OTC Modeling Committee
Regional Modeling HEDD Workgroup
DRAFT Version 4.3
Summary Report
July 16, 2009

HEDD Workgroup formed under the request of the OTC Modeling Committee 3/17/09

Charge:
Determine, from a regional modeling perspective, what information/data is needed in order to perform modeling that more accurately reflects electric generation unit (EGU) emissions on high electric demand days (HEDD) and in a way that can isolate and apply emission adjustments specific to the sector.

Goals:
- Identification of HEDD units
- Model and assess the impacts from HEDD units
- Assess the benefits from emission controls to HEDD units

Starting questions:
- What data are needed/available?
- What form does the data need to take?
- Is CEMS data available or will we need temporal profiles?
- Is episodic modeling acceptable or is seasonal modeling the best approach?
- Are regional models the appropriate tool or are dispersion models better suited for estimating the impacts of HEDD Units? If dispersion models are preferable, how are the modeling results reconciled with the regional models?
- What special considerations are needed?
- Do we need to invite other group members to address these issues?
- What units should be considered to be HEDD units, i.e., how do we define an HEDD unit?
- Is the variability in daily emissions primarily due to changes in emissions from base loaded, load following or peaking units?

Summary Brief:
- Emissions during high electricity demand days can be considerably higher than on other days.
  - Peaking and load following units often have higher emission rates than other units.
  - Peaking and load following units often operate on days with already poor air quality.
- Standard emission modeling procedures, including CEMS reporting units, can do a poor job developing modeling input files representing actual emission conditions.
- There are techniques being applied or being considered, but none are considered standard.
  - These techniques require extra effort and precise attention to detail.
- Episodic screening modeling for base year 2007 is proposed for OTC ozone modeling.
- States are to identify their HEDD sources based on their own state definitions
- Methodology for projection of hourly emissions to future years is not yet fully developed.
  - A new version of IPM is not yet proven and would be expensive.

Discussion of starting questions:

- What data are needed/available?
  - Hourly (SMOKE-formatted) data are available from CAMD. It is our understanding that pre-packaged CAMD data sets in SMOKE format match what can be retrieved interactively through queries on the CAMD website.
  - State reported annual and ozone season emissions (NEI data) in IDA or ORL format
  - NEI to CAMD cross-walk
- What form does the data need to take?
  - Hourly information for all pollutants either measured or calculated
- Is CEMS data available or will we need profiles?
  - Even though hourly data from CAMD is available (note, this is both for CEMS and non-CEMS units, i.e. at some units the hourly emissions are calculated, not measured), we may need hourly profiles (here after referred to as estimated profiles) for units without a match in the cross walk as well as for new units that may show up in future year runs. Estimated profiles should reflect some temporal average that is suitable for planning purposes and not identified with an individual economic/meteorological condition. Estimated profiles rather than hourly data were utilized in the recent ozone and $PM_{2.5}$ modeling for the base and future year for attainment demonstration purposes. Thus, generation of estimated profiles for units with no hourly data is recommended as part of the current SIP modeling effort, if needed.
- Is episodic modeling acceptable or is seasonal modeling the best approach?
  - Since HEDD activities are episodic it seems logical to use an episodic approach. This suggestion and the approach on estimated profiles noted above, needs the consensus of the OTC modeling group. However, if seasonal modeling is to be performed as part of a HEDD effort, then it must be recognized that the analysis is reflective of only the HEDD meteorological events modeled and is not necessarily reflective of all possible HEDD dispatching scenarios that may need to be addressed.
- Are regional models the appropriate tool or are dispersion models better suited for estimating the impacts of HEDD Units? If dispersion models are preferable, how are the modeling results reconciled with the regional models?
  - It must be recognized that the HEDD is not limited to a single urban area, but is regional as the energy generation and dispatch is performed over the electric energy grid. Also, the EPA recommended the use of regional modeling approach for ozone and $PM_{2.5}$ given the multi-day nature of these pollutants and because the models are capable of estimating the appropriate background levels.
- What special considerations are needed?
  - Hourly data from CAMD needs to be carefully reviewed and reconciled with annual data before use in modeling. Units which do not report emissions outside the ozone season but do actually have emissions outside the ozone season need to be identified and strategies for the proper temporal allocation of emissions from these units need to be developed.
- Do we need to invite other group members to address these issues?
  - This is a policy issue that is to be addressed by the Air Directors. As it stands we have the participation of EPA regional staff on the OTC committees that are addressing the modeling issues.
  - Others have been invited to help address targeted issues, including staff from EPA OAQPS and LADCO.

