CHAPTER 9

RECOMMENDATIONS AND CONCLUSIONS

Chapter 9 Objective: ***To summarize the findings, recommendations, and conclusions of this Assessment, and to outline a proposed plan for future progress.***

Over the past three decades, local, state, and national regulatory programs have significantly reduced and will further reduce emissions from the source categories responsible for the majority of criteria air pollutants. These continuing emission reductions have significant implications for emission inventories. When ambient concentrations are high and emissions are dominated by a few source categories, air quality management strategies are fairly insensitive to errors resulting from the neglect of extraneous sources. In many current circumstances, however, ambient concentrations are falling, atmospheric chemistry regimes have changed, and emissions are more evenly distributed across a larger number of source categories. In this evolving situation, contributions from diverse sources can have proportionately greater consequences. These include wrongly identifying the pollutant to be controlled (as in the case of ozone) and designing control strategies that miss the most cost-effective reductions because of erroneous information about relative contributions of source categories. This greater sensitivity of air quality management strategies to errors in emission inventories emphasizes the increasing pressure to improve the inventories' timeliness, completeness, and accuracy.

The preceding chapters reflect these evolving issues in documenting the current state of North American emission inventories and their supporting technologies, and note several needs for inventory improvement. Particularly important for supporting air quality management and pollution modeling, these needs can be summarized in terms of the following key shortcomings:

- Quality assurance and quality control procedures are not strictly applied in the development of most emission models and inventories, and the documentation of uncertainties and data sources in emission inventories are not adequate.
- There are significant uncertainties in mobile source inventories particularly regarding the speciation of VOCs, the magnitude of CO emissions, and the temporal trend of NO_x emissions.
- Emissions for many important categories such as fine particulates and their precursors, biogenic emissions, toxic air pollutants, ammonia, fugitive emissions, open biomass burning, and many other area sources are uncertain and inadequately characterized.
- Emission estimates are frequently based on a small number of emission measurements that may not be representative of real world activity; accordingly, the precision and accuracy of estimates developed from these measurements are limited.
- The process for developing information on emissions with the kinds of spatial and temporal resolution needed for location-specific air-quality modeling is problematic and a source of unquantified uncertainty in model results.
- Current emission inventories are not developed and updated in a timely manner.
- Methods used to estimate emissions of individual chemical species in many emission models are out of date and produce estimates that are not reliable.
- Differences in current emission inventories in the three countries create difficulties for jointly managing air quality.

To address these shortcomings, this Assessment has developed eight findings and recommendations, which are described in the following subsections. A plan for implementing the recommendations follows their description.

Priorities and categories of the recommendations are indicated in Figure 9.1. As shown, the highest priority is given to uncertainty reduction for specific emission categories that are currently undercharacterized but are becoming increasingly significant with the noted evolution of North American air-quality management (9.1.1). The next seven recommendations are of equal importance from a broad North American perspective. These can be roughly divided into categories associated with emission data production (9.1.2, 9.1.3, 9.1.4, and 9.1.8) and those associated with data processing and management (9.1.5, 9.1.6, and 9.1.7). Although individual agencies may have specific needs and opportunities that would give priority to one or more of these second-tier recommendations, NARSTO encourages agencies to address each recommendation to as great an extent as possible during the normal emission inventory update cycle. For example, as agencies collect data for emission inventories, they should collect speciated data where possible, apply the most capable measurement technologies, and take measurements to ensure that the uncertainties and variabilities associated with the measurements are quantified. Agencies should also collect and process these data so that they are compatible and comparable to other emission and ambient measurements, accessible, and collected and reported in as timely a manner as possible.

9.1 FINDINGS AND RECOMMENDATIONS

9.1.1 Reduce Uncertainties in Emission Estimates of Key Undercharacterized Sources

Finding: **Comparisons of national emission inventories with ambient measurements and other independent measures indicate that emission inventories for certain source categories and pollutants, particularly gaseous emissions from electric utilities in the United States, are well characterized and reported. Emission inventories for other source categories and pollutants are much more uncertain. Of particular concern are nonpoint sources including fugitive emissions and transportation categories, as well as sources of organic compounds, carbonaceous PM, ammonia, and HAPs.**

The emission inventory community has years of experience in developing data for inventories, and has identified associated areas of greatest uncertainty. The first step in improving North American inventories is to address key uncertainty areas, which will differ for different countries, states, and provinces. Priorities will differ for inventories in different stages of

First Tier	**9.1.1 Reduce Uncertainties in Emission Estimates of Key Undercharacterized Sources**	
	Data Production Activities	**Data Management Activities**
Second Tier	**9.1.2 Improve Speciation** **9.1.3 Improve and Develop Tools** **9.1.4 Quantify and Report Uncertainty** **9.1.8 Assess and Improve Projections**	**9.1.5 Increase Compatibility and Comparability** **9.1.6 Improve Accessibility** **9.1.7 Improve Timeliness**

Figure 9.1. Prioritization and Classification of Recommendations.

development, such as inventories for specific HAPs or black carbon, or specific political domains (states, provinces or countries).

