Using Historical Information to Improve Emission Projections (or How to Avoid Being Doomed to Repeat History)

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ABSTRACT

The poet and philosopher, George Santayana is often quoted as having said that "those who cannot learn from history are doomed to repeat it." While he certainly did not have emissions forecasting in mind when identifying this conceit, it does have application to air pollutant emission projection practitioners. Under contract to the Lake Michigan Directors Consortium, E.H. Pechan & Associates, Inc. is performing a study to analyze whether recent historical evidence suggests that EPA's emission projection guidance and tools may overstate future emission levels. The purpose of this on-going study, which focuses on a set of Midwest region priority stationary source categories, is two-fold: (1) compare default EPA emission activity growth rates with recent historical emission activity growth rates; and (2) analyze whether past trends indicate that significant stationary source emission reductions may be expected to occur beyond those forecast by EPA's projections methodology.

INTRODUCTION

To support the Regulatory Impact Analysis (RIA) of the 2006 National Ambient Air Quality Standards (NAAQS) for particle pollution,[1] EPA reviewed the historical trend in non-electric generating unit (EGU) stationary source emissions using 1990, 1996, 1999, and 2002 data from the National Emissions Inventory (NEI).[2] This EPA analysis focused on national total stationary source emissions for three pollutants – oxides of nitrogen (NOx), sulfur dioxide (SO2), and particulate matter with an aerodynamic diameter of 2.5 microns or less (PM-2.5), and also on SO2 emissions reported within four Standard Industrial Classification (SIC) groups: Chemical and Allied Products; Petroleum Refining and Related Products; Paper and Allied Products; and Primary Metal Industries. Each of these data sets indicated emission reductions over the reviewed period. The EPA also compared forecast 2002 non-EGU stationary source NOx and SO2 emissions from EPA's RIA for the 1997 particulate matter (PM) NAAQS with actual 2002 NEI emissions—while the forecast overestimated actual NOx emissions by about 25 percent, SO2 emissions were overestimated by approximately 75 percent. EPA's review concluded that, although their current projection methods appropriately reflect the impact of economic growth and emission control impacts on future-year emissions, they do not adequately reflect the impact of other factors such as technological innovation, capital turnover, fuel switching, and other activities that may have significant impacts on emissions. As a result, EPA adopted a no emissions growth assumption in forecasting non-EGU stationary source emissions for all pollutants modeled in the 2006 PM NAAQS (note that EPA extended the no growth assumption to volatile organic compounds and ammonia). The EPA identified this as an "interim" approach to acknowledge that EPA will work to develop improved and consistent emissions forecasting methods for future analyses.

During the process of developing the PM NAAQS RIA, EPA requested advice and comments from the Advisory Council on Clean Air Compliance Analysis and Air Quality Modeling Subcommittee (Council) of the Science Advisory Board on the PM NAAQS no growth forecasting approach. As part of this request, EPA asked the Council for suggestions that would assist EPA in developing a more sophisticated longer-term approach to emission forecasting for these source categories. The Council recommended that EPA model the technological change that is likely driving observed emission declines. The Council specifically suggested that EPA use historical trend data to estimate a declining "emissions intensity" as it relates to sector level output, and to assume the historical rate of decline (i.e., after removing declines attributable to the Clean Air Act) would continue to be constant in future years.[3] The Council recommended that the first step in this process should be to factor out any emission reductions that can be attributable to the Clean Air Act. The EPA responded to the Council by acknowledging the shortcomings of applying a one-size fits all default no emissions growth assumption for non-EGU stationary sources, and pledging to base future emission projection improvements on the results of source category-specific analyses.

