variability.
C (Average)	Factor is developed from A, B, or C rated test data from a reasonable number of facilities. Although no specific bias is evident, it is not clear if facilities tested represent a random sample of the industry. As with the A rating, the source category population is sufficiently specific to minimize variability.
D (Below Average)	Factor is developed A, B, or C rated test data from a small number of facilities, and there may be reason to suspect that these facilities do not represent a random sample of the industry. There also may be evidence of variability within the source population.
E (Poor)	Factor is developed from C and D rated test data, and there may be reason to suspect that the facilities tested did not represent a random sample of the industry. There also may be evidence of variability within the source category population.

influence common pollutants (PM or ozone) or relate to HAPs. Particular attention should be placed on small nonpoint stationary sources of NH_3, and carbonaceous compounds which challenge current measurement capabilities. The U.S. EPA's conceptual future for its emission factor program is presented and described in Box 4.2.

4.2.2 SPECIATE

SPECIATE is the U.S. EPA's repository of total organic compound (TOC)- and PM-speciated emission profiles for a variety of sources. Emission profiles are used, for example, to divide an estimate of total VOC into estimates of emissions of individual compounds. Emission profiles reflect source tests that may be representative of similar sources. Profiles are used in ozone formation models, source receptor models, and other source apportionment studies.

SPECIATE contains more than 1,000 speciation profiles of TOC and PM emission sources for use by the modeling community available in a user-friendly data management system. Many of the profiles in SPECIATE are outdated, reflecting, for example, gasoline formulations in the 1980s. For this reason SPECIATE requires continual updating. The model and additional information can be obtained at http://www.epa.gov/ttn/chief/software/speciate/. A project to update SPECIATE is underway in 2005.

Box 4.2. The Conceptual Future of the EPA's Emission Factor Program

The U.S. EPA is currently exploring methods for restructuring its emission factor program. EPA has identified four primary reasons for this restructuring effort. First, the existing process of developing emission factors for inclusion in AP-42 is labor-intensive, time-consuming, and expensive. Second, the existing emission factor rating system documented in Procedures for Preparing Emission Factor documents is largely subjective in nature and provides limited information regarding the precision, accuracy and in-source variability of the emission factors. Third, the emission factors presented in AP-42 are arithmetic means and do not indicate the range of values that might be applicable for a given factor. Fourth, emission factors are being used for many applications for which they were not intended.

The U.S. EPA is evaluating technology and innovative approaches to change the way the current emission factor program operates. For example, EPA is currently investigating methods and developing options for revising emission factor quality assessments. These new methods would provide a more objective assessment of emission factor quality and a more quantitative assessment of the precision, accuracy, and in-source variability of the emission factors.

The U.S. EPA is also exploring methods for automating many parts of the emission factor development and delivery process. For example, it is exploring the use of the eXtensible Markup Language (XML) to provide for data-rich source test reports. The underlying rationale is that the sources and test contractors would submit source-test reports in a digital format that lends itself to data extraction and manipulation. The process of submitting data-rich source tests electronically to state agencies would save time and make the data contained therein more usable and manageable.

The U.S. EPA is also exploring methods by which state agencies can make source test reports available for emission factor development. The rationale for this effort is that a wealth of source test data exists at state agencies that are not being used for the development of emissions factors. State and local agencies would be encouraged to make their source tests available online so that EPA can mine the reports for data used for the development of emissions factors. EPA is considering offering grant money to state and local agencies for the development of an online source test database base management system.

On its own end, EPA is considering the development of a state-of-the-art interactive website where users can download the latest emission factors online. In addition to the emission factors, conceptual plans call for the capability to obtain source-test data online, as well as background data on existing emission factors.

The U.S. EPA hopes that a restructuring of its emission factors program will result in a more streamlined process for developing and maintaining these factors. The restructuring is also intended to reduce the costs of the program while at the same time yield more up-to-date emission factors.

4.2.3 Factor Information and Retrieval Database (FIRE)

FIRE is a database management system linking emission estimation factors and source classification codes. It contains the U.S. EPA's recommended emission estimation factors for criteria and hazardous air pollutants and the master list for source classification codes. FIRE includes information about industries and their emitting processes, the chemicals emitted, and the emission factors themselves. FIRE allows easy access to criteria and HAP emission factors obtained from AP-42. The database and associated documentation for FIRE can be obtained at http://www.epa.gov/ttn/chief/software/fire/.

4.2.4 California Air Toxic Emission Factors (CATEF)

CARB sponsored a program to develop toxic air pollutant emission factors from source test data collected under California's Air Toxics "Hot Spots' Information and Assessment Act (AB 2588) of 1987. Approximately 2,000 emission factors were developed based on over 800 source tests collected from a wide range of devices including asphalt dryers, boilers and heaters, reciprocating internal combustion engines, turbines, glass and metal furnaces, polystyrene reactors, and coating and plating operations. Emission factors were calculated from a selection of 200 priority source tests for trace metals including hexavalent chromium, polychlorinated dibenzo-p-dioxin / polychlorinated dibenzo furan, PAH and other semi-volatile organic compounds (SVOCs), benzene, toluene, aldehydes, and H_2SO_4. The emission factors can be obtained by querying the CATEF database at http://www.arb.ca.gov/ei/catef/catef.htm.

4.2.5 Canadian Emission Factors

Studies and measurement campaigns are conducted by the Canadian government, industries, and industrial associations for the development of emission factors and speciation profiles that are specific to Canadian sources. These studies and campaigns take into account the effect of the climate, fuel types, and process equipment in use by Canadian industries. Canada makes use of AP-42 emission factors, and the speciation profiles of SPECIATE whenever Canadian-specific information is not available. In addition, it makes available a metric version of the U.S. EPA's FIRE database at http://www.ec.gc.ca/pdb/npri/documents/2004ToolBox/docs/sect_2_5_4_e.cfm.

4.2.6 Mexican Emission Factors

Several projects have been conducted to develop emission factors, activity data, and methodologies for Mexico-specific sources. The reports and manuals resulting from these projects are available on the U.S. EPA *Centro de Información sobre Contaminación de Aire en la Frontera entre E.U. y México* (CICA - Information Center on Air Pollution for the U.S.-Mexico border) bilingual website at http://www.epa.gov/ttn/catc/cica/cicaeng.html, unless otherwise noted in the following text.

Per Capita and Per Employee Emission Factors for Solvent Sources

As part of the development of the Mexican NEI, data were collected that provided the basis for development of Mexico-specific emission factors for some nonpoint source solvent categories. Per capita emission factors were developed for the architectural surface coating and graphic arts source categories; per employee emission factors were developed for the industrial surface coating, automobile body shop refinishing, and dry cleaning source categories. These emission factors are described in detail in Appendix C of the report "Mexico National Emissions Inventory, 1999, Final, Six Northern States" (ERG, 2004).

The basis for the per capita and per employee solvent emission factors was national-level sales statistics of paints, inks, and dry cleaning solvents from *Asociación Nacional de Fabricantes de Pinturas y Tintas* (National Association of Paint and Dye Manufacturers) and *Cámara Nacional de la Industria de Lavanderías* (National Chamber of the Dry Cleaning Industry). Because these per capita and per employee solvent emission factors are based upon national-level sales statistics, they can be used throughout Mexico.

Automobile Body Shops

A study co-sponsored by the U.S. EPA's OAQPS and CICA examined the paint and solvent emissions from automobile body shops operating in Cd. Juárez, Chihuahua, Mexico (U.S. EPA, 1999a). The study included a survey of a representative sample of automobile body shops in order to determine:

- Solvent content of various coatings (e.g., lacquer, enamel, water-based, urethane)
- Extent of solvents used in surface preparation and cleanup activities (e.g., thinners petroleum distillates, blends, gasoline)
- Types of applications (e.g., spray booth, spray gun, open or enclosed nonpoint, ventilation techniques)
- Handling and disposal of waste (e.g., rags, sandpaper, paper, cans, tape)
- Suitable types of control technologies.

The survey data were extrapolated across the entire population of automobile shops operating in Cd. Juárez. Also, potential control techniques were examined. Although emissions were estimated using U.S. EPA emission factors, the types of activity data collected by this project are useful in estimating emissions from automobile body shops in other areas within Mexico.

Street Vendor Cooking (Charcoal Grilling)

A study co-sponsored by the U.S. EPA/OAQPS and CICA examined emissions from street vendor cooking devices, prevalent in the streets of Mexicali, Baja California (U.S. EPA, 1999b). (A related study (U.S. EPA, 1999c) made recommendations on emission estimation methods for charcoal grilling, as well as for open canal and sewage emissions.) Emissions from street vendors were examined experimentally by measuring levels of PM_{10} and $PM_{2.5}$, VOCs, SVOCs, aldehydes, NO_x and SO_x from a test grill chosen to simulate the street vendor cooking devices in Mexicali. Nine test runs were made, and both chicken and beef were grilled. Charcoals from Mexicali and the United States were used, owing to a shortage of Mexicali charcoal available for the tests. Emission rates (g/hour) and emission factors (g/kg of meat) were estimated. The emission factors are useful for developing emission inventories for other areas in Mexico; they were used in a nonpoint source emission inventory for Cd. Juárez and in the Mexican NEI (ERG, 2003a).

Scrap Tire Combustion

A study jointed sponsored by the U.S. EPA/OAQPS, U.S. EPA/Office of Research and Development, and CICA examined air emissions from open burning of scrap tires and from tire-derived fuel in well-designed combustors (U.S. EPA, 1997). Existing laboratory test data were compiled for criteria pollutants, as well as for a list of 34 target compounds representing the highest potential for inhalation health impacts from open tire fires, along with test data on controlled burning of tire-derived fuel in a rotary kiln incinerator simulator.

Emission factors (i.e., g/kg tire mass) were compiled for VOCs, SVOCs, PAHs, and PM_{10} as well as organic and metal PM. Although these emission data were developed from tests conducted in the United States, the resulting emission factors are useful in the development of local emission inventories in Mexico where burning of tires in open pits and landfills may be prevalent. However, due to the difficulty in quantifying activity data (i.e., kg of tires burned), these emission factors may not be feasible for use in inventories covering larger geographic areas.

4.2.7 Emission Factors for GHG Inventories

The IPCC established a Task Force on National Greenhouse Gas Inventories in 1998 to oversee the IPCC National Greenhouse Gas Inventories Program (IPCC-NGGIP). A technical support unit has been established at the Institute for Global Environmental Strategies in Japan to administer the IPCC-NGGIP. The purpose of this activity is to establish an internationally-agreed methodology for the calculation and reporting of national GHG inventories and to encourage the use of this methodology by countries participating in the IPCC and by signatories of the UNFCCC. One product of the IPCC-NGGIP is a database on GHG emission factors (EFDB), accessible at http://www.ipcc-nggip.iges.or.jp/EFDB/main.php. EFDB contains emission factor information from IPCC guidelines and from CORINAIR. The IPCC Guidelines for National Greenhouse Gas Inventories (Houghton et al., 1996) contain recommended data and methodologies for calculating GHG emissions from a wide variety of source types (http://www.ipcc-nggip.iges.or.jp/public/gl/invs1.htm).

4.3 EMISSION-RELATED ACTIVITY DATA

Recent emission inventories show that nonpoint, mobile, and natural sources are an important fraction of criteria pollutant emissions – this is particularly true for VOCs – and that only limited progress has been made in improving the activity estimates used in North American emission inventories during the past 20 years. EIIP guidance has suggested that national and regional or local agencies conduct surveys in their jurisdictions to better quantify pollution generating activity for certain nonpoint source categories. While some regional planning organizations in the United States have sponsored research to improve activity estimates for certain nonpoint categories such as open burning and residential wood combustion, there is limited evidence that state, local and tribal agencies have performed surveys to improve activity estimates for nonpoint source categories. It is not likely that these agencies will invest the funds necessary to perform such surveys unless it is demonstrated that there is payoff to them in terms of reduced uncertainty in the emission estimates for certain source types, or added confidence in their ability to develop effective future control strategies for these categories. The U.S. CERR has been useful as a regulatory incentive for requiring state and local agencies to provide such information for non-permitted sources. However, association of the data collection to formal permitting approaches might be more effective for improving nonpoint source characterization.

For many nonpoint source solvent categories (e.g., consumer products, painting, auto body refinishing), emission factors are applied to surrogate activity indicators, such as population or industry employment to estimate emissions. These techniques rely on solvent usage patterns being consistent with time and there being a correspondence between product sales and usage. Pollution levels and fluxes from households are low enough that remote measurements are not likely to be effective in capturing hourly/daily activity patterns (and the emissions resulting from them).

For highway vehicles, there continues to be a significant amount of research on improving emission factor models (MOBILE and EMFAC; U.S. EPA, 2004a) as well as estimating VMT or VKT. The U.S. EPA is proposing to update these tools with MOVES. Developers of MOVES intend to build on current capabilities, improve upon them, and eventually replace them with a single, comprehensive modeling system. In MOVES, how activity is defined will depend on the emission process being modeled. For most processes, U.S. EPA plans to characterize total activity by *source-activity time* (source hours operating or source hours parked). Source time is an attractive way of characterizing activity, because it is common to all emission processes and operating modes. However, while source-time is an important new metric in MOVES, its use does not preclude areas using VMT to express activity of on-highway vehicles, because source hours operating and VMT are easily inter-changeable if average vehicle speed is known. In addition, some vehicle emission process activity is non-time based, so the activity indicator can be the number of vehicle starts, hours parked, engine-on hours, or gallons of fuel used.

Intelligent Transportation System data are now collected by roadway surveillance equipment that monitors traffic; namely, volumes, speeds, and lane occupancies. The most prevalent measurement technology is loop detectors embedded in the roadway. However, transportation agencies are increasingly turning to non-intrusive technologies, such as radar and video image processing. Video image processing offers the potential of providing length-based vehicle classifications, but this capability is still emerging. From an emission indicator improvement perspective, there are opportunities for better utilizing the more sophisticated traffic data collection devices available today to track travel demands on roadways and how these vary by time-of-day.

Roadway network usage is measured for many purposes, one of which is to provide estimates of vehicle travel activity for making emission estimates. Traditionally, measurements have been made using ground-based sensors. The sensors provide a temporally rich data set, but individual sensors lack spatial coverage, limiting their use and application. High-resolution imagery remotely sensed from satellite or airborne platforms is an attractive alternative that can potentially supplement and enhance the existing traffic monitoring programs with a spatially detailed data set. With the progress in image processing technologies, roads and vehicles can be identified from imagery automatically with a high level of accuracy.

During the last 10 years, tools or models have been developed by the U.S. EPA to allow users to perform more sophisticated assessments of nonroad vehicle/engine emissions. While default activity profiles are available in these models, these defaults may not provide acceptable information on actual activity for modeling specific areas of interest. Improvements can be obtained via surveys of off-road equipment usage, and stakeholders have been performing such surveys. Another research focus is on developing and using portable activity monitoring systems, either alone, or in conjunction with portable emission monitoring systems, to track how often equipment is used for the purpose of better quantifying activity by equipment type.

4.3.1 Onroad Sources

U.S. Mobile Activity Data

In the United States, several different types of activity data are used for calculating emissions from onroad sources. VMT is currently the most widely used activity factor for onroad sources, and is made available by the U.S. Department of Transportation (DOT). Other activity factors that are used in some cases include fuel consumed, duration of operation, number of vehicle trips, soak length (for hot soak emissions), and others.

One approach, used by the U.S. NEI, begins with data aggregated at the national level and allocates emissions to states or smaller geopolitical units using surrogate data such as fuel sales or road miles. Activity factors are based on VMT summaries by state and functional roadway class, and similar summaries for urban areas, collected by the Federal Highway Administration. The activity is then allocated to counties and functional roadway classes using a combination of county level population and roadway mileage by county and functional roadway class as VMT surrogates. A similar approach is applied in some cases using fuel sales data rather than VMT, and allocates accordingly. This type of approach to estimating activity for onroad sources has the advantages of applying a similar methodology and data source to a broad geographic area, such as the regional or national level. In the aggregate, these estimates are generally considered to be reasonable. However, when these activity data are examined for smaller geographic areas, such as at the county level, the estimates often vary significantly from actual activity.

Alternatively, activity data are developed from local factors such as measured activity and vehicle registration information. A more detailed approach to developing onroad activity is generally used in urban area modeling by metropolitan planning organizations. These organizations often use travel demand models to build link-level (i.e., roadway segment) VMT databases. Inputs to these models include factors such as land use and employment by zone within the modeled region. The models are calibrated to actual traffic count data. In addition to VMT, these models can also provide other types of activity related to onroad sources including number of vehicle trips, or hours of vehicle travel. Such models have the advantages of accounting for local detail and are generally considered the most accurate source of onroad activity for an urban area. These models sometimes have the capability to provide information on the temporal distribution of activity, by hour-of-day, day-of-week, or month-of-year, so that activity can be adjusted for any day of the year. Because so much detail is incorporated into the models, they provide more specific emission information than do other models. However, it is not possible to assemble such detail about larger geographic areas, such as statewide or regionally. For this reason this type of approach may be applied consistently only on the community scale.

In nearly every application, urban travel-demand models are built using data from household surveys. The surveys typically gather demographic and economic information for each household, plus a travel diary recording all of the trips each household member made during the survey period (generally one day). The survey data are used to estimate the coefficients of a hierarchy of models that mirrors a theoretical hierarchy of behavior by travelers. Trips are separated by purpose (such as home-to-work/work-to-home and home-to-shop/shop-to-home), and each purpose receives separate modeling treatment. Travel demand models based on population and employment are poorly suited for estimating heavy-duty diesel truck traffic that is mostly commercial in nature and driven by goods movement needs rather than population and workplace locations.

While travel models produce VMT estimates, some agencies and researchers directly estimate VMT from traffic counts or other types of empirical data. The most widely used method is the extrapolation from Highway Performance Monitoring System data. The Highway Performance Monitoring System includes data from traffic count stations that are used to monitor annual differences in traffic volumes by location. However, some urban areas need to improve their existing Highway Performance Monitoring System sample of links to ensure that they truly represent changes that are occurring throughout an area. More approximate VMT estimation methods are used in some areas. For example, some estimates have been based on aggregate fuel sales and the estimated fleet-wide fuel economy corrected for nonroad fuel consumption and out-of-state refueling and travel. Special studies, including license plate surveys, focused counts, and special travel surveys, may be used to estimate VMT for traffic not included in regional models, such as through trips, and truck travel.