Recommendation: **Focus immediate measurement and development efforts on areas of greatest known uncertainty within current emission inventories. Systematically continue to improve emission inventories by applying sensitivity and uncertainty analyses and by comparing them to independent sources of measured data. Such comparisons will help identify subsequent improvement priorities.**

Resources must be targeted to reduce the most important uncertainty sources in emission inventories, especially for those source categories whose control will be most effective in terms of cost and health risk reduction, in making progress toward air quality goals. Considerations in the previous chapters of this Assessment, combined with recommendations from other reports (NRC, 2004a,b; NARSTO, 2004), lead to the following recommended list of topics for initial action within this first-priority recommendation:

- Size-segregated, speciated emissions of fine particles and their precursors, including black and organic carbon emissions
- Toxic and hazardous air pollutants
- Emissions from the onroad vehicle fleet
- Emissions from agricultural and other area sources, especially ammonia
- Speciated, spatially and temporally resolved organic emissions from biogenic sources
- Emissions of VOCs and organic HAPs at petrochemical and other industrial facilities
- Emissions from offroad mobile sources including farm and construction equipment aircraft and airport ground equipment, commercial marine facilities, and locomotives
- Emissions from open biomass burning, including agricultural and forest prescribed burning, wildfires, and residential backyard burning
- Residential wood combustion, including woodstoves and fireplaces
- Paved and unpaved road dust.

9.1.2 Improve Emission Inventory Speciation Estimates

Finding: **Contemporary air quality issues such as PM and ozone nonattainment, and identification of "hot spots" of HAP concentrations require detailed information about the species being emitted from sources.**

Stakeholders increasingly require speciated emission estimates as inputs for the ever-more sophisticated models used to predict air quality, human exposure, and health effects. The species needed for each of these applications may differ; even so, the need for improved and updated speciated emission factors and speciation profiles is critical for making well-informed air quality management decisions. As an example, speciated emission estimates for PM and its precursors are needed to apply source apportionment methods as one means to help link adverse health effects to emissions from specific source types.

Recommendation: **Develop new and improve existing source speciation profiles and emission factors plus the related activity data needed to more accurately estimate speciated emissions for particulate matter and its precursors, volatile organic compounds, and hazardous air pollutants.**

A high priority commitment should be made to develop, through measurements or other means, speciated source profiles, emission factors and activity data for important source categories of PM (especially carbonaceous compounds), VOCs (including a separation between high- and low-molecular-weight material), and HAPs. Critical to this effort is the need to develop temporally and spatially resolved and compound-specific estimates of emissions from biogenic sources. Progress in this area has occurred over the last several years in the United States and Canada, but further effort is needed to develop more complete knowledge of

emitted chemical constituents. The most pressing speciation needs are for organic compounds, from both anthropogenic and biogenic sources.

The National Research Council recognized this as one of seven overarching scientific challenges for air pollution research (NRC, 2004b). Emission inventories are now being used to help link emissions from specific source categories with specific measures of health. As health research identifies specific compounds of importance to public health, the emission inventory community should be ready to respond positively. Work to improve emission inventory speciation will form a solid foundation for any future efforts to include species that may be identified by health researchers as important for better understanding the links between emissions and health.

9.1.3 Improve, Develop, and Apply Emission Inventory Tools

Finding: **Technical advances in instrumentation and computation have allowed measurements and analyses that were not previously possible; continuing development of these and other technologies is likely to further improve emission inventory measurements and analyses. Improvements in modeling and data processing capabilities provide the basis for more detailed and more accurate emission models and processors.**

Advances in instrumentation capability continue to encourage more extensive measurements at lower cost than previous technologies. Increases in computational capabilities are providing new tools for comparing emissions and ambient concentration data and developing more detailed models of emissions, especially from non-point sources. Continuing development of these technologies and concepts holds substantial promise for improving emission inventory measurements, applications, and evaluations.

Recommendation: **Continue the development of new and existing measurement and analysis technologies to enable expanded measurements of emissions and ambient concentrations. Apply these technologies in developing emission model and processor capabilities to allow models to more closely approximate actual emissions in time and space.**

Support for improving current measurement technologies and developing innovative measurement concepts must be continued so that emissions and ambient concentrations can be measured more frequently and more cost effectively. To be of greatest value to air quality managers, new emission models and processors must continue to be developed to ensure that future inventories achieve the required levels of temporal and spatial resolution and composition detail.