The Lake Michigan Air Directors Consortium (LADCO) requested that E.H. Pechan & Associates, Inc. (Pechan) consider the implications of the EPA's recent efforts to identify and address shortcomings of past emission projections for non-EGU stationary sources in developing growth and control factors to support forthcoming LADCO projection efforts. [Growth factors reflect the estimated change in emission activity between the base and forecast years; control factors represent the estimated change in emission rate between the base and forecast year due to the effects of one or more control programs.] Pechan is currently supporting LADCO in conducting source category-specific historical trend analyses to refine growth and control factors for the six LADCO States (Illinois, Indiana, Michigan, Minnesota, Ohio, and Wisconsin).

METHODS

In past studies for LADCO, Pechan developed sets of non-EGU source growth factors for a 2002 base year inventory. For most source categories, emission activity growth factors reflected projections data that were to be incorporated into Version 5.0 of the Economic Growth Analysis System (EGAS). The EGAS 5.0 projections data are typically derived from two main resources: (1) version 5.5 of Regional Economic Models Incorporated (REMI)'s State-level economic models; and (2) the Department of Energy (DOE)'s *Annual Energy Outlook 2004*.[4] In keeping with past EPA practice EGAS assumes that changes in industry sector output (sales) are directly related to changes in emission activity for most non-fuel combustion stationary source categories. This was also the underlying assumption employed in the 1997 PM NAAQS RIA. For a limited set of LADCO priority source categories, Pechan conducted past performance evaluations to identify the growth methodology with the most empirical validity based on how well each methodology had been able to predict past emission activity trends. Pechan then implemented the methodology to develop growth factors that, for non-fuel combustion sources, did not generally assume that a given percentage sales increase translates into the same percentage increase in emissions activity. In fact, sector-specific comparisons of historical emission activity and sales trends indicated that emission activity generally grew much slower than sales, and, in some cases, decreased while industry sector sales increased. This should not be too surprising given that industry sectors typically include many diverse production processes.

For the current ongoing study for LADCO, Pechan is updating existing growth and control factors to provide a comprehensive set of factors relative to a 2005 emissions inventory for the LADCO States. As part of this update, Pechan is reviewing/refining growth factors for a set of priority source categories. For some of these source categories, Pechan is compiling historical emission activity trend data for the LADCO States for comparison to forecasted trends for the emission activity surrogate growth indicator. Results of these comparative analyses are used to refine the forecasted trends to more closely align with observed historical trends.

In addition to undertaking the emission activity growth factor refinements noted above, Pechan is also working to improve upon the existing characterization of future year LADCO emission rates. Acknowledged shortcomings of the existing control factors are that they do not account for the effects of some control programs (New Source Performance Standards, Prevention of Significant Deterioration/New Source Review), and do not model emission reductions that can occur due to non-mandated technology/process changes. For this part of the study, Pechan is reviewing 1999-2005 emissions and emissions activity data to identify point source categories for which there is a significant decrease in historical emission rates that are not resulting from modeled control programs. The end product of this study will be a set of updated growth and control factors for use by LADCO in air quality modeling for ozone, fine particles (PM2.5), and regional haze. The following sections describe the methods that Pechan is using to refine LADCO growth and control factors.

Emission Activity Forecasts

The first step in refining emission activity forecasts is to identify the source categories for review. This step is necessary because the large number and diversity of non-EGU stationary source categories makes a comprehensive review impractical. Potential considerations in selecting priority source categories are:

- The magnitude of each category's projected uncontrolled emissions increase forecast by the existing growth factors;

- The availability of historical emission activity data specific to the source category/geographic area; and

- The level of effort associated with developing the historical emission activity data.