<u>Canadian Mobile Activity Data</u>

Compared to the United States, the availability of motor vehicle activity data in Canada is limited. Environment Canada does not have the ability to draw directly on vehicle registration data, as Canadian privacy laws restrict access. Private companies may purchase provincial/territorial vehicle registration files, aggregate the data and redistribute it. These are the data that Environment Canada uses for its emission estimates and vehicle fleet profiles. The private companies that aggregate this data do so for purposes other than emission estimation; thus, aggregated classes do not always align with the needs of emission estimation modelers.

While there is a similar tendency in the United States and Canada to use travel-demand models for urban planning and to estimate vehicle kilometers traveled, there are differences between the two nations' approaches. As yet, no network has been established in Canada to pool these data for use in Environment Canada's emission estimates. As the need for greater resolution in emission inventories increases, census-district level or municipal-level estimates may need to be established. Local travel-demand model data will be invaluable in meeting this need for greater resolution. However, the current framework - where individual urban areas model their respective regions for local purposes - often excludes a consistent manner of data generation or compilation. For the time being, Canadian onroad emission estimation relies on aggregated activity data collected by private companies and government departments, at the provincial/territorial and national level.

Partnerships between Environment Canada, Transport Canada, Natural Resources Canada (NRCan) and the use of Statistics Canada data have enhanced the ability to model onroad activity. Statistics Canada and Transport Canada developed and maintain the Canadian Vehicle Survey. This survey is an excellent source of fleet profile data, and utilizes travel diaries to capture driving behavior and trends. Statistics Canada ensures that the sample size is representative, allowing for both local and aggregated uses of the data. Also, Transport Canada has provided data from the Company Average Fuel Consumption values to be used as fuel-efficiency input data in MOBILE6.2C. Currently, Environment Canada's CAC division compiles annual emission inventories at the provincial/territorial level. However, MOBILE6.2C does allow for finer resolution of estimates. The model has the capability to provide information based on the temporal and spatial distribution of activity (e.g., daily, intersection-level estimates).

Environment Canada uses MOBILE6.2C to estimate CACs from onroad activity. Generally, the data requirements for MOBILE6.2C can be broken into the following categories: external conditions (e.g. calendar year, altitude), vehicle fleet characteristics (e.g. age distributions, diesel sales fractions), vehicle activity (e.g. VKT, trip end distribution), fuel characteristics (e.g. sulfur level, gasoline volatility), and other parameters (e.g. I/M programs, technology penetration rates). This approach is aligned with the methodology employed by the U.S. EPA. Harmonious emission estimation tools, techniques and methodologies are essential for meaningful comparisons to be made of emission estimates for trans-boundary air issues. MOBILE6.2C allows for the use of finer-resolution data on activity factors. Local data can be used as input, and region-specific estimates can be compiled. Local surveys on roadways use, vehicle counts, fuel characteristics, and travel behavior can all be incorporated into emission estimates. Further information on Environment Canada's CAC inventory, is available on the website http://www.ec.gc.ca/pdb/ape/cape_home_e.cfm.

Further partnerships with the two active I/M programs in Canada have recently allowed for corroboration of purchased data, data from other government departments and assumptions of Canadian-specific characteristics. AirCare in the province of British Columbia has been running since 1992 in the Lower Fraser Valley. Drive Clean has been in operation in Ontario since 1999. Pass and fail results from these programs allow for a partial validation of basic emission factors for MOBILE6.2C. Other information collected during the test (such as odometer readings) has been compiled into databases and can be formatted as annual kilometer accumulation rates for MOBILE6.2C. If links can be made between vehicles captured within the I/M programs and registered vehicles, local vehicle fleet characteristics can overwrite national level assumptions.

Canada's national transportation-sector GHG inventory is prepared using estimates at a provincial/territorial level of segregation. A vehicle fleet profile is established, based on model year and gross vehicle weight rating. So-called 'technology fractions' are attached to this fleet profile. The 'technology fraction' is a proxy for the emission control measures in the fleet (e.g., no catalyst, 3-way catalyst, advanced control diesel). This approach provides an estimate of average fuel consumption per vehicle class, per kilometer traveled. Fuel sales data, from Statistics Canada (http://www.statcan.ca/), are then used as a limiting factor. VKT is varied until all onroad fuel sales data are allocated. Emission factors are applied to these activity data and the GHG inventory is derived. This approach complies with the IPCC and UNFCCC guidelines for the estimation of GHG emissions. Further information on Environment Canada's GHG inventory is available on the website http://www.ec.gc.ca/pdb/ghg/ghg_home_e.cfm.

Mexican Mobile Activity Data

The availability of motor vehicle activity data in Mexico is limited in comparison with the United States and Canada. Travel demand models are not now widely used in Mexico to estimate VKT, and the development of such models for the entire country is not technically or economically feasible.

In Mexico's current *Programas para Mejorar la Calidad del Aire* (PROAIRE– Programs for the Improvement of Air Quality), VKT are typically estimated using vehicle registration statistics combined with assumed daily VKT based upon limited traffic count statistics, informal surveys, and anecdotal information. Fuel sales data can be used to estimate VKT in situations where other VKT estimates are not available, if assumptions regarding fuel efficiencies for various vehicle classifications are made. However, fuel sales data are not currently available at the municipality level for Mexico. Because of limited motor vehicle activity data in Mexico, a unique methodology was developed for the Mexican NEI that utilized modeled traffic volumes and congestion levels at representative urban areas for different city size categories to generate daily per capita emission rates (ERG, 2004; Wolf et al., 2003).

The development of daily per capita emission rates began with identifying seven urban area size categories with a representative urban area for each category. A basic assumption used in this methodology was that the daily per capita emission rates estimated for each of the representative urban areas are transferable to other urban areas of similar size. This assumption is reasonable because it has been shown that trip generation rates across different urban-area locations and sizes are fairly stable when disaggregated by socio-economic conditions such as household size, income, and employment (Pearson and Gamble, 1996).

Trip generation patterns were developed for each representative urban area based upon trip production and trip attraction rates from a well-documented transportation study conducted for Cd. Juárez, Chihuahua (Instituto Municipal de Investigación y Planeación, 1998). The trip generation patterns were developed for zone structures based upon census tracts called *Areas Geoestadísticas Básicas*. Relevant demographic and socio-economic information was obtained from INEGI for each of the representative urban area zone structures. Total trips for a zone were estimated from household size and income information and the number of employees across various economic sectors. Activity data used for MCMA emissions are taken from the data register of the Vehicular Verification Program of the Federal District and the State of Mexico.

A roadway network was developed for each of the representative urban areas in order to facilitate trip distribution. The networks were simplified versions of the current roadway infrastructure layout and include only freeways, main arterials, and collector roads. Local streets were modeled using artificial links called “connectors” which channel local traffic flows between the zones (represented at zone centroids) and the network system. Each link in the network was initially assigned a function class and flow direction based upon site visits and interviews with local transportation officials, and a link capacity and average speed based upon results from the Ciudad Juárez study. Individual link travel time was then computed using the assigned link speed. An iterative approach was used until the gravity model converged to a solution for the representative urban areas. A user-equilibrium algorithm was then used to assign traffic volumes to network links and then congestion levels between similar time alternatives using iteration.

Link-level VKT was estimated by multiplying each link’s traffic volume by the corresponding link’s length in kilometers. These link-level VKT estimates were combined with corresponding link-specific congested speed emission factors to estimate daily emissions on a link basis using PrepinPlus software. The link-specific congested speed emission factors were developed using MOBILE6-Mexico. The emission factors were developed for a generic set of scenarios with varied temperature ranges, altitude, and fuels. The speeds in the look-up matrices ranged from 4 to 100 kph in 2 kph bins.

Total hourly emissions for each link were estimated by combining the link-specific emission factors with link-level VKT. Daily emissions for each representative urban area were estimated by summing up emissions for each hour over the entire roadway network. These daily emissions were then used to estimate per capita emission rates for the generic temperature/altitude/fuel scenarios for each of the urban area size categories. Annual municipality-level emissions were then estimated by combining per capita emission rates with populations for each municipality.

It should be noted that although this methodology was considered appropriate to estimate mobile emissions on the municipality-, state-, and national-level for the Mexican NEI, an increase in the availability of detailed information on activity patterns at the local level is expected in the future. Hence, a methodology similar to those applied in the United States and Canada could be applied to future inventory updates.

4.3.2 Nonroad Sources

U.S. Nonroad Data

Nonroad engines/vehicles comprise a wide variety and size range of diesel and gasoline engines, which are used for numerous applications including aircraft, locomotives, agricultural and construction equipment, industrial and commercial equipment, and recreational vehicles. In response to the Clean Air Act Amendments of 1990, federal emission regulations have been developed for many of these engine types. With the increased recent interest in quantifying nonroad engine/vehicle emissions, both the U.S. EPA and CARB have developed models to more readily quantify emissions for many of these equipment types. These models contain estimates of equipment populations and usage patterns. Because the generic activity patterns in these models may not apply equally well in all areas, area-specific surveys of equipment populations and usage patterns are recommended for the most prominent equipment types in each area. Efficient survey techniques can vary significantly by equipment type/use because some equipment is used commercially and others by homeowners/consumers/recreators. Thus, activity is often based on non-economic factors.

Apportioning fuel use to nonroad applications can be an effective tool for determining whether other methods that have been applied have produced reasonable emission estimates. However, this requires that onroad and nonroad fuel use be differentiated.

Three nonroad engine/vehicle types are not included in the U.S. EPA models: aircraft, locomotives, and commercial marine vessels. Other agencies have been examining emissions from these sectors. In particular, CARB is currently working to incorporate commercial marine vessels into the state's OFFROAD model. Models for aircraft emissions can be developed using data collected by the U.S. Federal Aviation Administration (FAA), such as is the case with the Emission Dispersion Modeling System, further described in Section 4.4.10. These data are also used by the U.S. EPA for developing NEI emission estimates (U.S. EPA 2004d). Models for locomotive emissions can be developed using data collected by rail companies. The U.S. EPA is currently developing a model that will calculate emissions from aircraft, commercial marine, and railroads.

Aviation

Aircraft activity data, in varying levels of detail, may be obtained for all aircraft categories at airports with traffic control towers. Towers at U.S. commercial and other civilian airports are managed by the U.S. FAA and are required to keep detailed activity records of air carrier traffic and less detailed records for other aircraft categories (U.S. FAA, 2004). The majority of smaller airports do not have traffic control towers and are therefore considered to be uncontrolled by the U.S. FAA. The number of uncontrolled airports far outnumbers controlled airports. Data recorded by smaller airports are inconsistent and unreliable, making data acquisition for purposes of emission inventory development difficult.

Aircraft activity levels are normally expressed as landing and takeoff cycles, which consist of four aircraft operating modes: taxi and queue, take-off, climb-out, and landing. Default values for the amount of time a specific aircraft type spends in each mode, or the time in mode, are normally included in the U.S. FAA's aircraft emission model. Aircraft emissions vary significantly between airports. Although landing and takeoff times are similar for similar fleet mixes, the amount of idle varies significantly from airport to airport, representing a key factor in the variability of emissions from aircraft during airport operations. Local air quality concerns are generally directed at aircraft operating below 3000 feet about ground level. However, as air quality concerns expand from urban to regional and continental scales, emissions from aircraft in transit also become an issue (Penner et al., 1999).

Commercial Marine

Emission and activity data for commercial marine vessels are normally categorized by five vessel types: ocean-going, tugs, ferries, dredges, and fishing vessels. Estimates of ocean-going vessel activity are available from the literature for a limited number of U.S. coastal and inland ports. Ocean-going vessel activity for other non-surveyed ports is typically estimated using an assignment process based on similar port characteristics. Key ocean-going vessel operating modes include cruise, reduced speed zone, maneuvering, and hotelling/dwelling (idling). For non-ocean going commercial marine vessels, most of the emission inventory data collection effort is in estimating vessel populations, with activity (hours of operation) and load factors based on typical usage profiles (U.S. EPA, 1999d; U.S. EPA, 1999e).

Emissions are also estimated from large marine vessel operations using a power-based approach. This methodology uses power output and time-in-mode to estimate emissions. Power output in a given mode (e.g., slow speed, medium speed, hotelling) is multiplied by the time of operation in mode and by an emission factor. Power output by a vessel is estimated based upon the percent of full load for auxiliary engines and the Propeller Law for propulsion engines. The Propeller Law states that power demand increases with the cube of a vessel's speed. This approach can be used to develop estimates of power output on a vessel-by-vessel basis. The equation can also be used to develop power outputs for different segments of a transit into or out of port if there are significant differences in speed between segments (Starcrest Consulting, 2004). This methodology can also be applied to estimating emission from military marine vessels.

As for aircraft, marine vessel emissions from ports are of primary importance, but emissions from ships in transit are also of concern (Corbett and Fishbeck, 2000).

Rail

Locomotive activity is based on estimates of railroad locomotive diesel fuel consumption. Unless a rail company operates in a limited geographic area, the fuel consumption data for locomotives is typically available for a larger area than the inventory area. Three classes of railroads are defined for the United States. These are Class I railroads with operating revenues greater than $250 million, Class II railroads with operating revenues greater than $20 million and less than $250 million, and Class III railroads with operating revenues less than $20 million (49 CFR 1201). For Class I railroads, fuel consumption is typically estimated using locomotive fuel rates coupled with miles of track and traffic density in the inventory area. Fuel consumption for small railroads (e.g., Class II/III railroads and Amtrak in the United States) is based on system-wide fuel estimates allocated based on the percentage of track length within the inventory area. Fuel consumption reported in public sources may form the basis of national or regional locomotive emission estimates, which can be assigned to counties or other sub-state areas based on a surrogate indicator, generally rail track length or rail freight density.

<u>Canadian Nonroad Data</u>

Environment Canada compiles a CAC inventory that includes the contribution of nonroad engines/vehicles powered by a variety of fuel types (e.g., gasoline, diesel, compressed natural gas, liquefied petroleum gas or LPG, heavy fuel oil). Vehicle types covered are aircraft, marine vessels, locomotives and a variety of other applications such as residential and commercial equipment and off-highway vehicles. Emission estimates are handled distinctly for aircraft (sub-sector name 'Aviation'), for commercial marine vessels (sub-sector name 'Commercial Marine'), for locomotives (sub-sector name 'Rail'), and for all other nonroad applications (sub-sector name 'Nonroad'). The nonroad sector includes such things as recreational vehicles, lawn and garden equipment, and other commercial/residential engines and vehicles.

Aviation

Currently, Environment Canada uses a set of emission factors for various aircraft types. Activity level, in terms of number of landings and takeoffs, are used with these factors to estimate emissions. NAV Canada, Statistics Canada and Transport Canada all maintain databases on aircraft movement at Canadian airports that are used by Environment Canada for emission estimates for the aviation sector.

Commercial Marine

Considerable effort is being channeled into characterizing the commercial marine sub-sector and its related emission sources. A recent study (Entec, 2002) is considered to be an excellent source of information. Drawing on a large sample size, emission factors are generated for certain vessel classes under various modes of operation and an entire emission estimation methodology is outlined. This methodology relies on the use of the Lloyd's Marine Intelligence Unit (LMIU) database for determination of average vessel characteristics. The LMIU can be used in conjunction with other vessel activity data contained in the databases of the Canadian Coast Guard to develop marine emission inventories either with or without temporal and spatial resolution. The Coast Guard data are ideally suited for this purpose, as they allow for temporal and spatial allocation of emissions. The Coast Guard's data will be more attractive as they become entirely automated through the adoption of an Automatic Identification System. The Automatic Information System is endorsed and recommended by the International Maritime Organization and is currently being implemented in many other countries. Such an electronic database will be highly useful with GIS-based applications, and may facilitate a better articulation of marine emissions both nationally and internationally. Select Canadian port authorities, chambers of shipping, and ship-owners associations have expressed interest in supplying survey data to help validate assumptions concerning terms of times in mode of operations and other shipping activities.

Rail

In 1995 the Railway Association of Canada signed a memorandum of understanding with Environment Canada to provide national level, annual traffic volumes and diesel fuel consumption for mainline, branchline, yard switching, and passenger service for the period 1990 through 2005. Data from Statistics Canada are used to disaggregate the Railway Association's national estimates to the provinces/territorial level required for the CAC inventory. The Statistics Canada report apportions fuel use to provinces/territories, assuming that emissions follow the same trend as fuel use. The sulfur content in diesel fuel can be obtained from an annual publication by Environment Canada's Oil, Gas and Energy Branch (Environment Canada). The Railway Association assumes that fuel sulfur content is 0.15% for all years and all provinces/territories.

Nonroad

Environment Canada's CAC inventory and related forecast for the nonroad sector has been compiled using the U.S. EPA's NONROAD model, with estimates used in support of proposed Canadian regulations. Canadian input data and other adaptations were implemented in the use of the NONROAD model. Due to the lack of a single source of data on the numerous engine applications modeled through NONROAD, an attempt was first made to compile the required engine population estimates. For many types of nonroad equipment, the Canadian market relies almost exclusively on importation as there is only limited manufacturing of these products in Canada. Statistics Canada maintains an excellent importation database providing the annual quantity and value of imported goods organized under an international classification called *Harmonized System*. When the harmonized system coding is such that one can be fairly confident that all, or nearly all, goods classified under a given code are powered by internal combustion engines and correspond to a category of nonroad equipment, the Statistics Canada database for this harmonized system code can be used to estimate the corresponding nonroad engine population in Canada. An important assumption in the allocation of nonroad Canadian engine populations is that the distribution of Canadian engines with respect to different engine categories (i.e., 2-stroke, 4-stroke, and horsepower range) and fuel types (i.e., gasoline, diesel, LPG, and compressed natural gas) is directly proportional to the corresponding U.S. distributions.

<u>Mexican Nonroad Mobile Source Data</u>

The types of nonroad sources included in emissions inventories in Mexico include aircraft, locomotives, commercial marine vessels (CMV), and construction and agricultural equipment. Local and regional inventories (e.g., Mexico City and Monterrey Metropolitan Areas), and the Mexican NEI generally group the aircraft, locomotive, and CMV emissions within area (or nonpoint) sources. Only the Mexican NEI contains emissions for construction and agricultural equipment, as until recently, the activity data needed to estimate emissions from these types of equipment have not been available (ERG, 2004).