Open path laser-based technologies, CEMS for pollutants previously considered to be "trace" species (such as mercury), and aircraft plume measurements are among the techniques that have shown considerable promise in providing more accurate source measurements. Use of dilution sampling systems coupled with detailed organic speciation methods will help to develop more comprehensive emission inventories of potential biologically active compounds. The use of satellites for identifying sources of wildfires or dust, or for measuring ambient levels of pollutants across a broad area, provides information about times and locations of emissions that would otherwise be unavailable. These measurements need to be combined with improvements in emission models and processors and other tools to create an emission inventory system that functions as a coherent whole rather than as a collection of parts.

The application of appropriate technologies and approaches for estimating speciated emissions and incorporating them into emission inventories is likely to require more resources than the other recommendations.

9.1.4 Quantify and Report Uncertainty

Finding: **The emission inventories, processors, and models of Canada, the United States, and Mexico are poorly documented for uncertainties; as a result, the reliability of the emission estimates cannot be quantified.**

Quantifying uncertainties results in a clearer understanding of the reliability of emission estimates and the robustness of policy decisions that are based upon those estimates. Given the level of resources that are allocated to maintaining and improving air quality, it is critical to provide information to decision makers that clearly identifies the uncertainties associated with technical analyses.

Recommendation: **Develop guidance, measures, and techniques to improve uncertainty quantification, and include measures of uncertainty (including variability) as a standard part of reported emission inventory data.**

Greater attention should be given to improving quantification and reporting of uncertainty in emission estimates. The most effective emission inventories are those that provide the appropriate levels of accuracy as well as the temporal, spatial, and compositional resolution needed to address the issue at hand. In order to most fully characterize the "appropriate" levels of accuracy, resolution and completeness needed for an emission inventory, methods to quantify uncertainty and evaluate accuracy must be applied where possible and developed where needed. Guidance on applying these methods is needed by emission inventory developers at all levels. Definitive guidelines are especially required for characterizing the means by which uncertainties propagate from emission and activity measurements through to final emission rate estimates and into final air quality projections and predictions. Such guidance will serve to minimize confusion about terms, methods, and results, allowing a more informed and accurate comparison of uncertainty across different emission inventories.

Quantifying variability, documenting data sources, and comparing results with other, independent measurements can, and should, be done as emission or activity measurements are taken. The results of uncertainty analyses should be made available concurrently with the primary measurement results. In Chapter 8, several methods of quantifying uncertainty in a "top-down" manner were presented and can be applied practically in many cases. Crucial to many of these methods are independent tests of emission estimates, many of which involve comparing ambient data to emission estimates. Innovative options are being developed to test or evaluate emission inventories that involve innovative applications of emerging measurements and techniques (e.g., those described in Chapter 6). Where resources are available and uncertainties in emissions are significant, every effort should be made to use these techniques to improve emission estimates that have a significant bearing on determining investments in emission controls.

Generating this information retroactively for developed inventories will be expensive – possibly as expensive as developing the initial emission estimate. On the other hand it should be relatively inexpensive when incorporated as a routine part of emission estimation. In the long run, including uncertainty information will provide users with a greater degree of confidence in the reliability of decisions supported by emission inventories. This increased confidence can lead to more effective allocation of millions of dollars for control strategies, and could well outweigh any incremental costs for including uncertainty information in databases and models.

9.1.5 Increase Emission Inventory Compatibility and Comparability

Finding: **Numerous emission inventories have been developed by different organizations for different purposes and covering different spatial domains. Although substantial improvements have been made in reporting national emission inventories in a mutually consistent way by categories, estimation methods, and chemical constituents, further efforts are needed to make these diverse emission inventories more comparable across organizations, purposes, geographies and time periods.**

Emission inventories for different countries, states, and regions have followed different developmental paths. Although emission inventories in Canada and Mexico use techniques similar to those in the United States, coordination among nations and among different organizations still needs to be fostered to improve comparability across emission inventories.

Recommendation: **Define and implement standards for emission inventory structure, data documentation, and data reporting for North American emission inventories.**

Efforts to use mutually acceptable and consistent data formats for reporting and processing data have significantly improved the ability to apply emission inventory data across regional and political boundaries in all three countries, as well as trends over time. Further efforts are needed to make emission inventories as comparable as possible given the unique needs of each emission inventory developer.

Comparability of the emission inventories is essential for effective joint analyses, air quality modeling, and reporting. At a minimum, a standard reporting format is needed for units, chemical names, industries, and similar fundamental data through use of common coding schemes [e.g., source classification codes (SCC), European industrial classifications (NACE), and pollutant codes] and data interchange formats such as the NIF. Within the United States, harmonization of the NEI, TRI, and Greenhouse Gas Emission Inventories is needed.

It is appropriate to convene a panel of experts from across the North American emission inventory development and user communities to define and implement standards for emission inventories, perhaps under the umbrella of ongoing coordination by the Commission for Environmental Cooperation. Achieving this recommendation requires that the current cross-border interactions and collaborations be maintained and enhanced.