The purpose of the first criterion is to focus study resources on those categories whose base year emissions and current growth factors result in the largest estimated emissions growth over the projection period. For the LADCO study, more than 100 non-EGU point and a similar number of area/nonroad source categories are undergoing detailed emission activity review. Fuel consumption is the emission activity for many of these priority categories. For these source categories, Pechan is compiling LADCO region 1990-2004 energy consumption data from DOE. Pechan is then computing annual historical growth rates for comparison with the related projected 2005-2018 annual growth rates from DOE's *Annual Energy Outlook (AEO) 2007*.[5] Significant discrepancies are then identified. Given the inherent uncertainty in forecasting, as well as the particular limitations of the *AEO* forecasts (e.g., some forecasts are only reported on a national basis), it seems reasonable to assume that the historical long-term historical growth rates are as valid an indicator of future growth rates as the *AEO* forecasts. Therefore, for sectors/fuel types where the historical LADCO trend is for decreasing energy consumption while *AEO 2007* forecasts significant increases, growth factors will be incorporated that reflect a no emission activity growth assumption. In cases where the historical data indicate a significantly lower energy consumption growth rate than forecast under *AEO 2007*, growth factors will be developed that reflect the long-term historical trend rather than the *AEO 2007* forecast growth rates.

Similar historical comparisons are being developed for non-energy consumption sectors. For cement manufacturing kilns, for example, SO2 emissions are function of the amount of cement produced. The U.S. Geological Survey publishes State-level annual Portland cement production data that can be used to develop comparisons of historical regional production growth to forecasted growth (e.g., from cement industry sales projections).

Inventories sometimes report “throughput” values that represent the activity value (e.g., tons of steel produced) that is related to the amount of uncontrolled emissions produced. Unfortunately, throughput is not consistently reported in inventories, and in some cases, facilities may not report due to confidentiality concerns. Even in cases where historical inventories report this information, it is important to quality assure (QA) these data before they are analyzed, because there may have been a significant change in facility reporting of this information in inventories of different vintages. In instances where throughput data are reported consistently in an area’s historical inventories, these data provide an excellent means for developing reality checks of the growth rates reflected by the surrogate emission activity indicator forecasts.

Sample Emission Activity Trend Analysis

Industrial natural gas consumption is a key NOx emission activity, and provides an example of how the emission activity trend analysis is performed. EGAS 5.5 relies on *AEO 2004* regional projections of industrial natural gas consumption as the emissions activity growth indicator for industrial natural gas combustion source categories. For the six LADCO region States, Pechan compiled 1990-2004 industrial natural gas consumption estimates from the Department of Energy (2004 is latest year currently available).[6] The first row in Table 1 displays the LADCO region annual growth rates between each of three periods. These data indicate decreases in natural gas consumption in each period. The second row displays annual growth rates computed from *AEO 1998* industrial natural gas consumption forecasts for the East North Central region (covering 5 of the 6 LADCO States—Minnesota is one of 7 States included in the West North Central region). *AEO 1998* is included for comparison because earlier *AEO* versions were not readily available, and because this used 1996 energy consumption as the base year for projections. Unlike the actual historical trend, *AEO 1998* forecast growth in industrial natural gas consumption over both the post-1996 and post-1999 periods.

Table 1. Comparison of industrial natural gas consumption growth rates, 1990-2004.

Source	Annual Growth Rates		
	1990-2004	**1996-2004**	**1999-2004**
LADCO Region Actual	-0.01%	-1.65%	-2.27%
East North Central Region *Annual Energy Outlook* (AEO) *1998*		1.60%	0.14%

Table 2 reports the LADCO region natural gas consumption estimates for 1996, 1999, and 2004. To evaluate how well AEO forecasts trended with actual natural gas consumption, Pechan applied 1996-2004 growth in East North Central industrial natural gas consumption from *AEO 1998* to actual 1996 LADCO regional consumption. As indicated by Table 2, *AEO* overestimated actual consumption by 30 percent. To see if this may have been a one-time shortcoming specific to that particular edition of *AEO*, Pechan also obtained *AEO 2001* forecasts (base year = 1999), and applied 1999-2004 *AEO* growth rates to LADCO region 1999 industrial natural gas consumption. The *AEO* forecasts once again substantially overestimated actual 2004 consumption (by 28%). The historical activity trend analysis demonstrates that AEO has a record of overstating industrial natural gas consumption in the LADCO region. Given the fact that this is the emissions activity for several high NOx-emitting source categories in the LADCO region, it is particularly important that changes are not significantly over-/under-estimated for this emissions activity.