Aviation

Aircraft emissions are generated during approach, taxi/idle-in, taxi/idle-out, and climb out. Only those portions of the flight that occur between ground level and the mixing height are included in the inventory. Annual activity information for the numbers of landing and take-offs (LTOs) are provided by INEGI; however, LTO data are not available for all airports in Mexico. Sulfur content of aircraft fuels (needed to calculate SO_x emission factors) is available from *Petroleós Mexicanos* (PEMEX).

Rail

Emissions are generated from locomotives during line-haul and yard operations. Activity data used to estimate these emissions include locomotive fuel consumption and length of tracks. Annual national railroad fuel consumption for line-haul and yard locomotives is available from the *Secretaría de Comunicaciones y Transportes* (Secretariat of

Communications and Transport). National- and municipality-level track length for Mexico is available from Environmental Systems Research Institute in the form of GIS data and shape files. Locomotive fuel sulfur content is available from PEMEX.

Commercial Marine

CMV emissions are generated by engines powered by either diesel (distillate fuel) or steam turbines (residual fuel). Activity data used to estimate these emissions include fuel usage and volume of cargo handled in Mexican commercial marine ports. Annual national-level marine distillate and residual fuel usage is available from PEMEX. (Note that assumptions must be made as to the percentage of total CMV fuel actually consumed in port. For the 1999 MNEI, it was assumed that 25% of the residual and 75% of the distillate was consumed by CMV in port.) Data on the volume of cargo handled is available from INEGI. Commercial marine fuel sulfur content is available from PEMEX.

Construction and Agricultural Equipment

Construction and agricultural equipment activity data consist of estimated horsepower-hours of operation for each equipment type/fuel/horsepower range combination. These estimates are combined with emission factors from the U.S. EPA's NONROAD2002 model, modified to reflect Mexico-specific conditions, to estimate construction and agricultural equipment emissions for the 1999 MNEI. (A current project is underway to develop a NONROAD-Mexico model using local data collected in Mexico.) State-specific data for diesel-powered agricultural tractors and pumps, along with percentage breakouts by horsepower are available from INEGI. For the Mexico NEI estimates, agricultural equipment populations (e.g., balers) were assumed to be present in the same proportion as in the U.S. Annual fuel usage by the agricultural sector (from PEMEX) was compared with NONROAD2002's estimated fuel consumption for the Mexico-specific equipment populations to obtain an adjustment factor for equipment activity (hours/year/unit) (i.e., fuel consumption in Mexico was 15% lower than predicted by NONROAD2002 using U.S. default hour/year values, so the activity data file was adjusted to reflect a 15% decrease in hours/year for diesel agricultural equipment). Annual state-level emission estimates were allocated to the municipality level using census of operating tractors from INEGI.

In the absence of construction equipment population and usage data, it was determined that the number of employees actually working at job sites, available for each state, was the best indicator of likely equipment usage. (Other surrogates, such as gross domestic product, book value of assets, etc., were evaluated, but number of workers was the most reliable and direct surrogate for this category.) The ratio of Mexican construction workers (from INEGI) to U.S. construction workers (from the U.S. Census) for 1997 (i.e., 0.124) was multiplied by the U.S. equipment totals in the NONROAD2002 model to approximate the Mexican construction equipment population. U.S. defaults were used for hours/year of operation for each equipment type. State-level totals were derived from the fraction of total construction workers by state (from INEGI). Annual state-level emission estimates were based on municipality-level population (from INEGI.)

4.3.3 Stationary Nonpoint Sources

Because of the diverse nature of nonpoint sources, many types of emission activity factors are used to develop nonpoint source emission inventories. This section focuses on three of the most important: energy consumption/production, population, and employment.

U.S. Nonpoint Data

Energy Consumption/Production Data

Because energy consumption and energy production are emission activities for many source categories, energy consumption/production data represent a key set of nonpoint source activity data. Examples of such source categories are residual fuel combustion and Stage I gasoline distribution. The U.S. Department of Energy's Energy Information Administration (EIA) develops databases and publishes reports that provide energy consumption and production data at various geographic levels. These databases and reports either focus on a particular energy sector (e.g., residential energy consumption survey), energy source (e.g., annual coal report), or geographic area (e.g., state energy data). Depending on the particular resource, the EIA may report energy consumption/production on a national basis, by region (e.g., census division), or by state (county-level data are not provided) (see http://www.eia.doe.gov/ for information on each available EIA resource). The EIA's State Energy Data (formerly the State Energy Data Report) is a particularly valuable resource because it provides energy consumption data at the most-specific geographic level available, and covers most energy sources and energy sectors.

The EIA's State Energy Data is a database that provides historical annual energy consumption, price, and expenditure data. All of the State Energy Data estimates are developed using the State Energy Data System, which is maintained and operated by the EIA. Energy consumption is estimated using data from existing surveys of energy suppliers that report consumption, sales, or distribution of energy at the state level (State Energy Data can be accessed from the following EIA website http://www.eia.doe.gov/emeu/states/_use_multistate.html.

Population Data

For many nonpoint source categories, emissions are computed using per capita emission factors. For example, per capita emission factors are typically used to estimate consumer product emissions, if surveys cannot be conducted to develop local product use/sales data.

The Population Division of the U.S. Bureau of the Census develops annual July 1 population estimates at various geographic levels of detail for the United States and its territories. Population estimates are reported for the nation, as well as by state, county, metropolitan area, and city/town. Each census population data set can be downloaded from http://www.census.gov/popest/estimates.php. It is important to note that states, metropolitan areas, and cities may prepare population estimates for their own areas. Because these estimates may be developed using more specific local information, inventory preparers should investigate the availability of local population estimates as an alternative to using the census values (Census, 2004a; Census, 2004b).

Employment Data

Employment data are frequently used to estimate nonpoint source emission activity. Two primary U.S. agencies that compile employment data are the U.S. Department of Commerce's Bureau of the Census and the U.S. Department of Labor's Bureau of Labor Statistics (BLS, 2004a; BLS, 2004b).

The Bureau of the Census publishes County Business Patterns, which provide annual state and county employment data by industry. Beginning in 1998, County Business Pattern data are reported by 1997 North American Industrial Classification System (NAICS) industry. Data for 1997 and earlier years are reported using the Standard Industrial Classification (SIC) system. No data are published that would disclose the operations of an individual employer, and County Business Patterns excludes data on self-employed individuals, employees of private households, railroad employees, agricultural production employees, and most government employees. County Business Patterns employment data are available for download from the following Census website: http://www.census.gov/epcd/cbp/view/cbpview.html.

The Bureau of Labor Statistics (BLS) develops both occupational and industry employment estimates. The BLS' Occupational Employment Series reports national, state-, and metropolitan area-level non-farm employment estimates on an annual basis for each of over 700 occupations. The BLS also produces occupational employment and wage estimates for over 450 industry classifications at the national level. The industry classifications correspond to the 3, 4, and 5-digit NAICS industrial groups (pre-2001 data are reported by 4-digit SIC code). The BLS data do not cover self-employed persons, owners and partners in unincorporated firms, household workers, unpaid family workers, or farm workers. The BLS occupational employment data can be obtained from http://www.bls.gov/oes/home.htm.

The Quarterly Census of Employment and Wages (QCEW) program compiles employment data by industry sector; the data exclude members of the armed forces, the self-employed, proprietors, domestic workers, unpaid family workers, and railroad workers covered by the railroad unemployment insurance system. Available data include monthly employment by NAICS industry and county. These data are also aggregated to annual levels, to higher industry levels, and to higher geographic levels (national, state, and metropolitan statistical area, or MSA). At the state and MSA level, the QCEW program publishes employment data down to the 6-digit NAICS industry level, if disclosure restrictions are met. BLS withholds publication of employment data for any industry level when necessary to protect the identity of cooperating employers. More information is available on the QCEW program from the following BLS website: http://www.bls.gov/cew/home.htm.

Because the Bureau of the Census and the BLS do not report comprehensive employment data, it is worthwhile to supplement these data, if possible, with estimates from market research companies. Several private market research companies (e.g., Dun and Bradstreet, Inc.) compile and report employment estimates for all sectors/firms. Unlike the Census and BLS, however, a fee must be paid for access to these data (e.g., options for obtaining Dun and Bradstreet estimates are described at http://www.dnb.com/us/dbproducts/sales_marketing/index.html.)

Canadian Nonpoint Data

Energy-consumption, population, and employment data are compiled and published in Canada by Statistics Canada. As an example, Canadian energy consumption and production information is available on a monthly basis. It is provided as energy balance sheets in natural units and heat equivalents, in primary and secondary forms, by province. Each balance sheet shows data on production, trade, interprovincial movements, conversion and consumption by sector. Information on natural gas liquids, electricity generated from fossil fuels, solid wood waste, and spent pulping liquor is also made available in these balance sheets.

Mexican Nonpoint Data

Energy-consumption data are provided by PEMEX - aggregated to the terminal level. However it is not easy to allocate these data to the state or municipality level as is typically necessary for emissions inventory use. The *Secretaría de Energía* (SENER, Secretariat of Energy) publishes an annual energy balance that provides primary energy consumption prior to transformation (i.e., fuel sent to refineries, coke plants, gas plants, or electric generating facilities). Also, SENER publishes fuel-specific documents with details on distribution by sector and region, called *"Prospectivas"*, which can be downloaded from SENER's website (www.sener.gob.mx). INEGI compiles and publishes information on population, employment and economic activity.

4.3.4 Point Sources

U.S. Point Source Data

Activity indicators for point sources include fuel consumption, amount of product produced, amount of throughput, and size/capacity of storage tanks. These activity indicators, or Source Classification Code units, are designed to provide the linkage between activity and the emission quantity. Point-source activity indicators are direct measures of the input or output of specific industrial processes. Pollution-generating activity information is typically (and most reliably) collected directly from individual sites or facilities via surveys or through the facility permitting process. These surveys are normally performed by state/provincial air pollution control agencies, with such authority delegated to local pollution control agencies in some states (e.g., California) or large metropolitan areas. In some cases, local agencies may collect activity data for large point sources using CEMS.

There are also sector-specific data sources – many of which are mentioned in the nonpoint source discussion above – which can be used as supplements to the point source surveys and local permit data. This information can be used as top-down checks to ensure that all fuel use in a sector is being captured in the point-source inventory. Within the point-source sector, the most prominent and widely studied sub-sector is the EGU sector. The history of how activity indicators (i.e., fuel consumption) have been estimated for EGUs and their evolution and improvement with time is illustrative of the different methods that can be applied to estimate emission activity.

In the United States, the responsibility and authority for performing point-source activity surveys has resided with the states. The execution of these surveys and submission of the resulting data to the U.S. EPA were not performed consistently, which made it very difficult for regulators and researchers to quantify electric utility emissions, and to track changes with time. In the early 1980s, the use of annual power-plant survey data collected by the Department of Energy on fuel purchases and fuel consumption were used to develop methods for providing consistent longitudinal estimates of SO_2 emissions from EGUs. These methods were applied to estimate electric utility air pollution emissions for major research efforts such as NAPAP in the 1980s and early 1990s, and to establish a baseline for measuring progress toward meeting the Title IV requirements of the 1990 Clean Air Act Amendments.

More recently, researchers have taken advantage of the emission and activity information that is available hourly for the EGUs required to have CEMS. Activity information available for CEMS-equipped units are heat input and fuel use, by type. Because not all EGUs are required to have CEMS, state point-source surveys and fuel consumption information submitted to the Department of Energy continue to be valuable resources for quantifying pollution generating activity for this sector.

As trading programs are implemented to achieve regional or local goals for meeting Clean Air Act mandates, it is expected that continuous monitoring will be required for some non-EGU point sources. This change will improve the quantification of activity indicators for these sectors and sources.

Canadian Point Source Data

In Canada, activity indicators for point sources - such as materials consumed and produced, type, size/capacity, emission control equipment, and other characteristics of the processes used by the facilities - are collected by some provincial and regional air pollution agencies. This information is collected through permits and through surveys conducted to support the compilation of the emission inventories. The federal government also collects some of these data through special surveys conducted to support environmental and energy programs, and for the publication of annual statistics. Many EGUs across Canada are required to monitor and report their hourly emissions to the provincial agencies as required by their operating permits or specific regulations. As an example, an emission trading regulation for NO_x and SO_2 in Ontario requires that coal and oil-fired EGUs monitor their emissions using CEMS or other emission monitoring methods approved by the Ontario Ministry of the Environment. These emissions are reported annually to the Ministry and are used for the compilation of emission inventories. It is expected that other similar emissions trading programs will be implemented in the future in Canada. These programs may also include non-EGU point sources, and provide additional activity and emission information to improve the accuracy of the emission inventories.

Mexican Point Source Data

In Mexico, industrial facilities (i.e., point sources) operating in specific geographical “federal zones” or having potential significant interstate impacts or complex operating characteristics are under federal jurisdiction (i.e., SEMARNAT is in charge of regulating them). The federal government manages the regulation, administration, enforcement, and sanctions of facilities within its jurisdiction, and also manages emission inventory development for such facilities. These facilities include the following:

- Those within 100 km of the Mexican border (La Paz, 1984)
- Those included under Article 111 of the *Ley General del Equilibrio Ecólogico y la Protección al Ambiente* (General Law of Ecological Equilibrium and the Protection of the Environment or LGEEPA) (DOF, 1998)
- Public transportation terminals
- On- and off-shore federal lands (e.g., federal coastal zone, federal islands, reefs, and keys)
- Federal government facilities
- Mexico City Metropolitan Area
- Facilities or activities in one state that affect another state.

As described in Section 3.1.3, submission of annual operating reports (called *Cédula de Operación*

Anual – COA) is compulsory for these facilities. These reports include basic information on fuel consumption, operating conditions, and emissions and are compiled either at SEMARNAT's central offices or at its state *Delegaciones*. Additionally, State Environmental Authorities collect information on point sources not under federal jurisdiction through reports which may contain similar information as that required by federal COAs.

4.4 EMISSION INVENTORY MODELS

Inventory models (or emission factor models) are used to estimate emissions for source categories in which the conventional approach of multiplying an emission factor by an activity factor cannot adequately represent the complexity of the source category. Inventory models are most often used for nonpoint sources such as agricultural and biogenic emissions, or for mobile onroad and nonroad sources. These models can be simple or complex, depending upon the needs of the applications for which they have been developed.

4.4.1 MOBILE6

U.S. MOBILE6

MOBILE6 is an emission model developed by the U.S. EPA (http://www.epa.gov/otaq/m6.htm) for estimating emissions from onroad motor vehicles. The model provides criteria-pollutant (including PM and NH_3) and HAP emission factors for highway motor vehicles such as passenger cars, trucks, and buses. MOBILE6 calculates emission factors for 28 individual vehicle types in low- and high-altitude regions of the United States (U.S. EPA, 2002a; U.S. EPA, 2002b). MOBILE6 emission factors depend on conditions such as ambient temperatures, travel speeds, operating modes, fuel volatility, and mileage accrual rates. Many of the variables affecting vehicle emissions can be specified by the user through the use of an input file. MOBILE6 will estimate emission factors for any calendar year between 1952 and 2050. Vehicles from the 25 most recent model years are considered to be in operation in each calendar year. Emission factors generated by MOBILE6 are multiplied by VMT estimates to produce emission estimates.

MOBILE6 (and the latest release, MOBILE6.2) uses statistical relationships based on thousands of emission tests performed on both new and in-use vehicles. In addition to standard testing conditions, many vehicles have been tested at non-standard temperatures, with different types of fuels, including gasoline oxygenate/alcohol blends, and under different driving cycles. Relationships have been developed for vehicles at varying emission control levels, ranging from no control to projections of in-use performance of new technology vehicles.

Even though systematic emission measurements have been performed on the in-use vehicle fleet in the United States, substantial uncertainty remains regarding the applicability of these results. The primary sources of uncertainty are the sensitivity of vehicle emissions to the driving cycle, the wide variety of driving patterns, and the effects of sampling error. Remote sensing surveys indicate that a small fraction of high emitters in the fleet produce a large fraction of total vehicle emissions. Inclusion of one or more high emitters in a survey sample has a substantial influence on resulting emission rates/factors.

Since MOBILE6's release in January 2001, there have been two studies sponsored to evaluate and validate the model—one sponsored by the Coordinating Research Council (CRC – a cooperative research effort of the American Petroleum Institute and automotive industry in the United States) and U.S. EPA, and another sponsored by the American Association of State Highway and Transportation Officials (AASHTO).

The CRC/U.S. EPA project (ENVIRON, 2004) compared MOBILE6 HC, CO, and NO_x emission estimates with various real-world data sources, including tunnel studies, ambient pollutant concentration ratios, emission ratios from remote sensing devices, and heavy-duty vehicle emission data based on chassis dynamometer testing. Compared with tunnel studies, the CRC/ U.S. EPA study found that MOBILE6 over-predicts fleet average emissions, with the over-prediction being most pronounced for CO (and, in particular, newer vehicles). Estimates of NO_x emissions most clearly matched the tunnel data. Compared with ambient data, the HC/NO_x ratios developed from MOBILE6 appear to be reasonably accurate, and the CRC/ U.S. EPA data generally supported the HC deterioration rates in MOBILE6.

AASHTO (Sierra, 2004) evaluated several components of MOBILE6 including (1) PM emission factors, (2) toxic air pollutant emission factors, (3) assessment of emission factors when compressed natural gas is the fuel, and (4) methods to estimate CO_2. It was found that MOBILE6 appears to overestimate exhaust PM emissions from newer vehicles. For pre-1990 model years, MOBILE6 predictions fall within the range of recent test program expected values. The AASHTO study also found that MOBILE6 may be underestimating PM_{10} emissions from heavy-duty diesel trucks. The study also found that MOBILE6 brake-wear emission factors likely underestimate brake-wear emissions from the heavier vehicle classes.

Canadian MOBILE6

Environment Canada has developed a Canadian version of the U.S. EPA's MOBILE6.2 model. The Canadian model was based on reviewing the underlying MOBILE6.2 method and documentation, reviewing current and past Canadian inventory methods, modeling documentation and other related studies, and discussing the differences between U.S. and Canadian vehicle fleets with Canadian vehicle manufacturers.