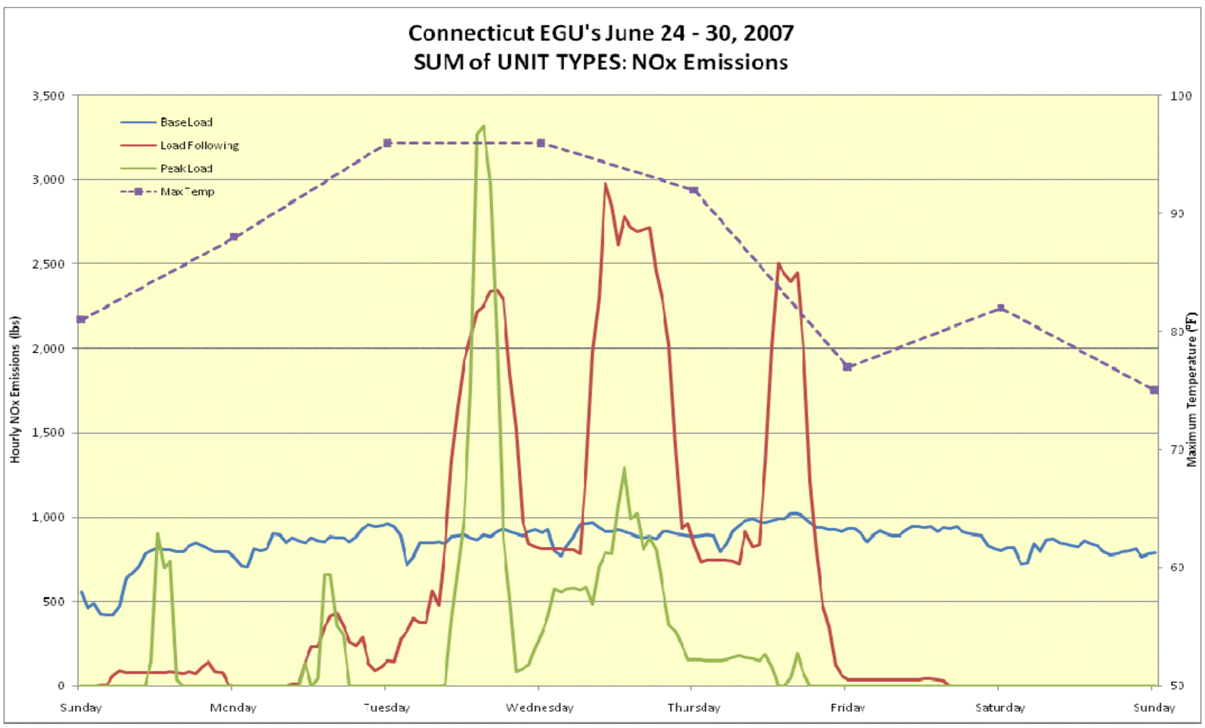
Findings Concerning Emissions:

Finding 1: The workgroup has identified at least general categories of generating units that add or potentially add to an increase in emissions on HEDD (described in qualitative terms):

A. major electrical generating units (boilers, combustion turbines)
B. distributed generation units

A) Major EGUs

The workgroup finds that load following boilers and peaking units (primarily combustion turbines) contribute significantly to total HEDD emissions of NOx. On some HEDD, emissions from these units may exceed those from base load units. In two cases (Wednesday and Thursday) shown in the graph below, load following units contributed more total NOx mass than peaking units. In one case (Tuesday) peaking and load following units contributed equally to total NOx mass. Because of the limited extent of this data (one week of data from one state), no conclusions can be drawn from this information. It is provided as an illustration only. Further study of other states and weeks is necessary to confirm this finding.