9.1.6 Improve User Accessibility

Finding: **The accessibility of emission inventories or emission models is presently very limited because of the sheer size of the databases, and the cumbersome manner in which the data have been reported and archived. Improved accessibility to emission data is critical to meet the diverse needs of the user community.**

Many data enhancement methods and improvements are not utilized by the community due in part, to the difficulty in accessing the data. This results in inefficiencies in effort or utilization of inferior data.

Recommendation: **Improve user accessibility to emission inventory data, documentation, and emission inventory models through the Internet or other electronic formats.**

High priority attention needs to be given to substantially improve user accessibility to emission inventory data and associated supporting documentation. An investment is needed in all three nations and at different governmental levels to improve accessibility, through the Internet or other electronic formats. For instance, the creation of a file transfer protocol site (ftp) to host the detailed emission inventory and related modeling files for the three countries could address some of the accessibility requirements of the air quality modeling community. The information concerning the data sources, methods by which they were collected, and where possible, the raw data from which the final emission inventory values were developed should be as easily available as the emission inventory values themselves. Accessibility also means that inventory data will be readily available to all those who need access to it, ranging from interested members of the general public to experienced air quality modelers.

Application of modern data management techniques can provide significantly improved user accessibility to emission inventory data, and can also improve the ability of emission inventory developers to incorporate new information into emission inventories as they are developed and updated. It should be noted that accessibility cannot be achieved by simply applying the appropriate technology. Data handling procedures and agreed-upon data formats and protocols (see Recommendation 9.1.4 on compatibility) are equally important to achieving effective user accessibility.

These approaches will likely require substantial additional investment in information technology infrastructure, including investment in personnel. In some cases, the necessary infrastructure is in place, while in others, investments are needed in adequate high-speed network access, modern computer systems, and dedicated information

technology support. Expertise in data management techniques, database development and maintenance, and related topics will also be needed. A combination of distributed control and centralized maintenance yields significant opportunities for pooling resources at the regional level. Such pooling may well be an effective approach to obtaining the resources to design, implement, and maintain improved emission inventory data systems.

9.1.7 Improve Timeliness

Finding: **Timely and historically consistent emission inventories are crucial elements for stakeholders to assess current conditions and estimate progress in improving air quality.**

The current emission inventory cycle is not short enough to capture changes in emissions caused by increasingly rapid economic and technical changes. Shorter update cycles will ensure that inventory estimates are more accurate in describing actual conditions. Shorter cycles also make it easier to identify trends that provide feedback about the effectiveness of air quality management strategies. Long emission inventory cycle times have inhibited the ability of all three nations to link emission changes with trends in ambient air quality.

***Recommendation*: Create and support a process for preparing and reporting national emission inventory data on a yearly basis.**

Efforts are needed to accelerate the preparation and reporting of annual, self-consistent national emission inventories. If historical estimates need to be changed to incorporate method improvements or for other technical reasons, updated historical inventories also must be reported in a timely way to ensure that such changes are clearly communicated to users. It may be necessary to create "draft" and "final" emission inventories or other means of version control that differentiate by level of quality review so that new data can be incorporated into inventories as rapidly as possible.

The emission inventory development community should strive for continual improvements in inventory responsiveness, using an annual emission inventory update cycle as their goal. Canada and California, for instance, have demonstrated approaches that significantly reduce the length of the inventory update cycle. However, there are limits to cycle time reduction, as data collection and reporting often must follow a detailed multi-step process, including legally mandated reviews of data in some instances. In addition, shortening the inventory cycle will require the cooperation of many organizations at the federal, provincial, and state levels. For the United States to accomplish this goal, the various federal agencies that collect and report data needed for compilation of emission inventories must provide this data in a more timely manner. This includes, for example, Department of Energy data on fuel use, Department of Agriculture data on acreage and livestock populations, Department of Transportation data on vehicle miles traveled, and NASA data on fires and ground cover. Achieving this goal may also require investments in personnel or data processing capacity to more rapidly collect and report inventory data.

The ability to quickly incorporate and report new information without significantly increasing uncertainty will provide a more up-to-date picture of the current emission situation and will therefore be of much greater value to policy development efforts. However, as the level of data quality assurance increases, the time required to report the final emission inventory results will also increase. Inventory users will need to balance the desire for rapid response with the need to apply the required level of data quality assurance.

9.1.8 Assess and Improve Emission Projections

Findings: **Emission projections are critical to developing control strategies for attaining air quality standards and goals, and for evaluating future year impacts associated with regulatory development.**

Current approaches for projecting emissions have not received the same level of attention as development of base-year emission inventories. However, they have a critical impact on the regulatory process. With the exception of the electric utility and some mobile source sectors, limited effort has been applied

to capture the societal and technological changes that will impact emissions in the future. Most source categories have only had limited evaluation and the emission projection procedures may not be applicable to the range of emitted compounds being recommended for inclusion in emission inventories.