The Canadian model does not change the functionality of MOBILE6.2 or its commands. Certain data needed to be changed from the U.S. default to properly reflect Canadian conditions, and those data are handled in two ways: either through available MOBILE6.2 input commands (the preferred method) or through code modifications (when input commands can not be used). In this manner, the model is designed to allow for the continued use of the U.S. MOBILE6.2 User's Guide and all commands in MOBILE6.2 are executed similarly in Canadian and U.S. versions. Input files may be more elaborate in Canadian modeling, as the pre-existing defaults in the U.S. version of the model are not always reasonable for Canadian conditions. Code changes also were implemented to address the differences in the light-duty U.S. and Canadian fleets prior to the 1988 model year. All code changes are invisible to the user. A full report on the Canadian conversion of the model is available (Air Improvement Resource, 2004).

The MOBILE6.2C model and all available data and resources, along with a graphic user interface in both official languages of Canada, will be made freely available from Environment Canada's website. The data resources are currently being updated, and when complete, may be accessed at http://www.ec.gc.ca/pdb/ape/cape_home_e.cfm.

Mexican MOBILE6

The basic structure of the MOBILE6-Mexico model is based upon the U.S. EPA's MOBILE6 model (ERG, 2003b). MOBILE6-Mexico estimates emission factors for 28 gasoline- and diesel-powered onroad motor vehicle types. Emission factors include hydrocarbons, CO, NO_x, PM, and CO_2. The specific emission factor estimates depend upon conditions such as ambient temperatures, average travel speed, vehicle operating modes, fuel volatility, and mileage accumulation rates. Nearly all of the required input variables can be specified by the user; however, default values are provided that should be appropriate for most areas of Mexico. MOBILE6-Mexico can be used to estimate emission factors for any calendar year between 1952 and 2050. For each calendar year, the overall vehicle fleet consists of the 25 most recent vehicle model years.

In its first application the MOBILE6-Mexico emission-factor model will be used to develop onroad motor vehicle emission estimates for the Mexican NEI (ERG, 2004).

4.4.2 EMFAC2002

California is the only state in the United States that has the authority to establish its own motor vehicle emission standards. California's emission standards are of equal or greater stringency than the federal standards for the other 49 states. In order to properly account for the effects of California's emission standards, the CARB has developed its own emission factor model -- EMFAC2002. The model produces emission-rate estimates for exhaust and evaporative hydrocarbons, CO, NO_x, as well as for PM associated with exhaust, tire wear and brake wear. Hydrocarbon emission estimates are produced for total hydrocarbon, total organic gases, and reactive organic gases. PM estimates are made for TSP, PM_{10}, and $PM_{2.5}$. The model also estimates emissions of sulfur oxides, Pb, and CO_2. The CO_2 inventory is used to estimate fuel consumption. Although the estimation of toxic air contaminants is currently performed outside of EMFAC2002, efforts are underway to include this capability in the next version of the model. The model, as well as information, can be obtained at http://www.arb.ca.gov/msei/onroad/latest_version.htm (ARB, 2002).

4.4.3 NONROAD

U.S. NONROAD

The NONROAD emission model, currently in draft form, predicts emissions for nonroad equipment ranging from lawn and garden equipment to heavy-duty commercial vehicles. The model includes more than 300 basic and specific types of nonroad equipment that use gasoline, diesel, compressed natural gas, and LPG. NONROAD estimates emissions for hydrocarbons, NO_x, CO, CO_2, SO_x, and PM (U.S. EPA, 2004b; U.S. EPA, 2004c). Even in draft form, the U.S. EPA considers it the best tool available currently for estimating nonroad emissions.

The geographic extent of each model run is user-defined and ranges from national total emissions to subcounty emissions. The subcounty level requires the user to supply the necessary input to distribute the emissions. NONROAD can estimate emissions for the current year, as well as project for future year emissions out to 2045 and backcast past-year emissions to 1970. The model includes growth and scrappage rates for equipment. Emissions are calculated for annual, seasonal, or monthly time periods, with estimates reported for the total period or for a typical day of the week. The NONROAD model and associated documentation can be obtained at http://www.epa.gov/otaq/nonrdmdl.htm.

The OFFROAD model, developed by CARB, has been used to develop nonroad vehicle emissions of hydrocarbons, CO, NO_x, and PM throughout California. More information about the model can be obtained at http://www.arb.ca.gov/msei/nonroad/updates.htm.

Canadian NONROAD

Environment Canada has developed Canadian nonroad engine population databases for use with the U.S. EPA's draft NONROAD 2004 model. At present, no sub-region or district-level data are incorporated into the Canadian engine population database. However, to provide for compatibility with these and other aspects of the model, Canada, the provinces and territories are mapped to certain American states and Federal Information Processing Standards codes. Environment Canada has also created modified spillage factor files, NO_x deterioration files, and technology files to reflect the difference in Canada and the United States. Full details of the changes to these files are outlined in the report by Vaivads (2004).

All available data, resources, modified files and documentation are available from Environment Canada's website at http://www.ec.gc.ca/pdb/ape/cape_home_e.cfm.

Mexican NONROAD

The U.S. EPA's NONROAD model was used to estimate construction and agricultural emissions (only) for the 1999 Mexican NEI. However, a current project is underway to develop a Mexico-specific version of this model for future use. NONROAD-Mexico will incorporate information on Mexican construction equipment population and usage obtained from field surveys conducted in Monterrey, Nuevo León, in January 2005. Updated agricultural equipment population information has been obtained from *Secretaría de Agricultura, Ganadería, Desarrollo Rural, Pesca y Alimentación* (SAGARPA, Secretariat of Agriculture, Livestock, Rural Development, Fisheries, and Food).

4.4.4 MOVES

To keep pace with new analysis needs, new modeling approaches, and new data, the U.S. EPA's Office of Transportation and Air Quality (OTAQ) is currently working on a new modeling system termed the Motor Vehicle Emission Simulator (MOVES). This new system will estimate emissions from onroad and nonroad sources, cover a broad range of pollutants, and allow multiple-scale analysis, from fine-scale to national inventory estimation. The foundation of the multi-scale approach is a common set of modal emission rates disaggregated by driving mode. These modes are then re-aggregated based on representative activity data to estimate total emissions at any scale over any driving pattern. The MOVES model uses a binning approach to define modal emissions. Vehicle-specific power and instantaneous speed are used to identify driving modes. This method produces 17 bins that segregate idle and deceleration, and splits the remaining cruise and acceleration operation into 15 bins defined by combinations of speed (less than 25, 25 to 50 and greater than 50 mph) and vehicle-specific power (U.S. EPA, 2002c).

The current draft version of MOVES (MOVES2004) only models energy (i.e., fuel consumption), methane, and NO_x. The U.S. EPA's plans call for adding hydrocarbons, CO, NO_x, and PM to the draft MOVES2006 model. The MOVES2007 model is expected to be considered "final" for criteria pollutants and will likely be the replacement for MOBILE6 in 2007 (Landman, 2005). Additional information regarding the MOVES model can be obtained at http://www.epa.gov/otaq/ngm.htm.

4.4.5 BEIS

First developed in 1988, the Biogenic Emissions Inventory System (BEIS) estimates VOC emissions from vegetation and NO emissions from soils. Because of resource limitations, recent BEIS development has been restricted to versions that are compatible with the Sparse Matrix Operational Kernel Emissions (SMOKE) system. There have been multiple releases of BEIS, with the most recent being version 3.12.

Characteristics of the various versions of BEIS (U.S. EPA, 2004c) are listed below:

- BEIS 3.12: This is the most recent version of BEIS. It is assembled as a stand-alone module to the SMOKE system for generating gridded, hourly emissions in a format consistent with air quality modeling.
- BEIS 3.11: This is a forerunner to version 3.12 of BEIS. BEIS 3.11 is a stand-alone module to the SMOKE system for generating gridded, hourly emissions in a format consistent for air quality modeling. BEIS3.11 revises the soil NO algorithm in BEIS3.10 to better distinguish between agricultural and nonagricultural land, and to limit adjustments from temperature, precipitation, fertilizer application, and crop canopy to the growing season and to areas of agriculture. A leaf-shading algorithm is added for estimating methanol emissions from non-forested areas.
- BEIS-2: This is an older version of BEIS. It calculates emissions from vegetation using 75 tree genera, 17 agricultural crop types, and urban grasses. Several data requirements are necessary inputs to the BEIS-2 model, including spatially gridded land-use and plant cover data, vegetation-specific emission factors for VOC and NO, and hourly gridded temperature data.

Documented physicochemical effects remain largely unaccounted for in the BEIS models. For example, the effects of plant stress and dew on biogenic emission rates are not accounted for in the model. Because the effects of these conditions are accounted for in existing dry-deposition models, these data are available for incorporation into BEIS models. Relative humidity and CO_2 concentrations also affect biogenic emission rates. Data to support these physico-chemical effects are available for incorporation into the BEIS models. The model and further information can be obtained at http://www.epa.gov/asmdnerl/biogen.html.

4.4.6 GloBEIS

The Global Biosphere Emissions and Interactions System (GloBEIS) is based on a collaboration between the U.S. EPA and the U.S. National Center for Atmospheric Research. GloBEIS allows users to estimate biogenic emissions of VOC, CO, and soil NO_x for any scale and domain. GloBEIS runs in Microsoft Access on a PC platform. Emission rates are a function of landcover and environmental conditions, which are characterized from user-supplied data using the most updated emission algorithms. The developers of GloBEIS identify its attributes as:

- Uses high resolution land use data, GIS data, or Biogenic Emissions Land Cover Data, Version 3 (BELD-3).
- Provides updated emission factor algorithms. The GloBEIS3 algorithms reflect the latest science compared to the BEIS2 algorithms.
- Compares different emission factor algorithms in the same model.
- Provides VOC speciation for atmospheric chemical mechanisms.
- Bases isoprene emissions on solar radiation data supplied from GOES satellite images. This accurately represents the impacts of clouds on biogenic emission inventories with hourly temporal resolution.
- Models effects of drought and prolonged periods of high temperature.
- Uses satellite-based leaf-area index data to determine the spatial distribution of emission and/or leaf age.
- Includes a leaf temperature model.

GloBEIS 3.1 has been adopted by Environment Canada to estimate Canadian biogenic emissions. Environment Canada uses the GIS-based Spatial Emissions Distribution Information System for integrating, processing, and calculating the geographic distribution of CAC emissions from the inventories. This system generates the various input files required to run the GloBEIS 3.1 model such as:

- Domain definition and specification of geographic units; including the identification, latitude, longitude and total area of each geographic unit (grid system or administrative regions)
- Land use distribution by geographic unit and by land use code; including land-use and land-cover information based on an advanced very high resolution radiometer land cover map of Canada
- Hourly temperature data for all stations across Canada
- Hourly cloud opacity data for all stations across Canada.

Some of the emission factors and other related information in the GloBEIS 3.1 model were also updated to reflect the Canadian information available. Information regarding the GloBEIS model can be obtained at www.globeis.com/. More Canadian meteorological data can be found at http://weatheroffice.ec.gc.ca/canada_e.html.

The GloBEIS 3.1 model was used to estimate biogenic emissions for the Mexican NEI (ERG, 2004). The following input data were compiled for use with GloBEIS:

- Land use data sets from the National Forestry Inventory for Mexico developed by the National Autonomous University of Mexico (UNAM) and SAGARPA (for agricultural crops).
- Hourly temperature data from *Servicio Meteorológico Nacional* (SMN, National Meteorological Service) for 15 sites in Mexico, augmented with data from the U.S. National Climatic Data Center (NCDC) for 116 sites in Mexico.
- Hourly cloud cover data from SMN.

4.4.7 BEIGIS

California has proposed developing a biogenic emission-estimation program that incorporates data on the specific vegetation in California and extensive land-use data. The proposed Biogenic Emission Inventory Geographic Information System (BEIGIS) model is described in further detail at http://www.arb.ca.gov/ei/ccosbeigis2.pdf.

4.4.8 TANKS

TANKS estimates VOC and HAP emissions from organic liquid storage tanks. It models emissions by simulating them as evaporation processes. The American Petroleum Institute developed the underlying equations to TANKS and licensed their noncommercial use to the U.S. EPA for the software and AP-42 documentation. Required inputs include tank size, structure and condition; environmental conditions; and physicochemical data describing the mixture of liquids contained in the tanks. The TANKS software, as well as user's guide can be obtained at http://www.epa.gov/ttn/chief/software/tanks/index.html.

4.4.9 WATER9

WATER9 is a Windows-based computer program developed by the U.S. EPA to estimate emissions from wastewater treatment. WATER9 includes a graphical user interface that allows the user to outline wastewater treatment processes present at a facility. The program can also generate reports of constituent fates, including air emissions and treatment effectiveness.

WATER9 contains a set of representative treatment components that can be used together in a project to provide a model for an entire facility. The model is able to evaluate a full facility that contains multiple wastewater inlet streams, multiple collection systems, and complex treatment configurations. WATER9 provides separate emission estimates for each individual compound identified as a constituent of the waste. The emission estimates are based upon the properties of the compound and its concentration in the wastes. To obtain these emission estimates, the user must identify the compounds of interest and provide their concentrations in the wastes. The identification of compounds can be made by selecting them from the database that accompanies the program or by entering new information describing the properties of a compound not contained in the database. WATER9 uses site-specific chemical-property information and estimates missing chemical-property values. Estimates of the total air emissions from the process are obtained by summing the estimates for the individual compounds. The model, as well as documentation, can be obtained at http://www.epa.gov/ttn/chief/software/water/.

4.4.10 Emission Dispersion Modeling System

The U.S. Federal Aviation Administration has developed a program to estimate emissions from airports which is called the Emission Dispersion Modeling System (EDMS). The original version of EDMS was released in 1997, and it has since been further developed. The most current version of EDMS is version 4.2. EDMS 4.2 provides emission data for the following pollutants: total hydrocarbons, non-methane hydrocarbons, volatile organic compounds, PM_{10} and $PM_{2.5}$ (there are no PM_{10} or $PM_{2.5}$ emission factors for aircraft). EDMS 4.2 interfaces with the U.S. EPA's latest version of AERMOD and its supporting weather and terrain processors. The latest version of EDMS also integrates the U.S. EPA's MOBILE software for estimating emissions from vehicles at parking lots and feeder roads. In addition, beginning with version 4.1, EDMS integrated the U.S. EPA's draft NONROAD program for estimating emissions from aerospace ground equipment/ground service equipment. EDMS allows users to build and customize aircraft, vehicle, and GSE fleets for individual airports. Subsequently, EDMS calculates emissions by airport. EDMS software can be obtained for a fee at http://www.aee.faa.gov/emissions/EDMS/EDMShome.htm.

4.4.11 Carnegie Mellon University Ammonia Model

The Carnegie Mellon University Ammonia Model is an emission factor model and database of activity data for NH_3 emissions based in part on AP-42 estimates. This model is frequently used in the United States, including in the NEI, for compiling NH_3 emission data. It stores county-specific activity data at the national scale and emission factors for a variety of NH_3 emission sources, including livestock, fertilizers, wastewater treatment facilities, mobile sources, natural biogenic sources, etc. Examples of stored activity parameters include livestock populations by animal type, fertilizer consumption rates, wastewater plant process rates, VMT by vehicle class and technology types, and land coverage by land use categories. This model and associated documentation can be retrieved at http://www.cmu.edu/ammonia/.

4.5 EMISSION PROCESSORS

Emission processing tools are used to prepare and manipulate existing emission estimates and related data (e.g., temporal profiles, chemical speciation profiles, and control strategies) for input to air quality simulation models. The principal emission processors are described below.

4.5.1 SMOKE

SMOKE processes emission data using matrix-vector multiplication. It performs the core functions of emission processing including spatial allocation, temporal allocation, chemical speciation, control-technology application, and generation of biogenic emission estimates. SMOKE implements the MOBILE6 model and also uses a reorganized version of the Urban Airshed Model – Biogenic Emissions Inventory System (UAM-BEIS-2). Alternative mobile-source models such as EMFAC2002 and biogenic models such as BEIS-3 may be run external to SMOKE and their results incorporated into the SMOKE processing stream. SMOKE can be obtained at http://www.cep.unc.edu/empd/EDSS/emissions/.

4.5.2 Emission Processing System

One of the most widely used emission processing tools is the Emission Processing System (EPS)2.0/2.5 developed under U.S. EPA sponsorship as a FORTRAN-based emission processing system. EPS was designed to prepare county-level seasonal or annual emission inventories for use in urban models and was released as version 1.0. As a result of the 1990 Clean Air Act Amendments, a growing emphasis on the use of urban models led to a series of enhancements. EPS2.0/2.5 provides expanded capabilities to handle the 1990 Clean Air Act Amendments requirements with all the necessary modules to prepare spatially, temporally, and chemically detailed emission inventories. EPS2.0/EPS2.5 is publicly available and allows the development of emission inventory inputs for urban models with a minimum of additional data because it comes with a set of national defaults for many of its required inputs.

Canada has developed its own emission processor, based on the U.S. EPA's EPS2 and on BEIS2. The CEPS1.0 was developed to process current Canadian and U.S. annual national inventories of criteria air pollutants and to generate emission input files for each air quality model as required. CEPS1.0 differs from its U.S. counterpart mainly in the form of regional and country-specific modifications. Areas where the U.S. EPS2.0 and BEIS2 were changed include: data structure, input files for the accommodation of different map projections, and arbitrary grid windows, grid orientations, and grid increments. Further changes were required to the base programs as follows: chemical mechanisms other than carbon bond IV, multiple time zones, updated and enlarged spatial allocation factor fields, various major/minor point-source partitioning options, and the use of gridded meteorological fields in calculating mobile and biogenic emissions.