Table 2. Actual and projected industrial natural gas consumption, 1996-2004

Source	Consumption (million cubic feet)			% Difference vs. Actual
	1996	1999	2004	
LADCO Region Actual	1,467,921	1,442,061	1,285,432	
Projected from 1996 using 1996-2004 growth from *AEO 1998*			1,666,961	30%
Projected from 1999 using 1999-2004 growth from *AEO 2001*			1,651,214	28%

Emission Rate Forecasts

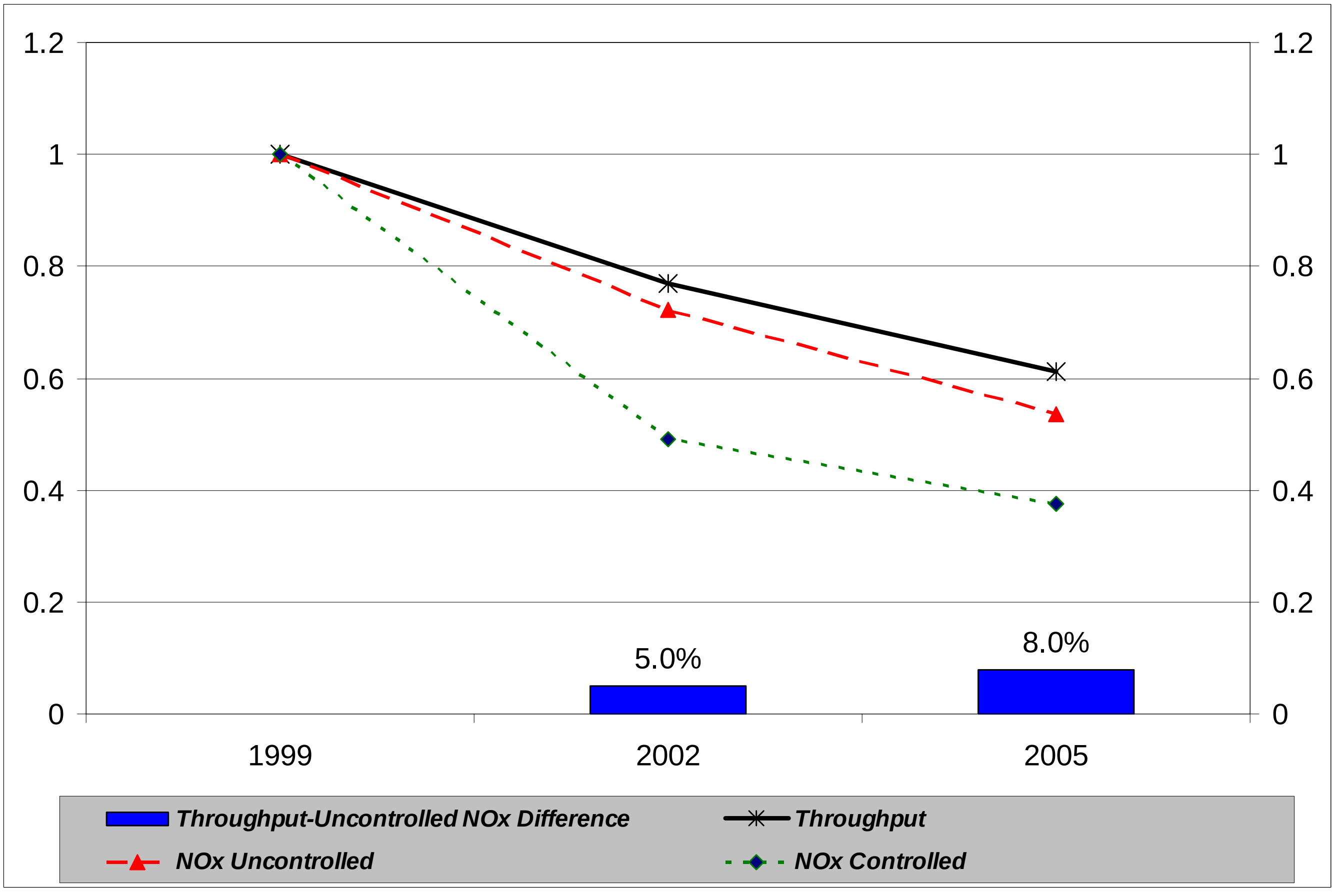
Previous stationary source emission projections, including earlier EPA forecasts to support NAAQS RIAs, have incorporated source category-specific control factors that estimate the emission reduction percentages in each forecast year relative to base year emissions. However, projection efforts generally do not account for the impact of control programs that require information that is not typically available. Two examples of these control program are New Source Performance Standards (NSPS) and Prevention of Significant Deterioration/New Source Review. For a NSPS, for example, information is not available on the proportion of future emissions in a given area that are affected by the standard. Similarly, a lack of data characterizing the emission reduction impacts of process changes that are not mandated by Clean Air Act programs (i.e., implementation of less costly production processes/technologies that yield a lower emissions rate per unit of output) has hindered efforts to model the effects of such changes in non-EGU stationary source emission forecasts.