Recommendation: **Emission projection methodologies for all emission inventory sectors in North America should be evaluated to determine the accuracy of past projections and identify areas of improvement for future projections.**

Publicly available models or approaches for estimating future emission changes should be developed for all emission sectors. It is preferable from a scientific perspective to make the models widely available and to encourage further model development through comparisons of modeled results in technical literature. However, development of alternative models could be expensive and have a limited market. These factors can limit the ability of researchers and others to conduct studies of projected emissions using different assumptions.

A retrospective analysis of practical growth estimation techniques should be undertaken to understand how well past projections have predicted actual emissions. Retrospective evaluations can also identify areas in which projections can be improved. However, combining or comparing nation-, state-, or province-specific projections requires agreement among future conditions, including projection year or years and control and economic scenarios.

Uncertainties associated with projections (both forecasts and backcasts) should be explicitly quantified and reported based on backcasting and assessment of alternative demographic and technological scenarios. Uncertainties can be presented in terms of probabilistic assessments, upper and lower bounds, or comparison with other projections, but information on projection uncertainties is needed to ensure that decisions based on forward (or backward) projections are able to account for the possibility of other outcomes. For instance, some comparisons of Economic Growth Analysis System projection results with alternative approaches have taken place or are underway.

Projections for greenhouse gases are necessarily different from those associated with air quality management, due to the time scales involved and the key role of fundamental technology changes in greenhouse gas emission mitigation. Projections that account for technology innovation and diffusion involve fundamental differences from short-term projections of emissions related to air quality, and need to be considered in a complementary way.

9.2 IMPLEMENTING THE RECOMMENDATIONS

The eight recommendations are an ambitious list of items, and will clearly require money, expertise, and time to implement. Unfortunately, the resources now available may not be adequate to meet current requirements, let alone an ambitious new agenda. Nevertheless, guidance and approaches for policy makers to consider when faced with decisions about resource allocations are provided below.

The implementation of these recommendations must be considered within the context of existing requirements. It is understood that inventories are developed because of existing legislative and regulatory requirements. Even so, implementing these recommendations will ensure that inventories are able to meet air quality management needs well into the future.

Four actions were considered to be common to the three North American countries in implementing the recommendations:

- The implementation efforts should be led by Environment Canada, the U.S. EPA, and SEMARNAT over the next 10 years. Interim milestones for emission inventory improvement should be developed to support regulatory deadlines in each country.
- Federal support for regional, state, and provincial emission inventory development and improvement needs to be continued to ensure that emission inventories are able to provide the expected quality of information.

- The interactions and collaborations among and across Canada, the United States, and Mexico should be maintained and enhanced.
- Increased training of agency staff at federal, state and provincial, and local levels and industrial stakeholders (regulated sources, testing organizations, etc.) will be required to effectively implement these recommendations.

Outlined below is a series of first steps toward a full implementation of the eight recommendations for each of the three countries. These action plans are intended to provide initial guidance; each lead agency should develop more detailed steps to fully implement the above recommendations across all governmental levels in all three countries.

The cost estimates in the action plan were developed based upon the experience of the Assessment's combined authors, with the understanding that these are preliminary planning estimates that must be further refined for each issue. These cost estimates are intended as a starting point for additional discussion.

The call for increased funding should not be construed to mean the current emission inventories are inadequate to support current regulatory activities; rather, the need for increased investments is a recognition that future emission inventory improvement needs to be accelerated to enhance the effectiveness of air quality management and more clearly assess both ongoing progress and remaining air quality issues.

9.2.1 Action Plan for Canada

1. Improve the emission inventory for $PM_{2.5}$ and its precursors. The adverse health effects of $PM_{2.5}$ due to exposure to ambient air pollution are well documented. The requirements for Canadian jurisdictions to meet the new ambient air quality standards for $PM_{2.5}$ by the year 2010 provide an additional incentive to reduce the uncertainties associated with the current emission inventory for $PM_{2.5}$ and its precursors, for the development of provincial implementation plans. The national inventory will be improved through the development of new emission factors using the latest measurement techniques, and the compilation of activity statistics through detailed surveys. These activities should be conducted for industrial and non-industrial sources, including particulate matter and ammonia emissions from the agricultural sector. **Estimated Cost:** $1.5 million (US) per year.

2. Improve speciation profiles for PM and VOCs. Many of the speciation profiles currently available are based on measurements and information compiled a number of years ago reflecting mainly industrial and non-industrial activities in the United States. The use of the latest measurement techniques will allow the current speciation profiles to be expanded to provide a more accurate representation of the Canadian emission sources, taking into account the differences in the climate, fuel characteristics, processes and activities. These new profiles will improve the characterization of the Canadian emission sources providing better information for air quality models and air quality management. **Estimated Cost:** $2 million (US) per year.