4.5.3 Emission Modeling System

The Emission Modeling System versions (EMS-95 and EMS-2000) compute model-ready emission estimates for point, nonpoint, mobile, and biogenic sources. Both EMS versions are based on the Geocoded Emission Modeling and Projections (GEMAP) system developed for CARB during the early 1990s and include a number of enhancements and extensions to the original GEMAP system. EMS is composed of six primary modules: the Grid Definition Model, the Point Source Model, the Area Source Model, the Motor Vehicle Emissions Estimates Model, the Biogenic Model for Emissions Estimates, and the Speciation Model. While its approach to generating emission inventories for regional scale air quality modeling is flexible and comprehensive, the software requirements (SAS, ArcInfo, and a FORTRAN compiler) make EMS an expensive system to use. EMS is specifically designed to perform the following activities:

- Modify emission parameters and inputs efficiently
- Define a modeling grid
- Process point and nonpoint source emission estimates, based on annual average or day-specific emissions
- Calculate onroad mobile source emission estimates
- Calculate biogenic emission estimates
- Calculate crude oil storage tank emission estimates
- Spatially distribute, temporally allocate, and speciate emissions for use in photochemical modeling
- Develop projected emission inventories for future-year scenarios.

EMS-HAP, designed initially to process the 1996 National Toxics Inventory (NTI), is a system of computer programs that process toxic air pollutant (or HAP) emission inventories for use in the Assessment System for Population Exposure Nationwide (ASPEN) or the Industrial Source Complex (ISC3) Dispersion Models (ISCST3) air quality models. EMS-HAP differs from EMS-95 in that it is specific to the NTI and ASPEN/ISCST3. It also is capable of estimating future year emission data for these models. EMS can be obtained at http://64.27.125.175/tech/emis/index.html.

4.6 EMISSION PROJECTIONS

Emission projections are performed in support of several goals, such as providing a basis for developing control strategies for SIPs, conducting attainment demonstration analyses, tracking progress towards meeting air quality standards, and evaluating future-year impacts associated with national rulemakings. Emission projections are a function of change in activity (growth or decline) combined with changes in the emission rate or controls applicable to the source. Changes in emission rates may occur via air pollution regulations and standards or through technological change that occurs with time. The methodologies, tools, and data sources that are used to prepare future-year emission inventories are specific to the inventory sector.

It should be recognized that uncertainties in projection inventories are significantly greater than uncertainties in current (or baseline inventories). These added uncertainties are due to the difficulty in projecting future economic activity by sector and projecting the consequences of unforeseeable actions, such as the decline of the U.S. steel industry in the 1980s or the dot.com bust in the San Francisco Bay area in the 1990s. Thus, it is especially critical for projection inventories to include measures of uncertainty and variability, and to bound projections when possible. In order to characterize the robustness of projections, it is critical that projection models be transparent so that the underlying assumptions can be understood and modified as necessary. The best check on the accuracy of emission projections is the comparison of periodic inventories with projections.

The following discussion identifies key emission projection concepts, and tools and data sources that have been developed and used in preparing emission projections. Additional background projection information is available on the following websites developed in support of the EIIP: http://www.epa.gov/ttn/chief/eiip/techreport/volume10/x01.pdf and http://www.epa.gov/ttn/chief/eiip/committee/projections/evaltools.pdf.

4.6.1 Emission Activity Forecasts

Because source-specific future year emission activity forecasts are difficult or impossible to obtain, projection-year inventories are typically based on forecasts of population, industrial activity, or other surrogates for emission activity changes. In the United States, the U.S. EPA has developed the Economic Growth Analysis System (EGAS) to support emission activity level forecasting. The latest version of EGAS (4.0) provides default emission-activity growth factors for the period 1996-2020

(Pechan, 2004). This Windows-based software tool provides growth factors for nearly 10,000 source classification codes for each county in the continental United States based on forecasts for surrogate emission activity growth indicators such as output by industry sector. Growth factors in EGAS are defaults and forecasters should rely on more specific information whenever it is available. The following link on the U.S. EPA's Emissions Modeling Clearing House provides the EGAS 4.0 installation files, reference manual, and user's guide: http://www.epa.gov/ttn/chief/emch/projection/egas40/index.html.

U.S. EPA is currently developing EGAS 5.0, which will extend projection capability through at least 2025, and include activity growth indicators for all 50 states and the District of Columbia. Some state and local agencies have their own emission forecasting systems. For example, in California, CARB as well as the two of the largest air districts (South Coast Air Quality Management District and the Bay Area Air Quality Management District) develop their own emission forecasts.

Although EGAS provides emission activity growth factors for every emission sector, the NONROAD model has been developed in the United States to support emission projections for most nonroad source categories. The NONROAD model and associated documentation is available from http://www.epa.gov/otaq/nonrdmdl.htm#model. EGAS projections and growth factors can potentially be incorporated into future NONROAD releases.

For fuel combustion sectors, EGAS 4.0 incorporates energy consumption projections prepared by the EIA in Annual Energy Outlook 2001 (EIA, 2004a; EIA, 2004b). Because EIA updates its energy consumption projections annually, emission forecasters can obtain EIA's current energy consumption projections from http://www.eia.doe.gov/oiaf/aeo/index.html. The two main methods that have been used to prepare VMT projections are through travel demand forecasting (preferred) and extrapolation of historical VMT trends. MOBILE6 makes future year projections using changes in future technology and increases in VMT. MOBILE6 uses a 2 percent compounded annual growth rate for VMT.

The importance and complexity of the EGU sector has led to the development of computer models to evaluate the effects of air pollution control strategies and other important changes influencing this sector (Pechan and Wilson, 1984). These models seek to represent generation, transmission and pricing of electricity subject to fuel prices, the costs of capital and domestic investment, and electricity load shape and demand. Such models also typically include a linear programming component to allow evaluations of the cost and emission impacts of proposed policies to limit EGU sector emissions of SO_2, NO_x, CO_2, and mercury via trading programs. In the United States, the Integrated Planning Model (IPM) has been developed for preparing EGU emission projections (ICF, 2004). The IPM is a proprietary model. Information on recent U.S. EPA IPM modeling runs is available from the following U.S. EPA Clean Air Markets Division link: http://www.epa.gov/airmarkt/epa-ipm/.

4.6.2 Emission Rate/Control Forecasts

In the United States, future year emission rates for most source sectors are maintained in sector-specific models (e.g., EGU emission rates in IPM; onroad mobile source rates in MOBILE, and nonroad mobile source rates in NONROAD). These models produce emission forecasts that incorporate the impact of equipment turnover on the emission rates of new vehicles/equipment.

Because no emission estimation model has been developed for the non-EGU stationary point and nonpoint sectors, no single resource provides future-year emission rates for these sectors. To assist in identifying future-year stationary-source emission rate/control assumptions, forecasters can obtain emission-inventory forecast documentation prepared in support of rulemakings. This documentation generally includes estimates of the emission reductions associated with the mandated control for one or more future implementation years. The percent emission reduction then can be calculated and applied in preparing non-EGU stationary source emission forecasts. A potential source of emission reduction information for some stationary sources is AirControlNET (Pechan, 2003), a U.S. EPA relational database that contains emission reduction and cost information for a series of mandatory and discretionary point and nonpoint source emission control strategies. Information on AirControlNET is available from http://www.epa.gov/ttn/ecas/AirControlNET.htm.

Also, no tool is available in the United States for modeling the impact of equipment turnover and technology changes on future non-EGU stationary source emission rates. Although this is not likely to have a significant impact on short-term projections, emission forecasters should consider incorporating the impact of stationary source equipment turnover whenever possible. A recent example of a stationary point source emission projection effort that modeled this effect is the WRAP 2018 year forecast. More information on the WRAP emission projections methodology can be found at http://www.wrapair.org/forums/ef/documents/2002-12_PECHAN_FinalReport_Base-Annex-Bart.pdf.

4.6.3 Canadian Emission Projections

Like the U.S. EPA, Environment Canada compiles emission projections on a regular basis to support the development of federal and provincial emission-control strategies (federal and provincial implementation plans), to evaluate their future impact on air quality, and to support the reporting requirements of domestic and international programs and agreements. Using the latest emission inventory available, the Canadian projections for industries and power-generating utilities are developed using annual growth factors, which are calculated from surrogate data or indicators obtained from the energy outlook compiled by Canada's ministry of natural resources, NRCan. The projections also take into account changes in technology and equipment turnover for different industries.

NRCan has adapted the U.S. National Energy Modeling System (NEMS) for developing the Canadian energy outlooks. NEMS is an energy-economy modeling system, designed and implemented by the U.S. EIA. NEMS projects the production, imports, consumption, and prices of energy, subject to various assumptions such as macroeconomics, resource availability and costs, costs and performances of energy technologies, behavioral and technological choice criteria and demographics.

Emission projections for onroad vehicles are developed using the Canadian emission estimation model, MOBILE 6.2C. Emission projections for nonroad transportation vehicles (excluding aviation, marine and rail) are calculated using the U.S. NONROAD model. This model takes into account the VKT each year, the turnover of vehicle fleets, and the characteristics of the gasoline and diesel fuel being used, as well as future impacts of current energy policies and emission reduction programs.

A base case forecast is developed using the provincial and territorial projections compiled by Environment Canada. The base case forecast is a "business/policy as usual" projection, in the sense that all current energy, environment and related policies are held constant over the projection period. The impacts of modified or additional control regulations that have not been officially implemented (at the time the forecast is prepared) are not included in a base case. The base case is thus a reference case, against which control scenarios can be built to compare the impacts of potential emission reduction measures. A review of the base case forecast is performed through consultations with industrial sector experts, provincial and territorial governments, industry associations, and other interested parties.

Environment Canada is currently validating and improving the Energy 2020 Model to project the emissions for both CACs and GHGs. Energy 2020 is an integrated energy system that calculates the energy demand, the energy supply and the associated emissions. The model projects end-use energy demands in major sectors (residential, commercial, industrial, agriculture and transportation) based on macroeconomic assumptions. It also dynamically simulates the supply of various types of energy (electricity, oil, gas, biomass) to meet these end-use demands. Finally, it calculates the CAC and GHG emissions associated with these demands and supplies of energy. As an integrated model, Energy 2020 can estimate how changes in energy demand behaviors in one sector can impact other sectors via fuel consumption, fuel supply and fuel prices.

The Energy 2020 model is widely used in Canada, the United States, Europe, and around the world, with each region or jurisdiction configuring the model to meet the detail levels specific to the country. Environment Canada has adapted the model to cover the 10 provinces and 3 territories. Other enhancements to Energy 2020, which take into account the particularities of Canada, include additional categories in the transportation sector, the regulate/deregulate supplies of electricity, disaggregation of fuel types, and CAC emission factors.

The Canadian version of the Energy 2020 model will be used as a starting point for future emission projections. It will become a policy tool to analyze the impacts of current and future environment policies, energy options and control measures to reduce future CAC and GHG emissions. It will be calibrated to the energy outlooks prepared by NRCan on a regular basis.

The latest emission projections available for Canada are based on the 2000 emission inventory and cover the period from 2001 to 2020.

4.6.4 Mexican Emission Projections

Methodology for Projecting the Border Baseline Emission Inventory (1999) to 2002 and 2012

The Mexican emission-inventory base year is 1999. Inventories for the years 2002 and 2012 were estimated in order to characterize the impact of growth and existing control strategies on future emissions within the Mexico/U.S. border region (defined by the La Paz Agreement as the area within 100 kilometers either side of the international border). This section describes the methodology used to project the 1999 baseline inventory to the years 2002 and 2012 (ERG, 2005).

Point Sources

Because the U.S. EGAS model is not applicable to Mexican point sources, point-source projection factors were developed by extrapolating existing industrial statistics. Mexican industrial production statistics from 1995 to 2000 were obtained from the Organization for Economic Co-operation and Development, or OECD (OECD, 2004). The production statistics were aggregated to the 3-digit NAICS level and then extrapolated to 2002 and 2012 to develop appropriate projection factors. The industrial statistics did not provide any information for mining and waste management activities (NAICS codes 212 and 562); for this reason the projection factors for these sectors were set to 1. Information regarding future projections for electric utilities activity was obtained from SENER (2003a). Emissions for electric utilities were projected using estimates of electricity generating capacity (projections of future electricity use were unavailable). Projected emissions from utilities were assigned only to existing facilities (as of 1999) even if future electricity generating capacity was planned for a new location.

Nonpoint Sources

Projection factors for future year Mexican nonpoint sources were based upon a variety of published data. These data included the following:

- Regional energy forecasts (*Prospectivas*) from 2003 to 2012 for four energy sectors (i.e., electricity, petroleum liquids, natural gas, and LPG) were obtained from SENER (SENER, 2003a; SENER, 2003b; SENER, 2003c; SENER, 2003d). Projection factors were derived directly from the specific energy forecasts and applied to all nonpoint source fuel combustion and distribution nonpoint source categories for 2002 and 2012.
- Annual state-level agricultural and livestock statistics from 1993 to 2002 were obtained from SAGARPA (2003). Projection factors for agricultural sources (e.g., Technical Memorandum – Draft Final September 30, 2004 Page 10 livestock ammonia, fertilizer application, agricultural tilling, etc.) were developed by extrapolation of 10-year statistics.
- The industrial point-source statistics described under the Mexico point-source section were used to develop projection factors for four industrial nonpoint sources (i.e., bagasse combustion, coke production, industrial surface coating, and degreasing).

- Future-year population forecasts through the year 2030 at the municipality level were obtained from Mexico's National Council on Population (*Consejo Nacional de Población* – CONAPO) (CONAPO, 2003). Projection factors were derived directly from the specific population forecasts for 2002 and 2012.

Because of difficulties in projecting future levels of wildfires, wildfire activity was assumed to be constant in 1999, 2002, and 2012. Because future-year control information was not available, the projection factors only include the effects of growth.

Onroad Motor Vehicles

Unlike the other Mexican source types, the future-year projection factors for Mexican motor vehicles included both growth and control factors. The growth factors were based upon the future-year SENER regional fuel forecasts. Control factors were estimated by running future-year MOBILE6-Mexico scenarios. Because of the large number of MOBILE6-Mexico runs that were necessary for development of the base year Mexico NEI, it was not feasible to rerun all possible scenarios for 2002 and 2012. However, scenarios representing a typical vehicle speed (i.e., 30 mph) were run for summer and winter conditions at low and high altitude (i.e., >1,400 meters) for the northern portion of Mexico for 1999, 2002, and 2012. The results from these scenario runs were then used to develop the control factor part of the projection factors.

Nonroad Sources

Projections for nonroad sources were based upon regional fuel forecasts (for nonroad equipment including construction and agriculture) as provided by SENER for 2002 and 2012.

<u>Methodology for Projecting the MCMA Baseline Emission Inventory (1998) to 2000, 2006 and 2010</u>

The following is a brief description of the methodology used in the projection of the 1998 emission inventory for the MCMA (GDF, 1998) to the years 2000, 2006 and 2010.

Point Sources

The projection of emissions from point sources was conducted assuming the existence of a direct relationship between emission growth rates and the Gross Domestic Product (GDP) by federal entity and economic activity. In this case, the growth rates used were: 0 percent for the electric sector in the Federal District and 3.7 percent for the municipalities of the State of Mexico; for other point sources (industrial, manufacturing, etc.) a GDP growth rate of 4.2 percent was used for the Federal District and 4.5 percent for the State of Mexico. These values correspond to the annual average growth rates of the GDP for the period 1993-1999 and assume constant growth rates until 2010.

Nonpoint Sources

To estimate emissions from nonpoint sources for the years 2000, 2006 and 2010, projection factors were obtained from a relationship between the activity level during the base year and the activity level for the projected year. The activity level for the projected years was obtained from local behavior studies or projections of the population growth (CONAPO, 2003), as well as growth trends in fuel consumption (gas, diesel, industrial diesel, LPG and natural gas) (SENER, 2000b).

Given the difficulties encountered in projecting the behavior of certain sectors, such as forest fires or structural fires, these activity levels were assumed to remain constant for the projection. The factors used in the projection only include the effect of growth and do not take into account any planned control measures.

Mobile Sources

Net growth of the private auto fleet was estimated based on historical data on the vehicle fleet composition and on new car sales in the metropolitan area. These classifications were used to estimate survival and growth rates, respectively. For the rest of the fleet, projections were based on estimates from the Energy Secretariat (SENER, 2000a). Once the growth of the vehicle fleet for the years 2000, 2006 and 2010 was defined, emissions were calculated for each type of vehicle. Emission factors for NO_x, HC and CO for private autos 1998 and older are derived from the 1998 inventory. After 1999, all automobiles are assumed to have TIER I technology. Emission factors for other types of vehicles are the same as those reported in the1998 emission inventory, only shifted for the year of projection. For instance, for the projected year 2010, an emission factor for 1974 and older vehicles in the 1998 inventory would correspond to vehicle model years 1986 and older. Likewise, a vehicle model year 1975 would correspond to model year 1987 for the 2010 projection. Each model year is shifted successively with 1998 corresponding to model year 2010.

Methodology for Projecting Mexican Greenhouse Gas Emissions

Projections of energy demand from 1995 to 2010 were estimated using a primary and final energy-demand model. This model considers a population scenario based on the average projection from INEGI (1.42% annual growth throughout the study period) and three economic growth scenarios. The first two scenarios correspond to high and low economic growth, with average annual growth rates of 4.81 and 2%, respectively. The third scenario corresponds to the reference scenario, which assumes an average annual growth rate of 3.4%.

In addition, two options were included for energy intensities (energy used for each Mexican peso produced): a constant, based on average values in agreement with available historical data, and an expert opinion. Under these assumptions the model showed CO_2 emissions for the year 2010 increasing by between 50% and 100% over 1990 emissions, depending on the scenario (INE, 2004). Further information may be obtained at http://www.ine.gob.mx/dgicurg/cclimatico/mycc/mycc2_4a.html.

4.6.5 Projection Coordination

In the United States, Canada, and Mexico, consistent tools have been developed or adapted for developing sector-specific emission projections for onroad, nonroad, and EGUs. Previous sections in this chapter have described how the U.S. EPA's MOBILE6 model has been adapted for use in estimating current and future Canadian and Mexican motor vehicle emissions. Similar efforts are planned, or are underway, for nonroad vehicles using the U.S. EPA's NONROAD model. EGU modeling efforts in the United States have been dominated by the IPM. As part of the joint projects announced in June 2003 by U.S. EPA and Environment Canada under the Border Air Quality Strategy, a Canadian module intended to provide representation of the Canadian electric power sector has been developed for the IPM model. The new module will allow the two countries to conduct joint analyses of the feasibility of cross-border trading of capped emissions of NO_x and SO_2, and explore opportunities for coordinated air quality management. Mexican EGU emission projections do not use a simulation model. U.S. efforts for non-EGU point and nonpoint sectors have recently focused on using growth and control factors within emission processors for making future-year emission estimates for these sectors. However, this approach does not capture some of the important long-term influences on emissions such as international competition and technological changes/advances. These factors have produced significant emission changes for some industries in the past 20 years – most notably for copper smelters and iron and steel production. Therefore, more sophisticated tools are needed for non-EGU point and nonpoint sectors, so that when North American emission estimates are developed for forecast years, emission estimates are comparable among countries. Development of such tools needs to take into account the differences in data sources and data availability.