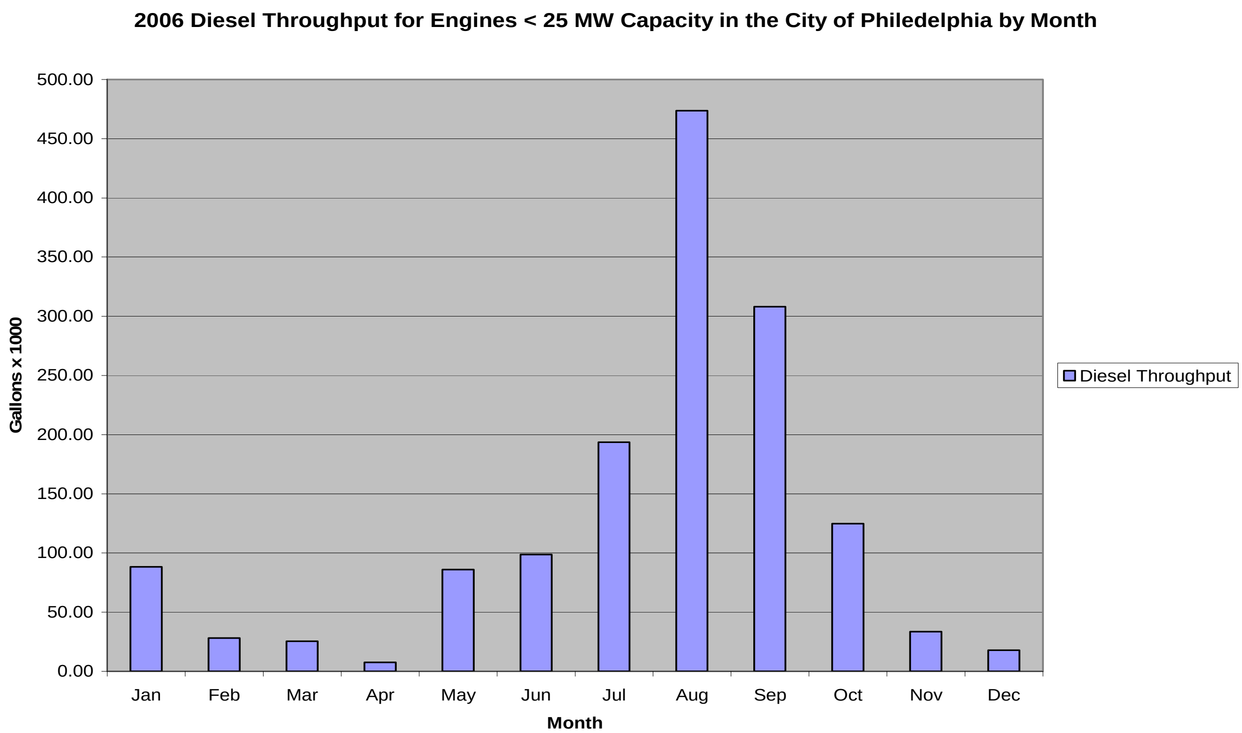


B) Distributed Generation Units

Distributed generation (DG) units are small, modular, decentralized, grid-connected or off-grid energy systems located in or near the place where energy is used.[1] Units used for distributed generation include diesel generator sets, microturbines, and fuel cells. These units are most frequently used during times of high electric demand.

Diesel generator sets are not only used during emergency periods but are also used during times when electricity rates (cost) are the highest (a practice commonly referred to as peak shaving) or to participate in a demand response program. Electricity rates are usually the highest and demand response programs are usually initiated on HEDD.

Diesel generation units in Philadelphia have shown usage patterns which appear to follow HEDD. Diesel generation emissions are estimated to be substantial in the southern portion of the OTR. DE, NJ, PA, and VA indicated that DG may be important peak day emission sources in their states.