3. Improve the point source emission estimates. The point source emissions collected in Canada through programs such as the NPRI are currently of variable quality for selected sectors. There is a need to collect more information on the emission sources for each facility to more easily assess the completeness and accuracy of the reported emissions. The implementation of an enhanced verification program conducted in conjunction with technical studies and source measurements would provide additional support to the industries to improve their emission estimates. Performed in collaboration with the industries and the industrial associations, this program would improve the accuracy of the emission inventories, and more precisely monitor the progress of different emission reduction programs and initiatives. **Estimated Cost:** $1.5 million (US) per year.

4. Improve the timeliness for the dissemination of the emission inventory trends and projections. The dissemination of the emission inventory trends and projections in a more timely fashion

is required to meet the reporting requirements of domestic programs, international agreement and protocols, the air quality modelers and the public. With the current efforts in Canada to compile and disseminate the national emission inventory on an annual basis, there is a need to increase the current capacity to produce the required reports, and data files. The emission trends and projections should also be reviewed on a regular basis to ensure their accuracy and consistency with the latest emission inventory. An increase in personnel and an update of the national emission inventory database system are required to meet these requirements. **Estimated Cost:** $0.6 million (US) per year.

5. Engage appropriate stakeholder groups to develop a national strategy to implement the eight recommendations of the Assessment. The compilation and the improvement of the national emission inventory are performed in collaboration with the federal, provincial, territorial, and regional governments, and with industries, industrial associations, academia, and nongovernmental organizations. Consultations with these stakeholder groups should be held to discuss the eight recommendations of this Assessment, identify their priorities, and develop a national strategy with specific timelines for implementation. **Estimated Cost:** $60,000 (US) for the first two years to conduct the consultations with the stakeholder groups.

The cost to implement these initial steps as part of a national strategy is estimated to be approximately $6 million (US).

9.2.2 Action Plan for United States

1. Enhance the emission inventories and associated tools (such as SPECIATE) for $PM_{2.5}$ and its precursors, especially for carbonaceous particles. From a public health perspective, $PM_{2.5}$ has been associated with premature mortality and appears to be the single greatest contributor to public health risk due to exposure to ambient air pollution. Furthermore, of the ten highest-priority source categories identified as needing immediate attention, nine are directly relevant to $PM_{2.5}$. **Estimated Cost:** An additional $5 million per year at the federal level for additional measurements, plus $0.1 million per year (ongoing) to maintain SPECIATE. Development of improved mobile emission models and data should continue at current levels for the foreseeable future.

2. Establish emission inventory reporting requirements for HAPs and integrate data into the National Emission Inventory. No requirement currently exists for sources or state agencies to report emissions of HAPs in the same way as criteria pollutants and their precursors. Under Title V of the *Clean Air Act* and the requirements of the Toxic Release Inventory, many of these data are being reported to the states on regular basis, but are not necessarily transferred to the national emission inventory system. **Estimated Cost:** Initial, short-duration costs to implement a rule would be on the order of $0.5 million per year for three years. Development of a data management system to facilitate harmonization and stakeholder accessibility of these data could be $10 million.

3. Improve the capacity of state, local, and tribal agencies to develop inventories to meet State and Tribal Implementation Plan and other regulatory requirements. As inventories become more complex, the resources required by state, local, and tribal agencies to meet their regulatory requirements increase tremendously. Much of the investment made by these agencies is in the form of personnel expenses. Many actions can be taken to increase the capacity of these agencies to meet the needs of increasingly complex inventories. Changing the data collection process to allow facilities to submit data online, providing additional and more in-depth training, and consolidating data reporting requirements (see item 2 above) can all improve the ability of state, local, and tribal agencies to meet inventory development challenges. **Estimated Cost:** Investments in state/local/tribal personnel should be doubled from the current estimated expenditures of $10 million/year.

4. Engage appropriate stakeholder groups to develop action plans to implement the full range of recommendations. Considerable effort is underway to improve U.S. emission inventories across the federal government, by state governments, and by affected industries. Coordination of efforts toward addressing the eight recommendations would provide the greatest return on those inventory investments and would ensure that the recommendations of greatest importance to the stakeholder communities are being addressed. The appropriate stakeholders will vary depending upon the location and the type of inventory (criteria, toxic air pollutants, mercury, greenhouse gases, etc.), but will include the following general groups: the U.S. EPA (Office of Air and Radiation, Office of Research and Development), the Committee on Environment and Natural Resources Research (to coordinate across federal agencies), STAPPA/ALAPCO, industry experts, environmental and other nongovernmental groups, and academic researchers. **Estimated Cost:** $0.25 million per year for two years to support stakeholder meetings. Resources to implement these plans should be provided in concert with these planning resources. To get the process underway, it is estimated that $10 to 20 million would provide the necessary initial support for critical programs to address the Assessment's recommendations. The stakeholder groups will determine appropriate base level funding for future years.