Other practical issues affecting the ability of the United States, Canada, and Mexico to use each other's emission projections are the need to agree on the specific projection years of interest and on common approaches to providing consistent future information. Achieving this agreement will require coordination of control and economic scenarios. Within the United States, such coordination needs to involve the RPOs, states, and the U.S. EPA, because all will be involved in the regional modeling efforts for ozone, fine PM, and regional haze that take place this decade. At present, U.S. EPA regulatory analysis projections are made in 5 to 10 year increments, while RPOs and the states focus on attainment years (2009, 2018).

Canada's most recent emission projections cover the period 2001 to 2020 to support the reporting requirements of domestic programs and international agreements. The 2010 forecast was included in the 2004 progress report of the United States-Canada Air Quality Agreements. Canada has developed 2010 and 2020 emission estimates for both a base case and a control case that have been used recently in joint transboundary air quality modeling studies with the United States. The Mexico 2012 border emission estimates, when available, can serve as a reasonable proxy for 2010 emission estimates in U.S.-Mexican transboundary studies for that time period. The U.S. EPA has 2010 emission databases available from its national regulatory analyses. These data can be used to establish a representative 2010 North American criteria pollutant modeling inventory. The U.S. EPA efforts may be improved by ongoing RPO projection efforts. These efforts should update the U.S. EPA's work by accounting for how states are implementing new rules/regulations, in practice.

A worthwhile longer-range objective is to have each country develop a set of 2018 emission projections. The RPOs have established 2018 as a common year for evaluating progress in meeting U.S. regional haze rule goals. Because these 2018 emission estimates will be used in regional modeling efforts, it is important that Canadian and Mexican emission estimates for the same time period are developed and made available in consistent formats. Inter-country coordination to produce 2018 emission forecasts should include information exchange about economic and control scenarios.

4.7 EMISSION TEST METHODS

4.7.1 U.S. Emission Measurement Methods

Over the past 30 years, the U.S. EPA has developed emission test methods to ensure compliance with New Source Performance Standards (NSPS), National Emissions Standards for Hazardous Air Pollutants (NESHAPS), and Maximum Achievable Control Technology (MACT) standards. These methods provide the basic emission data for inventories, emission factors, compliance determinations, state data collection requirements, and control technology research and development. Table B.2 in Appendix B lists the U.S. EPA's promulgated, proposed, and conditional test methods and alternative approved methods by criteria and hazardous air pollutant. Links to these methods can be found at http://www.epa.gov/epahome/index/.

All methods include specific QA/QC requirements that must be met, and they provide estimates of method precision. The pollutant-specific methods are generally applicable to multiple categories of stationary source categories. Methods specific to a particular source category are given a letter suffix.

A major limitation to using U.S. EPA test methods for inventory or emission factor development is that each test is conducted at a specific set of operating and ambient conditions. It is therefore difficult to assess the representativeness of the test results. In particular, emission tests are generally not conducted during periods of startup, shutdown, process changes, or malfunctions, when emissions may be higher than during steady state operation.

It is also important to note that the applicability, precision, detection limits, and accuracy of a method developed for a specific pollutant and source category are not necessarily applicable to other categories that have different emission stream characteristics (e.g., temperature, humidity, concentrations, interferences). Also, because many of the test methods are two or more decades old, they were derived to measure emissions characteristic of that period. For example, U.S. EPA Method 7E was developed to measure NO_x emissions from combustion turbines when typical levels were 300 ppm. The best controlled modern combustion turbines emit less than 5 ppm NO_x making the precision and accuracy stipulations of Method 7E inappropriate for modern turbines.

4.7.2 Canadian Emission Measurement Methods

Most of the Canadian measurement methods for stationary emission sources are similar to those used in the United States. Some, like those for vinyl chloride, arsenic, total reduced sulfur (TRS), and SVOCs, preceded or were developed in parallel to their U.S. EPA counterparts, and retained some significant differences.

The mercury method developed by former Ontario Hydro has been adopted by ASTM as D6784-02 Standard Test Method for Elemental, Oxidized, Particle-Bound and Total Mercury in Flue Gas Generated from Coal–Fired Stationary Sources.

Some Canadian methods were developed as companions to specific regulations (such as the Ontario total hydrocarbon regulation for incinerator and the ambient odor guideline) or programs (such as Method EPS 1/RM/15 as companion to the National Emission Guidelines for Commercial / Industrial Boilers and Heaters).

Environment Canada's reference methods for stationary sources are summarized in Table B.1 in Appendix B. The Alberta and Ontario methods are also included in Appendix B.

Environment Canada is currently working on the following emission measurement methods:

- Update EPS 1/PG/7 (CEMS for NO_x and SO_2 budgets)
- Revision of RM/15 (addition of low-level SO_2 and NO_2)
- Ethylene oxide control efficiency from sterilizers
- Integrated NO_x sampling method
- Dilution sampling method for condensable particulate matter
- Mercury emissions from landfills
- Ozone depleting substances from low pressure chillers.

Environment Canada's measurement methods for mobile sources are identical to U.S. EPA methods. Currently Ontario is evaluating methods for isocyanate emissions from automotive coating (manufacturing and repairs), in cooperation with stakeholders.

4.7.3 Mexican Emission Measurement Methods

A listing of Mexico's reference methods for stationary sources is provided in Appendix B.

4.7.4 Continuous Emission Monitoring Systems (CEMS)

<u>U.S. CEMS</u>

CEM systems perform continuous measurements of pollutants emitted to the atmosphere from point sources. Typically, a CEMS combines a pollutant analyzer with a manual or software calculation tool that calculates and reports the mass, concentration, or rate of pollutant emissions. Primary driving forces for the use of CEMS are to support the acid rain allowance trading program and to demonstrate continuous compliance with emission limitations established at the federal and state level. The advantage of CEMS over stack testing is that emissions are measured under all operating conditions, including startup and shutdown, not just during a one steady-state operating condition. CEMS typically record and report emissions on an hourly basis. The data can be summed to calculate daily, weekly, monthly, seasonal, or annual emissions, or used as recorded for air quality modeling. While opacity monitors fall under the category of CEMS, they do not provide quantitative emission data and are thus not considered in this section. Table 4.5 provides an overview of representative CEMS technology.

The largest users of CEMS in the United States are EGUs, which are mandated by Title IV of the *Clean Air Act* (the Acid Rain Program or ARP) to reduce emissions of SO_2 and NO_x. The ARP uses an allowance-trading program (each allowance is equal to one ton of SO_2 emitted during a year) to ensure compliance with the emission reductions. Hourly CEMS data from EGUs provide the assurance that each allowance represents one ton. The ARP requires each EGU larger than 25 megawatts (with certain exceptions) to install CEMS for SO_2, NO_x, volumetric flow, and either O_2 or CO_2. The CEMS are subject to stringent certification requirements,

Table 4.5. Representative CEMS Technologies. Proven technologies exist for SO_2, NO_x, CO_2, CO, flow, PM, and opacity.

Pollutant	Measurement Principle	Status
SO_2	UV Absorption	Mature technology
NO_x	Chemiluminescence	Mature technology
CO_2	NDIR[a]	Mature technology
CO	NDIR	Mature technology
Flow	Various	Mature technology
PM	Light Scattering/Beta Attenuation	Mature Technology
Opacity	Light Transmission	Mature Technology
Hg total	Carbon tubes/CVAF[b]	Under development
Hg, total, speciated	Aqueous/AF[c]	Under development
NH_3	UV Absorption	Under development
Carbon Black	Multi-angle absorption	Under development

[a]NDIR = non-dispersive infrared absorption
[b]CVAF = cold vapor atomic fluorescence
[c]AF = atomic fluorescence

QA/QC procedures, and record keeping rules (40 CFR Part 75). The U.S. EPA's Clean Air Markets Division (CAMD) receives hourly data from over 2,600 units each quarter. These data are summed to calculate annual mass emissions of SO_2 for the ARP allowance trading program and used to provide annual emissions for the NEI, state, and RPO inventories from EGUs. The hourly data are available for use as inputs for atmospheric dispersion and deposition models.

The U.S. EPA has recently established the NOx Budget Trading Program to reduce ambient ozone levels in the eastern United States. This program, which affects EGUs and industrial boilers and turbines with fuel inputs greater than 250 mmBtu/hr (and cement kilns in New York), receives hourly NO_x emission data from more than 1,000 units each quarter. These hourly data can be used in the same manner as ARP hourly data for SO_2.

On March 10, 2005, the U.S. EPA issued the Clean Air Interstate Rule (CAIR) intended to assist states in meeting NAAQS for ozone and $PM_{2.5}$ by significantly reducing emissions of SO_2 and NO_x from electric utilities in 28 states in the eastern United States and the District of Columbia. This rule relies on a cap and trade program similar to that used in the acid rain program. It is expected that the CAIR rule will increase the number of electric utility sources that use CEMS for SO_2, NO_x, CO_2, and flow. In addition, the March 15 Clean Air Mercury Rule designed to reduce emissions of mercury from electric utilities also relies on a cap and trade approach. When implemented this rule will require the use of mercury CEMS.

CEMS are also required for 20 NESHAPS categories under 40 CFR 63 and four NSPS source categories under 40 CFR 60. Pollutants monitored under these standards are SO_2, NO_x, CO, TRS, VOCs, and THC. Performance specifications for these CEMS are specified in Appendix F to 40 CFR 60. In addition, many states require continuous emission monitoring of sources in addition to the federal requirements. For example, Pennsylvania requires the operation of about 500 CEMS in addition to those required under the federal ARP, NESHAPS, and NSPS programs. Because CEMS installed for NESHAPS, NSPS, and state mandates are used to monitor continuous compliance with emission standards, they generally measure pollutant concentrations, not mass emissions. Although the concentration data, in many cases, could be used to calculate mass emissions, this is generally not done and these data are not typically used in calculating emission factors or in emission inventories.

Canadian CEMS

CEMS implementation in Canada is generally specified by the certificate of approval or permit of the facility, which is issued by provincial regulatory agencies. The majority of CEMS are required to monitor process conditions linked to emissions, such as ozone and CO at municipal solid waste incinerators, wood waste combustors, cremators, and other sensitive sources. Mass emission-rate CEMS are installed at major sources such as thermal power stations, primary smelters, and cement plants.

Technical guidance for CEMS installation, certification, operation and data reporting in Canada is provided by the federal "Protocols and Performance for Continuous Monitoring of Gaseous Emissions from Thermal Power Generation" Report EPS 1/PG/7. Although this is a guideline for thermal power stations, the general principles can be adapted to other processes and have been referenced on numerous permits for other sectors. 1/PG/7 is currently under review, to update QA/QC provisions associated with SO_2 and NO_x budget programs.

At the provincial level, Alberta has developed guidelines similar to 1/PG/7, named "CEMS Code," and expanded their scope to include in-stack opacity, TRS, and CO. Alberta and Ontario require generating units with greater than 73 MW to report SO_2 and NO_x emissions on the basis of CEMS measurements.

Mexican CEMS

Currently, Mexican specifications pertaining to monitoring frequency are included in a standard called NOM-085-ECOL-1994 (DOF, 1997). According to this standard, only those facilities with combustion equipment larger than 110,000 MJ/hr are required to perform continuous emissions monitoring of NO_x emissions. Other regulated pollutants are monitored either one, two or three times per year, depending on the fuel used, the size of the combustion equipment and the nature of the pollutant. This standard is currently being revised and is expected to be updated soon.

4.7.5 Other Emission Measurement Methods

Several agencies in the United States and worldwide have developed additional emission measurement methods. Some of the first U.S. source testing methods were developed by the American Society of Mechanical Engineers (ASME). These and other ASME methods are called Performance Test Codes (PTCs). One of the first PTCs related to the abatement of atmospheric pollution was PTC 21, "*Dust Separating Apparatus*." PTC 21 was published in 1941. That was followed in 1957 by a stack testing method, PTC 27, "*Determining Dust Concentration in a Gas Stream*." PTC 27 and the similar Western Precipitation WP 50 procedure collected particulate matter isokinetically using a ceramic (alundum) thimble filter medium. These methods were used for performance evaluations of particulate removal equipment and for determining PM emission concentrations and mass emission rates. In 1965, ASME published PTC 28, "*Determining the Properties of Fine Particulate Matter*." This method included procedures for characterizing the properties of the particulate matter.

ASTM International (ASTM), originally known as American Standards for Testing and Materials, was formed over a century ago. It is one of the largest voluntary standards development organizations in the world. ASTM has developed stack-testing methods for a number of years, and continues to do so today. Some of the more recent ASTM stack testing methods are:

- D6331-98 Standard Test Method for Determination of Mass Concentration of Particulate Matter from Stationary Sources at Low Concentrations (Manual Gravimetric Method)
- D6348-03 Standard Test Method for Determination of Gaseous Compounds by Extractive Direct Interface Fourier Transform Infrared (FTIR) Spectroscopy
- D6420-99 Standard Test Method for Determination of Gaseous Organic Compounds by Direct Interface Gas Chromatography-Mass Spectrometry

- D6522-00 Standard Test Method for Determination of Nitrogen Oxides, Carbon Monoxide, and Oxygen Concentrations in Emissions from Natural Gas-Fired Reciprocating engines, Combustion Turbines, Boilers, and Process Heaters Using Portable Analyzers

- D6735-01 Standard Test Method for Measurement of Gaseous Chlorides and Fluorides from Mineral Calcining Exhaust Sources – Impinger Method

- D6784-02 Standard Test Method for Elemental, Oxidized, Particle-Bound and Total Mercury in Flue Gas Generated from Coal-Fired Stationary Sources (Ontario Hydro Method)

- D6831-02 Standard Test Method for Sampling and Determining Particulate Matter in Stack Gases Using an In-Stack, Inertial Microbalance.

These methods are produced by the ASTM D22 Subcommittee. The D22 Subcommittee has Work Groups that are assigned to specific methods. The U.S. EPA has been involved on some of the ASTM D22 Work Groups and has adopted some of the most recent methods as Reference or Alternative Methods. In addition to the published methods, ASTM D22 Work Groups are currently working on:

- Practice for Certification of Opacity Monitors for Low Level (<10%) Applications

- Continuously Monitoring Low Levels of NO_x, Carbon Monoxide and Ammonia

- Test method for Determination of $PM_{2.5}$ Mass and Species Emissions from Stationary Combustion Sources by Dilution sampling.

In addition to the consensus groups, ASME and ASTM, several U.S. state and local agencies have developed their own stack testing methods. Examples are the CARB, the Commonwealth of Pennsylvania, and the SCAQMD. Other states adopt U.S. EPA methods with some variation such as Maryland that requires the use of 70° F as standard temperature instead of 68° F as used by U.S. EPA. Many states have guidelines for stack testing and although they may not have specific methods, some of the state guidelines apply the U.S. EPA methods.

Section 12(d) of Public Law 104-113, the *National Technology Transfer and Advisory Act of 1995* directs federal agencies to use voluntary consensus standards, such as the ASME and ASTM standards noted above, in lieu of government-developed standards where possible. This law is implemented by Office of Management and Budget.

4.7.6 Predictive Emission Models (PEMS)

PEMS can be used in certain applications as a less expensive alternative to CEMS to provide hourly emission data. PEMS were developed as an outgrowth of process-control software that monitors and adjusts operating parameters to maximize process efficiencies. For environmental applications, the software can be modified to predict emissions of pollutants of interest from the same parameters monitored for system performance. In 2001, over 75 PEMS had been installed, the vast majority on gas-fired combustion turbines, with the remainder on gas-fired boilers and internal combustion engines. The majority of approved PEMS have been installed in Texas which allows PEMS to be used to report NO_x emissions from combustion turbines. To date, 80 percent of all approved PEMS across the United States have been used to measure NO_x.

PEMS can be classified as first-principles, statistical regression, and neural network models. A first-principles model calculates emissions based on the chemical kinetics and thermodynamics of the combustion or other process using the operating parameters of the system. Uncertainty analysis is generally not a part of a first-principles method. Regression models establish the relationship between emissions of a pollutant of interest, process operating parameters, and ambient conditions such as temperature and humidity based on a probability model. An error structure for the model is assumed (usually based on a normal distribution), allowing the estimation of error in the coefficients in the model and the propagation of error through the model into predictions made with the model. The method consists of two steps: (1) a model-fitting step that estimates model coefficients, and (2) a prediction step, where the model is used to estimate emissions. This method facilitates conducting an uncertainty analysis at different levels, including model prediction error, parameter error, and random error. A neural network method infers emissions based on an established set of logic commands and causal linkages between emissions, operating and ambient parameters. Some neural-network applications involve statistical techniques. In a network, emissions are inferred from a set of linkages (defined by the user) that establish the relationship between how a combustion source is operated and the expected emissions. Unlike first-principles methods, neural networks require the user to establish "fault trees" or "event trees" consistent with standard engineering techniques. Uncertainty analysis is not generally performed in a neural network framework, but is conceptually possible.

The U.S. EPA's OAQPS and CAMD, the Texas Council on Environmental Quality, and SCAQMD have established or are developing PEMS performance requirements. All protocols require comparison of PEMS predictions to measured emission tests, relative accuracy tests, sensor drift limitations, and QA procedures.

Technical issues related to the accuracy, precision, and reliability of PEMS predictions include: the amount of paired PEMS/CEMS (or manual test) data to be collected at each condition for accuracy determinations; the definition of the operating envelope over which PEMS predictions are reliable; the startup, shutdown, and transient conditions (PEMS are designed for predicting emissions at steady state); the duration and timing of the demonstration period (e.g., combustion turbine operations differ by season); the frequency of relative accuracy testing.