In keeping with the recommendations of the Council, Pechan is currently performing analyses of non-EGU stationary point source emissions for a small set of LADCO region priority source categories. These analyses compare LADCO region emission activity changes between 1999 and 2005 to regional emission changes over the same period. For the LADCO priority categories, Pechan is compiling throughput data from LADCO States' 1999, 2002, and 2005 inventories and requesting that States QA the validity of both the 1999-2005 emissions and throughput trends. In cases where control programs are known to have impacted post-1999 emission rates, Pechan and the LADCO Stats are estimating the emission reduction impact of these programs so that their effects can be removed. Finally, comparisons are developed of the change in emission rate between 1999 and 2002 and 1999 and 2005. LADCO plans to incorporate forecast adjustments to account for cases where the historical data indicate enduring reductions in emissions per unit of activity for a give source category.

<u>Sample Emission Trend Analysis</u>

Figure 1 presents data for a hypothetical sample emission trend analysis on an index basis (1999 values = 1.0). This figure displays throughput, emissions, and post-1999 emissions after removing reductions from identifiable post-1999 controls. The solid top line represents the throughput trend for the category in the area of interest. The dotted bottom line presents the trend in actual NOx emissions, while the middle dashed line characterizes NOx emissions after removing the effect of known incremental post-1999 emission reductions (e.g., impact of NOx SIP call). The key element of interest is the difference between the trend in throughput and the trend in 'uncontrolled' emissions (i.e., emissions after removing known post-1999 reductions). For the example in Figure 1, the 2002 emission rate was 5 percent lower than the 1999 emission rate after accounting for known control programs. Similarly, an 8 percent unexplained emission rate reduction was observed between 1999 and 2005.

Figure 1. Sample emission trend analysis.



In lieu of information to the contrary, a reasonable assumption is to assume that persistent unexplained emission rate reductions will continue in the forecast period. In some cases, it may be possible to identify specific evidence supporting this assumption (e.g., existence of a NSPS). At a minimum, it will be useful to incorporate any significant unexplained emission trend adjustments into emission forecasting uncertainty analyses.

CONCLUSIONS

Because air quality standards continue to increase in stringency as the health effects of air pollution are better understood, and as time horizons of air pollution policies continue to expand (e.g., climate change), it becomes more important to refine our emission projection methods. Forecasting practitioners that ignore this reality may continue repeating past forecasting errors. The implications of overstating future emissions are considerable since they may result in implementing emission controls that are unnecessary for achieving air quality goals. Historical information is a valuable resource for identifying the need for such refinements as well as providing data to support these refinements. It is hoped that additional historical trend analyses will be performed after this study is completed. Such analyses serve to improve forecasting accuracy, and ultimately improve policymakers' ability to identify future emission control requirements.

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KEY WORDS

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