5. Increase support of research to develop and improve emission inventories. Several of the Assessment's recommendations call for improved technologies, tools, methods, and guidance. These improvements can only occur if the research necessary to develop them is adequately supported. Inventory-related topic areas should be regularly included in federal competitive grants programs and technology development programs such as the Small Business Innovative Research program. **Estimated Cost:** A minimum of 10 percent of the base budget for implementing these recommendations (as determined by the stakeholder groups discussed above) should be allocated to stimulate research activities by academic, institutional, and governmental researchers on the science and technology of emission inventory development and improvement.

9.2.3 Action Plan for Mexico

1. Complete the National Emission Inventory for Mexico. The most critical need is to complete the initial NEI for Mexico. Mexico's NEI is nearing completion, and when done it will represent a major accomplishment in Mexico's air quality management program. Not only will completion of this inventory provide a comprehensive overview of air pollutant emissions in Mexico, but it will also set the foundation upon which improved inventories will be developed in the coming years. **Estimated Cost:** $0.6 million (US) per year for two years.

2. Develop and implement a communications strategy to disseminate the results of the NEI. Upon completion of the NEI, it is critical to get the information out to other federal agencies, states, localities, industries, researchers, and the general public in Mexico. As the value of the inventory is recognized by stakeholders, support for future inventories will increase. This support may take the form of measurements from industrial sources or access for such measurements, as well as sustained funding from both Mexico and outside sources. **Estimated Cost:** $80,000 (US).

3. Develop and fulfill requirements at the national level to enable emission inventory updates on a three-year cycle. As the NEI nears completion, data gaps and lessons learned can be evaluated and used to develop requirements for the next cycle. In conjunction with the communications strategy above, discussions with stakeholder groups can provide valuable input to facilitate the update of the NEI. **Estimated Cost:** $85,000 (US) per year for three years.

4. Build emission inventory development capacity among state environmental agencies. In order to maintain and update the NEI, state environmental authorities require basic emission inventory

development capacity. Intensive training is required for state government officials and technicians in the areas of information retrieval, emission factor use, QA/QC activities, and inventory compilation in general. Interaction with SEMARNAT to integrate the NEI will be facilitated if all state agencies act upon the same technical baseline. **Estimated Cost:** $1 million (US) per year for three years.

5. Expand capabilities among Mexican agencies. Mexican agencies at the federal and state level often have access to data and facilities that will significantly expand the ability of SEMARNAT to develop emission inventories and updates. Expanding the capabilities of these other agencies to measure and collect emission and activity data will substantially facilitate future NEI development. **Estimated Cost:** $80,000 (US) per year for three years.

6. Continue to improve the capabilities to develop emission inventories through interactions with the U.S. and Canada. Partnerships to enhance Mexico's emission inventory development capacity have been of enormous value to both Mexico and the US and need to be continued. Where appropriate, such efforts should be expanded across North America through NARSTO, the Commission for Environmental Cooperation, and similar multinational entities. Partnerships at the state level, such as with the Western Governors' Association, are also highly beneficial to states on both sides of the border. Areas requiring special attention include training for Mexican inventory developers at the federal and state levels, and emission measurement pilot-project activities to develop Mexico-specific emission factors. **Estimated Cost:** $0.3 million (US) per year for three years

7. Improve programs to conduct direct emission measurements by identifying sources needed to develop Mexico-specific emission factors and by developing vehicle fleet characterization data for mobile sources. Many of the emission estimates in the current draft of the NEI are based upon U.S. data. Although these data provide a meaningful starting point, it is important to improve the emission estimates by conducting emission measurements on Mexican sources to reflect differences in activity patterns, technology use, and fuels. Equally important is the need to develop Mexico-specific vehicle fleet data. Differences in vehicle mix, age, emission controls, and use patterns will have significant impacts on the estimated emissions from mobile sources. **Estimated Cost:** $3 million (US) per year for five years.

8. Develop a national data system. A common data system for reporting and analyzing emission data is critical to the long-term ability of SEMARNAT to maintain and update emission inventories. Data processing hardware and software are needed to handle the increasing amounts of data that will be collected as emission inventories are updated and improved. Expanding the emission inventory data system infrastructure to states will further enhance the capabilities for developing and updating emission inventories. **Estimated Cost:** $1 million.

9. Increase human resources available at federal and local levels for emission inventory compilation, maintenance and update. The first ever National Emission Inventory is being compiled by the limited personnel available at federal and state agencies with the help of a consulting team. However, to effectively follow up on the most pressing next steps, more personnel are needed for the compilation, maintenance and update of data. This would assure continuity of present efforts. **Estimated Cost:** $1 million (US) per year.