4.8 DATA MANAGEMENT

Emission inventory data-management systems have changed dramatically over the last 20 years from older mainframe systems (such as the U.S. EPA's National Emissions Data System [NEDS] which later became the Aerometric Information Retrieval System [AIRS]) to simple spreadsheets (used initially to develop the U.S. EPA's National Emission Trends). AIRS can be accessed at http://www.epa.gov/Compliance/planning/data/air/afssystem.html. The NEDS data format was used to store U.S. EPA emission data including data developed for the 1985 NAPAP emission inventory. Current emission inventory data-management-system development efforts revolve around issues of database size, data usage, data accessibility, resources, and to a certain extent, the familiarity of the user/developer with certain database management software systems. Most of the large database management systems currently in use or in development are based on relational approaches that use structured query language (SQL) to retrieve, store, sort, and provide overall data handling and management. These systems typically reside on client/server networks. However, emission data are still managed with smaller systems including spreadsheets and smaller relational systems such as Microsoft Access.

The Canadian emission inventories are maintained in two different databases for storage, retrieval, and processing. The CAC emission data collected annually from industrial and commercial facilities through Environment Canada's NPRI are stored into the NPRI database. The NPRI database is a relational database available in Microsoft Access and in Microsoft SQL server for main storage. Copies of this point-source database, which includes information for more than 323 pollutants including CACs and heavy metals, can be downloaded at the following location: http://www.ec.gc.ca/pdb/npri/npri_dat_rep_e.cfm. The database can also be accessed using online querying and mapping tools available at the following locations: http://www.ec.gc.ca/pdb/npri/npri_online_data_e.cfm, http://www.ec.gc.ca/pdb/ape/cape_home_e.cfm.

The comprehensive emission inventories for CACs, heavy metals, and persistent organic pollutants compiled to support the development of emission reduction policies, air quality modeling, and emission trends are stored in a separate relational database system called the Residual Discharge Information System. This database system was designed in 1998 and incorporates many of the features available from provincial and state database systems available at that time. This Microsoft SQL database was designed to handle multi-media emissions and provincial emission inventory information, which are submitted in various file formats. The database is not publicly available owing to confidentiality of the historical point-source information. Efforts are currently underway to export the Canadian emission inventory data in the latest NEI Input Format (NIF).

A new Microsoft SQL database called OWNERS is currently being developed in Canada. This new database will provide one window for the Canadian industries to report their releases and other information required under different regulations online using a new electronic reporting form. The database will also merge the information from the NPRI and the Residual Discharge Information System databases, and is expected to be ready in 2005.

A National Emission Inventory Database System is being created in Mexico as a tool to help in the development, use, management and update processes of national inventories. This system will compile emission information from the Mexican NEI, the Mexican PRTR (*RETC*), and the GHG inventory, as well as inventories developed for the air quality management programs (PROAIREs) from cities throughout the country.

Development of the Emission Inventory Database System will facilitate

- Concentrating emissions information in a single source
- Providing user-friendly access to emissions inventories for environmental officials, researchers and the general public
- Institutionalizing the maintenance and update processes of the inventories
- Meeting deadlines of international agreements, such as those of the UNFCCC and the CEC.

This system will include data input, manipulation, QA/QC procedures, storage, accessibility, and dissemination. The different areas in SEMARNAT in charge of emission inventories are working together to address significant data management issues such as transparency, applicability, quality, quantity, accessibility, dissemination, and lag time of the stored data. The system is expected to start operations in spring 2006.

4.8.1 Data Transparency

Data transparency refers to the ability to easily access and understand data and the ability to use data in multiple database programs. Several efforts are currently underway to provide data transparency. In most data-management systems, the first step toward understanding data is the development of metadata. Metadata are "data about the data." Metadata describe the data in a database and assist users in understanding what the data elements represent.

Generally the next step is the development of a data dictionary. This step frequently depends upon how formal the database management system will be. If the data are likely to be stored in a spreadsheet or a stand-alone PC-based database management system, this step may not be required. However for relational databases, this step is virtually mandatory.

For example, the U.S. NEI is hosted on an Oracle relational database. Data are entered into the NEI using NIF. The NIF fully defines the data fields and their attributes necessary to submit and store data in the underlying database. The U.S. EPA has developed the NIF format in a precise manner so that data submitted by state, local, tribal and other reporting agencies can be stored in the database management system. Use of the NIF creates a relational, normalized data set that conforms to the relational standards and structure of U.S. EPA's Oracle database that stores the NEI data. This format avoids duplication of information that may otherwise occur in a flat file format, and it reduces the size of the resulting database. This format also provides flexibility to support the changing requirements of the U.S. NEI over time. The NIF is currently one of the most widely used formats by state, local and tribal agencies to report emission data to the U.S. EPA.

The NIF is divided into four source groups – point, nonpoint and nonroad mobile, onroad mobile, and biogenic. The table structure for the current NIF is shown in Table 4.6. The number of fields per table is shown in parentheses. These tables and fields contain the detailed information on emission sources, such as processes associated with the emissions, location, periods of operation, pollutants emitted to

Table 4.6. NIF 3.0 Source Tables.		
Source	**Tables**[a]	
Point	Transmittal (19) Site (20) Emission Unit (15) Emission Release Point (29)	Emission Process (23) Control Equipment (18) Emission Period (21) Emission (33)
Nonpoint and Nonroad mobile	Transmittal (19) Emission Process (21) Emission Period (18)	Control Equipment (12) Emissions (27)
Onroad Mobile	Transmittal (19) Emission Period (12)	Emissions (17)
Biogenic	Transmittal (19)	Biogenic (13)

[a]The values in parentheses indicate the number of fields in the table.

the atmosphere, and control technologies. Key fields provide the linkage between the many tables in the relational structure.

While the national data format is precisely defined, state, local, and tribal agencies may maintain their emission databases in formats that meet their own particular needs and still report data to the U.S. EPA using the NIF format. This is an example of data transparency. The format and characteristics of the data are fully described so that either submitters or users of the data may easily and straightforwardly send or receive data from the database management system. Such transparency can be important for entities outside of the United States. For example, data transparency may be of particular importance for Canada and Mexico and their development of national emission inventories. If all three countries used the NIF, it would be possible to develop a tri-national emission inventory. However, the use of the NIF by other countries is subject to each country's regulations and needs.

Other entities have gone different routes to ensure that their data are fully understood and to make sure that the user can readily obtain and use the emission data. For example, the Global Emission Inventory Activity (GEIA) has developed a standard format for storing emission data. Information on that format can be found on the GEIA data website at http://www.geiacenter.org/emits/geiadfrm.html. In addition to a description of the data format, GEIA also provides a tool to read their data into a series of arrays that can be used for pre-processing. Information on that tool is available at http://www.geiacenter.org/emits/geiadfrm.html#Program.

4.8.2 Data Applicability

One of the biggest issues in emission-data management is the applicability of the data. In some situations emission-inventory data management is relatively straightforward because the usage (applicability) is simple. In other cases the usage is multifaceted and complex. For example, the U.S. NEI provides an example of the complexity associated with data management issues of large, complex emission inventories. The NEI database is used for air quality modeling, human exposure modeling, risk assessment, regional compliance strategy development, and emission trends tracking. Because of these many demands on NEI, the data input requirements and data base have become very complex.

Other data applicability issues result from temporal, spatial, and species requirements. For example, the focus of the NEI has largely been on criteria pollutants at either an annual, seasonal, or daily basis. More recently HAPs have been added to the NEI, resulting in modifications to the database structure because the original structure was not designed to include HAPs in the database. Emissions in the NEI are limited to the U.S. states and territories, with point sources specifically located using latitude/longitude (or UTM) coordinates and nonpoint and mobile sources located within counties.

For GEIA, the focus is on global emissions of a wide variety of compounds/species that are available on a one-degree grid for the entire world. The data are reported with annual, seasonal or monthly resolution. Most data are provided for the surface level, but there is vertical resolution for some chemical emissions.

Recent evaluations of the use of the NIF for specifically locating wildfire emissions have shown some limitations of the format for these types of emissions. While the NIF as currently structured will largely work for most aspects of fire emissions, current thinking is that these emissions should be treated more like point sources than nonpoint sources. This shift has created issues with the current NIF structure, particularly the way that the NIF structure deals with plume characteristics of fires.

Other entities have found other limitations to the NIF structure. WRAP has recently embarked on the development of an Emission Data Management System, which is largely based on the NIF structure. However, in that effort, WRAP has developed modifications to the NIF structure to handle fires, meteorological and geographic information.

As another example, the current NIF structure is not particularly well suited for handling link-based mobile source data. Most mobile-source inventory data stored in the NIF currently are housed at the county level.

Under most current regional air quality modeling systems, emission data must be “pre-processed” for use in the model. Thus, most data management systems are not currently set up to handle ”model-ready” data. To some degree, this is a consequence of the different input requirements of the air quality models.

Clearly, the application of the emission data plays a large role in determining the overall requirements of an emission data-management system. However, even when most of the applications of the data are known, the data may frequently be used in applications different from those originally intended. This can be clearly seen from the changes that the NIF has undergone over the last few years.

4.8.3 Data Quantity

The total amount of data that a database management system must store will frequently determine the characteristics of the system. Data requirements depend upon the types of data being stored, the period of time the emissions cover, and the data usage. For example, the amount of data received by the U.S. EPA from submitters to the NEI can be significant. A decade’s worth of emission inventory data in the NEI requires approximately 50 gigabytes of storage space. This amount of data requires advanced data-management systems and capabilities. Local inventories for a county or municipality, on the other hand, can be housed effectively in a spreadsheet or a Microsoft Access (or similar) database management system, especially if the use of the data is limited to simple inventory needs rather than for air quality modeling.

Current trends have been toward larger and larger datasets. There are three reasons for this: First, the amount of computing power and data storage capacity that an individual or group has at their disposal has significantly increased over the last decade. Second, the tools with which to manage larger amounts of data have significantly improved. Third, the uses of the data have typically expanded. These factors have generally led to a significant increase in the quantity of data that many emission database management systems must handle.

4.8.4 Data Quality

Data quality has become an issue of increasing concern for emission inventory developers and users. Estimates of uncertainty and an understanding of the lineage of the data have become increasingly important for current inventory practices. This trend is particularly true for the NEI. For the NEI, state/local/industrial/tribal agencies frequently either do not collect the necessary data or do not have access to it. In those cases, the U.S. EPA may use surrogate data or use default values to fill in missing data. For example, for HAPs toxic release inventory data are often used to fill in missing or incomplete information. Data used for the development of

MACT standards have also been used as inputs for the NEI HAP data. Growth factors are sometimes applied to old NEI data in order to calculate emissions for more current years for NEI submittals. This data mix has resulted in inconsistent data of uncertain quality and inconsistent lineage.

Several attempts have been made to improve the understanding and the actual quality of emission inventories. For example, the U.S. EPA developed the Data Attribute Rating System, designed to assign qualitative numerical rankings to the various aspects of inventory development (such as emission factors or activity data) so that the overall quality of individual data elements could be ascertained. Specific guidance for applying the numerical ratings to these data elements was developed and the results were typically used to characterize which sectors of the inventory were of higher or lower quality than others.

Since implementing the NIF, the U.S. EPA has also attempted to provide QA tools for the actual data submitted to the U.S. NEI. As part of this attempt, the U.S. EPA has developed a program called the Basic Format and Content Checker. Based on ASCII text or Microsoft Access database inventory files, the program generates multiple reports identifying missing and invalid information in the submitted inventory. This check allows the submitter to make necessary data corrections early in the process, when the information is more readily available. After submittal, work is done to conduct additional quality checks on the data, fill in data gaps, and prepare the data for loading into the NEI database. Thus, the majority of state submittals still require extensive data manipulation efforts in order to be placed in the NEI. While the Basic Format and Content Checker provides a significant mechanism for ensuring that the data submitted are within likely bounds, and that the data are amenable to use in a relational database system (e.g., by checking for widowed and orphaned records), it does not address the lineage of the data received, nor does it address the mixture of data levels that can be submitted to the inventory. In addition, it is intended only for the NIF format and does not provide QA tools for other inventory data.

Environment Canada does not provide a quantitative estimate of the uncertainty for its emission inventories. Qualitative estimates are available and were included in the NARSTO PM Assessment (NARSTO, 2004).

Different QA/QC tests are performed on the information contained in the NPRI and Residual Discharge Information System databases. For example, the information collected through the NPRI is verified using a series of validation functions which are triggered within the electronic reporting form used by the industries. Similar validation functions are also applied to the information reported by the industries before it is transferred into the main database for storage and querying. These validation functions include:

- Verification of all required fields
- Verification of reported values to ensure that they are within expected ranges
- Comparison of new data to previously reported data for each facility.

Data outliers are identified and facilities are contacted to correct the data anomalies.

Verification of the information contained in the Residual Discharge Information System database is also performed on a regular basis. The provincial information received usually includes process-level information and undergoes the same validation functions as the NPRI data. Additional validation performed on this information includes:

- Verification that all CAC contaminants were estimated or reported
- Verification that emission levels are within the expected levels and ratios
- Verification that emission methodologies and emission factors reflect the most up to date information available.

4.8.5 Data Accessibility

In current systems, accessibility (including data dissemination) is largely an issue of making emission data more readily available on a quicker schedule than in the past, to a wide variety of users, and in a format that is relatively transparent (or at least easily understood). However, there are other issues regarding data accessibility that may be important to specific user groups. For example, one user group may want to access emission data to make comparisons across geographical regions, whereas another user group may wish to obtain detailed emission data to be used in modeling applications. Consequently, data accessibility has varying definitions depending upon user needs.

Under current capabilities, the primary mechanism for data access and dissemination is the Internet. The U.S. NEI data and documentation are made available through the U.S. EPA's website: http:/www.epa.gov/ttn/chief/eiinformation.html. NEI data files on this website are in Microsoft Access format, and can therefore be used by people having access to the Internet and a PC. The amount of data present in the NEI requires the use of a robust PC and knowledge of Microsoft Access. The data are also available using file transfer protocol (FTP) sites. For large data sets, this is the quickest means of accessing complete data sets.

The U.S. EPA has also developed a series of programs with which NEI data can be accessed over the Internet. For example, the U.S. EPA has developed a user-friendly web-querying tool called NEON (NEI on the NET). This system allows users to access data down to the process level from the NEI. For example, NEON allows users to select the information that they wish to see, and the data can be output on screen or downloaded in Microsoft Excel spreadsheet format. In coordination with the SAS Institute, the U.S. EPA has developed the AirData system that provides color-coded geographic maps displaying varying intensities of air pollution. The SAS software allows users to map air pollution to the county level for all states for which data is present in the NEI. However, NEON is currently only available internally via the U.S. EPA intranet to EPA personnel. Future plans include providing public access to this information. In the meantime, a number of State and local agencies provide access to data they collect on their own websites.

The California Air Resources Board makes emission data available at http://www.arb.ca.gov/ei/emissiondata.htm. Emission data included on this website are onroad, offroad, stationary, area wide and top-25 source categories. In addition, data can be obtained on a statewide, air basin, county, or neighborhood geographical scale. Finally, the website also allows a user to search individual facilities for emission data.

As was stated in Chapter 3, there are numerous ways in which the U.S. EPA's TRI database can be accessed. For example, TRI data can be obtained by geographical area, industry type, or individual facility at http://www.rtk.net. TRI data can be obtained at varying levels of detail. For example, a user can select to obtain either low, medium, or high levels of detail when obtaining facility specific TRI data.

In Canada, accessibility and dissemination of emission information is also largely done through the internet on Environment Canada's Greenlane. The national emission summaries for CACs (with provincial and territorial breakdown) are accessible in tabular format at the following location: http://www.ec.gc.ca/pdb/cac/cac_home_e.cfm. Copies of the point-source database (in Microsoft Access format), which includes information for more than 323 pollutants including CACs, heavy metals, and persistent organic pollutants, can be downloaded from the following location: http://www.ec.gc.ca/pdb/npri/npri_dat_rep_e.cfm. Facility specific releases and the emission the summaries for various air pollutants are also accessible at various resolutions (national, provincial/territorial, postal code, major urban centers, community, user defined areas) using online querying and mapping tools available at the following locations: http://www.ec.gc.ca/pdb/npri/npri_online_data_e.cfm, http://gis.ec.gc.ca/npri/root/main/main.asp. The Canadian provinces also provide access to their emission summaries on their respective Internet sites.

4.8.6 Data Dissemination

While the NIF defines a particular format, agencies may submit the inventory in one of several different electronic formats: flat file, Access database, and eXtensible markup language (XML). XML is designed to store any kind of structured information and improve the functionality of the Internet by providing more flexible and adaptable information identification. XML makes it possible for diverse computer systems (and data applications specifically) to share data stored in different formats across multiple computer platforms in a convenient fashion. XML makes it easy for a computer to generate data, read data, and ensure that the data structure is unambiguous across platforms, formats, and applications. XML enables a user to define a custom markup language for transferring data.

4.8.7 Data Lag Time

A major issue facing emission inventory data management is data lag time. As usage of the Internet and other "data now" capabilities increases, the expectation is that emission inventory data should also be available in real time. Current practices within the U.S. EPA generally show a lag time of several years between the actual date and the most recent inventory year of record. For example, in 2005 the most current version of the U.S. NEI was a draft emission inventory for calendar year 2002, a lag time of more than two years. This concurrency issue is perhaps one of the biggest problems facing inventory data management. Building the infrastructure necessary to successfully collect and calculate emissions from various sources in a time frame that is close to real time is a major challenge. Real-time emission data management is unlikely for many types of sources. However, the availability of real-time emission estimates for some point sources is becoming an increasing reality. The use of CEMs provides one example of the potential for real-time reporting of emission values. They also provide further support for the increase in the amounts of data being reported to regulatory and other agencies.

Legislatively imposed data-quality requirements in the United States may also limit the reductions in lag times. Data used in significant regulatory actions must undergo adequate QA/QC procedures, including external peer review. An evolution toward faster data accessibility may be possible, although users must recognize that immediately accessible data are more likely to contain errors. "Official" inventories that have been adequately validated and reviewed will likely continue to include significant processing delays.

These features -- data transparency, data applicability, data quantity, data quality, data accessibility, data dissemination, and data lag time -- prevent simple solutions to data management issues. However, over time, significant progress will be made toward addressing these future needs.