9.2.4 Additional Commentary on Cost

It is estimated that the U.S. federal government currently invests approximately $25 million per year to develop and update emission inventories. In Canada, approximately $6 million (US) per year is invested for the compilation of the national emission inventory. Mexico has invested approximately $600,000 (US) per year in the development of the NEI in Mexico. As a basis for comparison, the U.S. EPA's total budget for air programs, not including climate change, was nearly $600 million in 2003. Investments in emission inventory research, preparation, and reporting will

need to increase substantially to achieve emission inventories that provide the quality and quantity of information expected by air quality management decision makers, the regulated community, and the general public. Increases ranging from double to an order of magnitude may be required, depending upon the specific area and current levels of investment. Although additional resources are being invested by state, provincial, and local agencies (an estimated $10 million per year in the United States), the total available resources are not sufficient to achieve the desired improvements in emission inventory programs.

The cost of developing emission inventories is strongly dependent upon their purpose. The relatively low cost to develop Mexico's NEI is a consequence of a relatively low data detail level and the use of previously existing information. At the upper end of the cost scale, the Electric Power Research Institute invested $50 million to quantify emissions of hazardous air pollutants from utility boilers (EPRI, 1994). The American Petroleum Institute, the U.S. Department of Energy, and other contributors have spent approximately $6 million to measure combustion emissions from refinery equipment. These more expensive examples reflect the higher cost of collecting highly detailed information, including quantification of speciated organic and metal compounds that are normally present in flue gases at concentrations as low as part-per-billion levels.

These examples indicate the reasons for such disparity in costs, but they also illustrate that as the demands for detailed data increase, inventories become increasingly expensive. This need for more detailed emission information to adequately support the development of air quality management decisions is driving the need for more accurate and more expensive emission inventories. In this context, estimates of an order-of-magnitude increase in resource needs are not as extreme as they may initially appear, and in some cases may even be conservative.

Investment in emission inventories is roughly $40 million per year across North America. This substantial sum can be put into context. It has been estimated that the United States spent about $19 billion in 1999 to meet the requirements of the *Clean Air Act*. Thus, approximately $2 out of every $1,000 spent to meet the *Clean Air Act* requirements was spent on emission inventories. A doubling of the investment in emission inventory development can significantly improve well-informed air quality management decisions, and may in fact reduce the total amount that spent on *Clean Air Act* compliance if more targeted air quality strategies can be developed.

9.3 CONCLUSIONS

Emission inventories are the foundation upon which air quality management strategies are built. Substantial progress has been made over the past three decades in improving air quality across North America due to the application of good scientific and technical information by air quality managers. However, emission inventories are now expected to provide high-quality data for applications for which they were not designed, and to provide those data more rapidly, more transparently, and more broadly.

Several scientific advisory groups in the United States recently have underscored these expectations. The National Research Council reports on air quality management and PM research, the recent NARSTO Ozone and PM Assessments, and the Clean Air Act Advisory Committee have all identified emission inventories as needing additional attention (CAAAC, 2005). These groups have each pointed to the importance of accurate, timely, and complete emission inventories as the foundation for scientifically sound air quality management decisions.

Experience in Texas, California, and elsewhere has shown that well focused cooperative efforts among government, industry, and academia can facilitate the development of improved emission inventories. Although such concerted efforts initially appear costly, it is much more costly to embark upon a control strategy that is ineffective in solving the environmental problem at hand. In short, the return on investment in accurate and timely emission inventories can be more than offset by the savings derived from more cost-effective control strategies.

The ambitious vision described in Chapter 2 – "all significant emissions from all sources, time periods, and areas with quantified uncertainties and timely accessibility" – provides a long-term target for emission inventory improvement. The progress made to date by the three countries of North America to develop and improve emission inventories represents a clear success for the field of air quality management. To build on this success and to achieve the quality of environment the people of North America expect, allocation of management attention and resources to emission inventories continues to be critical. The recommendations above are an important step toward ensuring that the progress of the past is maintained and that future progress is achieved.

REFERENCES FOR CHAPTER 9

CAAAC. 2005. Recommendations to the Clean Air Act Advisory Committee. www.epa.gov/air/caaac/pdfs/report1-17-05.pdf, Air Quality Management Work Group, January 2005.

EPRI. 1994. Electric Utility Trace Substances Synthesis Report. EPRI TR-104614, Electric Power Research Institute, Palo Alto, CA.

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

NRC. 2004a. Air Quality Management in the United States. National Academies Press, Washington, DC. ISBN 0-309-53027-X.

NRC. 2004b. Research Priorities for Airborne Particulate Matter (IV). Continuing Research Progress. National Academies Press, Washington, DC. ISBN 0-309-09199-3.

U.S. EPA. 2001. Final Report to Congress on Benefits and Costs of the Clean Air Act. EPA-410-R-99-009, Office of Air and Radiation, Washington, DC.