4.9 QA/QC METHODS

The IPCC provides definitions for both QA and QC as these activities relate to emission inventories. The IPCC defines emission inventory QA as follows:

> *Quality Assurance (QA) activities include a planned system of review procedures conducted by personnel not directly involved in the inventory compilation/development process. Reviews, preferably by independent third parties, should be performed upon a finalized inventory following the implementation of QC procedures. Reviews verify that data quality objectives were met, ensure that the inventory represents the best possible estimates of emissions and sinks given the current state of scientific knowledge and data available, and support the effectiveness of the QC program) (IPCC, 2000).*

The IPCC provides a rigorous definition for QC as it pertains to emission inventories. Specifically, the IPCC definition sets forth three goals for QC systems:

> *Quality Control (QC) is a system of routine technical activities, to measure and control the quality of the inventory as it is being developed. The QC system is designed to:*
>
> 1. *Provide routine and consistent checks to ensure data integrity, correctness, and completeness;*
> 2. *Identify and address errors and omissions;*
> 3. *Document and archive inventory material and record all QC activities.*
>
> *QC activities include general methods such as accuracy checks on data acquisition and calculations and the use of approved standardized procedures for emission calculations,*

> *measurements, estimating uncertainties, archiving information and reporting. Higher tier QC activities include technical reviews of source categories, activity and emission factor data, and method (IPCC, 2000).*

In June 1997, the EIIP (IPCC, 1997) published a guide of QA/QC methodologies that can be employed for emission inventories (EIIP is a jointly sponsored effort by STAPPA/ALAPCO and the U.S. EPA; see Section 4.1 for more information). EIIP methodologies include, in order of decreasing complexity, reality checks, peer review, sample calculations, automated checks, sensitivity analysis, statistical checks, independent audits, and emission estimation validation.

The format of the emission inventory is a key driver in determining how QA/QC routines are applied. For example, an emission inventory built on the basis of a spreadsheet will have different QA/QC requirements than an emission inventory built around a database. The size of the emission inventory is also a driver to the type of QA/QC routines that are used. For example, automated routines may not be necessary for small inventories but are essential for regional or national ones.

Large emission inventories contained in databases are of particular concern due to their size and complexity. Three useful QA/QC methods for assessing the quality of an emission inventory are (1) examining the content of supplemental fields, such as SIC and NAICS codes, geographic location, and pollutant, (2) if there are multiple tables in a relational database, checking that correct parent-child relationships exist, and (3) evaluating the emission numeric values.

In the first method, one can check that those fields in the inventory that are required to have an entry do have an entry, whether it is valid or invalid. As a second step for those fields that are restricted to certain values, the entry can be compared to values in a lookup table. For example, the NAICS codes, SIC codes, and pollutants in the inventory can be compared to an acceptable list of codes or names. For locational data, the x- and y-coordinates of a point source can be checked to see if they lie within the boundaries of a geographic entity such as a county or state.

If the inventory is defined in terms of relationships between tables, in which there is an association between common fields in two tables, then the second method is used to check these relationships. For example, if there is a relationship between a table with geographic information for point sources and a table with emission values for those point sources, one can check that for each record in the table of geographic information there is at least one record in the emission table.

The third method of assessing an emission inventory is to examine the actual emission data by filtering the data with different criteria. These methods can be simple lists, statistical comparisons, or graphical methods. Lists of top emitters (facilities or sources at facilities) by pollutant can be compiled to determine if any of the emissions appear to be too large relative to the emissions of other facilities or points. Similar lists can be compiled by geographic region to determine if one region's emissions exceed those of other regions. If this appeared to be the case, then the list of top emitters, as described above, in that region could be examined. Emissions by a specific classification group, such as the NAICS, can be examined. Not only can the emission values be checked, but if specific pollutants are known to be associated with a classification, then the inventory can be checked to be sure there are no pollutants that do not belong to the classification. Graphical methods include frequency histograms to provide graphical representations of the distribution of the emissions that illustrate the distortion and spread of the data, as well as the presence of outliers. Another graphical aid displays emission density maps to see where the majority of the emissions occur. These ideas can be applied to a single inventory or comparing two inventories, such as one year to another, or one region (e.g., county) to another.

The U.S. EPA has developed two programs that perform varying QA/QC checks on incoming state NEI submittals. The first program, called the Basic Format and Content Checker is designed to QA/QC MS Access or ASCII submittals in Version 3 of the NIF. This program checks to ensure that mandatory fields are filled, that tables and field names are correct, and it also checks for duplicate data records. In addition, the program performs referential integrity checks to ensure that relationships between tables are correct. Finally, as an option, the program can also perform contents checks. In this case, it compares reported values against those provided by lookup tables.

The U.S. EPA has also developed the Extended QA tool which is designed to review hazardous air pollutant and criteria air pollutant related data in NEI submittals. The Extended QA tool is used to examine actual emission data contained in NEI submittals. The tool can be used to identify top emitting facilities by geographic region or by NAICS/SIC code. Depending upon the availability of data, the tool can also analyze multi year emission data. This tool is particularly useful for identifying outliers within data submittals.

While objective methods for assessing an emission inventory can be developed, the analysis of the results from those methods require the intervention of someone familiar with the inventory to ultimately decide whether or not the data in the inventory are valid or need to be modified. Consequently, QA/QC tools are of importance, but the ultimate checks must be performed by those familiar with the sources and magnitudes of emissions.

REFERENCES FOR CHAPTER 4

40 CFR 60, "Standards of Performance for New Stationary Sources," *Code of Federal Regulations*, as amended.

40 CFR 63, "National Emission Standards for Hazardous Air Pollutants for Source Categories," *Code of Federal Regulations*, as amended.

40 CFR 75. "Continuous Emission Monitoring." *Code of Federal Regulations*, as amended.

49 CFR 1201. "Railroad Companies." *Code of Federal Regulations*, as amended.

Air Improvement Resource and Senes Consultants. 2004. Development of the Canadian Version of the MOBILE6.2 Model.

ARB. 2002. California Air Resources Board, EMFAC2002: The Latest Update to the Onroad Emissions Inventory, Sacramento, CA, September 2002 (Release Document) www.arb.ca.gov/msei/onroad/briefs/2002.pdf. Reference no longer valid, did not find new document—only results of onroad emissions.

BLS. 2004a. Occupation Employment Statistics [data files], Prepared by U.S. Department of Labor, Bureau of Labor Statistics, available from http://www.bls.gov/oes/home.htm.

BLS. 2004b. Quarterly Census of Employment and Wages [data files], Prepared by U.S. Department of Labor, Bureau of Labor Statistics, available from http://www.bls.gov/cew/.

Census. 2004a. Population Estimates [data files], Prepared by U.S. Department of Commerce, Bureau of the Census, available from http://www.census.gov.php.

Census. 2004b. County Business Patterns [data files], Prepared by U.S. Department of Commerce, Bureau of the Census, available from http://www.census.gov/epcd/cbp/view/cbpview.html.

CONAPO. 2003. Escenarios demográficos y urbanos de la Zona Metropolitana de la Ciudad de México, 1990-2010.

Corbett, J.J., Fishbeck, P.S. 2000. Emissions from Waterborne Vessels in the U.S. Continental and Inland Waterways. Environmental Science and Technology, vol. 34 (15), pp. 3254-3260.

Diario Oficial de la Federación (DOF). 1984. Convenio entre los Estados Unidos Mexicanos y los Estados Unidos de América sobre cooperación para la protección y el mejoramiento del ambiente en la zona fronteriza, firmado en La Paz, Baja California, el 14 de agosto de 1983. Published in the DOF on March 22, 1984. México.

Diario Oficial de la Federación (DOF). 1996. Decreto que reforma, adiciona y deroga diversas disposiciones de la Ley General del Equilibrio Ecológico y la Protección al Ambiente. Published in the DOF on December 13, 1996. México, D.F.

Diario Oficial de la Federación (DOF). 1997. Modificacion a la Norma Oficial Mexicana NOM-085-ECOL-1994, publicada en el Diario

Oficial de la Federación el 2 de diciembre de 1994. Published in the DOF on October 7, 1997.

EIA. 2004a. State Energy Data 2000 Consumption tables (formerly State Energy Data Report), Prepared by U.S. Department of Energy, Energy Information Administration, available from http://www.eia.doe.gov/emeu/states/_use_multistate.html.

EIA. 2004b. Annual Energy Outlook 2004, with Projections through 2025, DOE/EIA-0383(2004), Prepared by U.S. Department of Energy, Energy Information Administration, available from http://www.eia.doe.gov/oiaf/aeo.

Entec. 2002. Quantification of Emissions from Ships Associated with Ship Movements Between Ports in the European Community.

ENVIRON. 2004. Evaluation of the U.S. EPA MOBILE6 Highway Vehicle Emission Factor Model, Prepared by ENVIRON International Corporation for the Coordinating Research Council and the U.S. Environmental Protection Agency, CRC Project E-64, March 2004.

Environment Canada. 1999. On-Road Vehicle and Engine Emission Regulations Statutory Authority. Available from http://www.ec.gc.ca/ceparegistry/documents/regulations/g1-13613_r1.cfm

ERG. 2003a. Development of an Area Source Emissions Inventory for Ciudad Juárez, Chihuahua, Mexico, Final. Prepared by Eastern Research Group, Inc. for the Texas Commission on Environmental Quality, Austin, TX.

ERG. 2003b. "MOBILE6-Mexico Documentation and User's Guide." Prepared by Eastern Research Group, Inc. for the Western Governors' Association and the Binational Advisory Committee.

ERG. 2004. Mexico National Emissions Inventory, 1999: Six Northern States, Final, Developed by Eastern Research Group, Inc. for the SEMARNAT/INE, the U.S. EPA, the WGA, and the NACEC.

ERG. 2005. "Border 2012 Baseline Emissions Inventory." Prepared by Eastern Research Group, Inc. for the U.S. EPA, WGA, and the SEMARNAT. EPA Publication Number 400-R-05-001.

GDF. 1998. Gobierno del Distrito Federal. Inventario de Emisiones : Zona Metropolitana del Valle de México.

GloBEIS. The Global Biosphere and Emissions Interaction Model (GloBEIS). http://www.globeis.com/about.html.

Gobierno del Distrito Federal (GDF). 2004. Inventario de emisiones a la atmósfera, Zona Metropolitana del Valle de México 2000.

Houghton, J.T., Meira Filho, L.G., Lim, B., Treanton, K., Mamaty, I., Bonduki, Y., Griggs, D.J., Callender, B.A. (Eds). 1996. Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories, IPCC/OECD/IEA, UK Meteorological Office, Bracknell.

ICF. 2004. Integrated Planning Model, Prepared by ICF Consulting, background information available from http://www.icfconsulting.com/Markets/Energy/ipm.asp, accessed June 2004.

INE. 2004. Estudio de País: México ante el Cambio Climático. México, DF. México.

Instituto Municipal de Investigación y Planeación, Ciudad Juárez. 1998. "Estudio Integral de Transporte para Ciudad Juárez." Technical Memorandum Series. Chihuahua, Mexico.

Instituto Nacional de Ecología. 1998. México ante el Cambio Climático. México, DF. México.

IPCC 1997 - QA/QC methodologies.

IPCC. 2000. IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Emissions. Retrieved electronically from the World Wide Web at: http://www.ipcc.ch/pub/pub.htm.

Landman, L. 2005. Personal communication with Mr. B. Haneke, MACTEC Federal Programs, Inc., on February 25, 2005, regarding the replacement of MOBILE6 by MOVES.

NARSTO. 2004. Particulate Matter Science for Policy Makers. Cambridge University Press, Cambridge, UK. ISBN 0-521-84287-5.

National Technology Transfer Act of 1995. Public Law 104-113.

OECD. 2004. OECD Statistical Profile of Mexico. Available at: http://www.oecd.org/publicationanddocuments/0,3023,en_33873108_33873610_1_1_1_1_1,00.html.

Pearson, D., Gamble, A. 1996. Urban Travel in Texas: An Evaluation of Travel Surveys. Research Report 1099-3F prepared for the Texas Transportation Institute.

Pechan, E.H. 2003. E.H. Pechan & Associates, Inc., AirControlNET, Version 3.2, Documentation Report, Springfield, VA, Prepared for U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards, Research Triangle Park, NC.

Pechan, E.H. 2004: Economic Growth Analysis System: Version 4.0 [computer software], Prepared by E.H. Pechan & Associates, Inc. for the U.S. Environmental Protection Agency, available from http://www.epa/gov/ttn/chief/emch/projection/egas40/index.html, accessed June 2004.

Pechan, E.H., Wilson Jr., J.H. 1984. Estimates of 1973-1982 Annual Sulfur Oxide Emissions from Electric Utilities, JAWMA, 34, 1075.

Penner et al. 1999. Aviation and the Global Atmosphere. Special report of IPCC Working Groups I and III.

Radian Corporation. 1997. General QA/QC Methods, Final Report. Prepared for the EIIP Quality Assurance Committee.

Radian International. 1996. Development of Mobile Emissions Factor Model for Ciudad Juárez, Chihuahua. Technical report prepared for the Texas Natural Resources Conservation Commission, Air Quality Planning Division. SAGARPA 2003

Secretaría de Energía (SENER) 2000a. El sector energía en México, Análisis y prospectivas. México.

Secretaría de Energía (SENER) 2000b. Prospectiva de Mercado de GNC 2000 – 2010. México.

Secretaría de Energía (SENER). 2003a. Prospectiva del sector eléctrico 2003-20012. 1st Edition. México

Secretaría de Energía (SENER). 2003b. Prospectiva de petrolíferos 2003-20012. 1st Edition. México

Secretaría de Energía (SENER). 2003c. Prospectiva del mercado de gas licuado de petróleo 2003-20012. 1st Edition. México

Secretaría de Energía (SENER). 2003d. Prospectiva del mercado de gas natural 2003-20012. 1st Edition. México

Sierra. 2004. Evaluation of MOBILE Models: MOBILE6.1 (PM), MOBILE6.2 (Toxics), and MOBILE6/CNG, Prepared by Sierra Research, Inc. for the American Association of State Highway and Transportation Officials (AASHTO).

Starcrest Consulting Group, LLC. 2004. Port-Wide Baseline Air Emissions Inventory. Prepared for the Port of Los Angeles, California.

Statistics Canada 2004. Various reports on rail in Canada, available at: http://www40.statcan.ca/cbin/sf01.cgi?dtype=fina&lan=eng&se=Rail.

U.S. EPA. 1997. Air Emission from Scrap Tire Combustion, EPA-600-/R-97-115, U.S. Environmental Protection Agency, Washington, DC.

U.S. EPA. 1999a. Emissions and Prevention/Control Techniques for Automobile Body Shops in Ciudad Juárez, Mexico, EPA-456/R-99-006, U.S. Environmental Protection Agency, Washington, DC.

U.S. EPA. 1999b. Emissions from Street Vendor Cooking Devices (Charcoal Grilling), EPA-600/R-99-048, U.S. Environmental Protection Agency, Washington, DC.

U.S. EPA. 1999c. Emission Estimation Techniques for Unique Source Categories in Mexicali, Mexico, EPA-456/R-99-002, U.S. Environmental Protection Agency, Washington, DC.

U.S. EPA. 1999d. Commercial Marine Activity for Great Lake and Inland River Ports in the United States, Final Report, EPA 420-R-99-019, Prepared by U.S. Environmental Protection Agency, Office of Mobile Sources, Assessment and Modeling Division.

U.S. EPA. 1999e: Commercial Marine Activity for Deep Sea Ports in the United States, Final Report, EPA420-R-99-020, Prepared by U.S. Environmental Protection Agency, Office of Mobile Sources, Assessment and Modeling Division.

U.S. EPA. 2002a. User's Guide to MOBILE6.0 – Mobile Source Emission Factor Model, EPA 420R-02-001, U.S. Environmental Protection Agency, Office of Transportation and Air Quality, Ann Arbor, MI, 2002.

U.S. EPA. 2002b. User's Guide to MOBILE6.1 and MOBILE6.2 – Mobile Source Emission Factor Model, EPA 420-R-02-028, U.S. Environmental Protection Agency, Office of Transportation and Air Quality, Ann Arbor, MI.

U.S. EPA. 2002c. Draft Design and Implementation Plan for EPA's Multi-scale Motor Vehicle and Equipment Emission System (MOVES), EPA420/P-02-006, U.S. Environmental Protection Agency, Office of Transportation and Air Quality, Ann Arbor, MI.

U.S. EPA. 2004a The MOBILE and MOVES emissions models-descriptive literature. U. S. Environmental Protection Agency, OTAQ, Research Triangle Park, NC (http://www.epa.gov/otaq/models.htm).

U.S. EPA. 2004b. Draft NONROAD2004, [computer software], Prepared by U.S. Environmental Protection Agency, available from http://www.epa.gov/otaq/nonrdmdl.htm.

U.S. EPA. 2004c. EPA Modeling Applications Using the Integrated Planning Model, Prepared by U.S. Environmental Protection Agency, available from http://www.epa.gov/airmarkt/epa-ipm/.

U.S. EPA. 2004d. Biogenic Emissions Information System (BEIS), Prepared by U.S. Environmental Protection Agency, available from http://www.epa.gov/asmdnerl/biogen.html.

U.S. EPA. 2004e. Documentation for Air, Rail, Locomotive, Commercial Marine Vessel. Prepared by the U.S. Environmental Protection Agency, available at http://www.epa.gov/ttn/chief/net/2002inventory.html.

U.S. EPA. 2005. Compilation of Air Pollutant Emission Factors. Volumes I and II. Fifth Edition with Updates. Available at: http://www.epa.gov/ttn/chief/ap42/index.html.

U.S. FAA. 2004. Air Traffic Activity Data System (ATADS), 1990-2004 Instrument Operations, Prepared by Federal Aviation Administration, available at http://www.apo.data.faa.gov/faaatadsall.HTM.

Vaivads, R. for Environment Canada. 2004. User's Guide for the Canadian Adaptation of the U.S. EPA's Draft NONROAD2004 Emissions Inventory Model.

Wolf, M.E., Fields, P.G., González-Ayala, S. 2003. Developing a National Emissions Inventory for Mexico: Onroad Mobile Source Emissions Inventory. Presented at the U.S. EPA Emissions Inventory Conference, San Diego, California, April 29 – May 1, 2003.