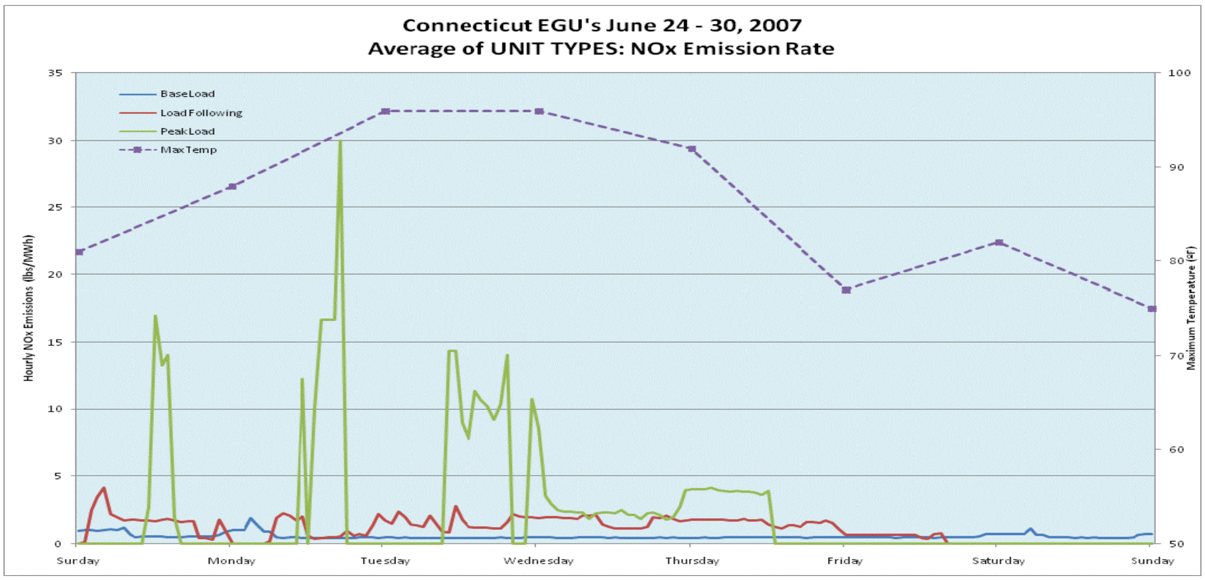


[1] www.epa.gov/greenpower/pubs/glossary.htm

Finding 2: Infrequently operated units usually have higher hourly unit NOx emission rates.

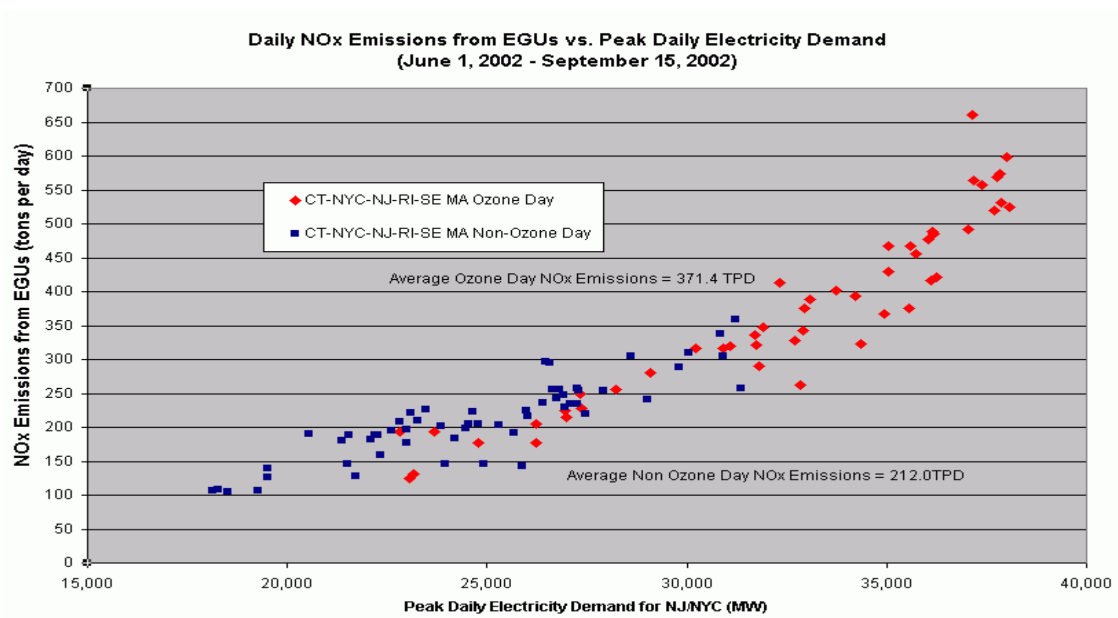
A) Major EGUs

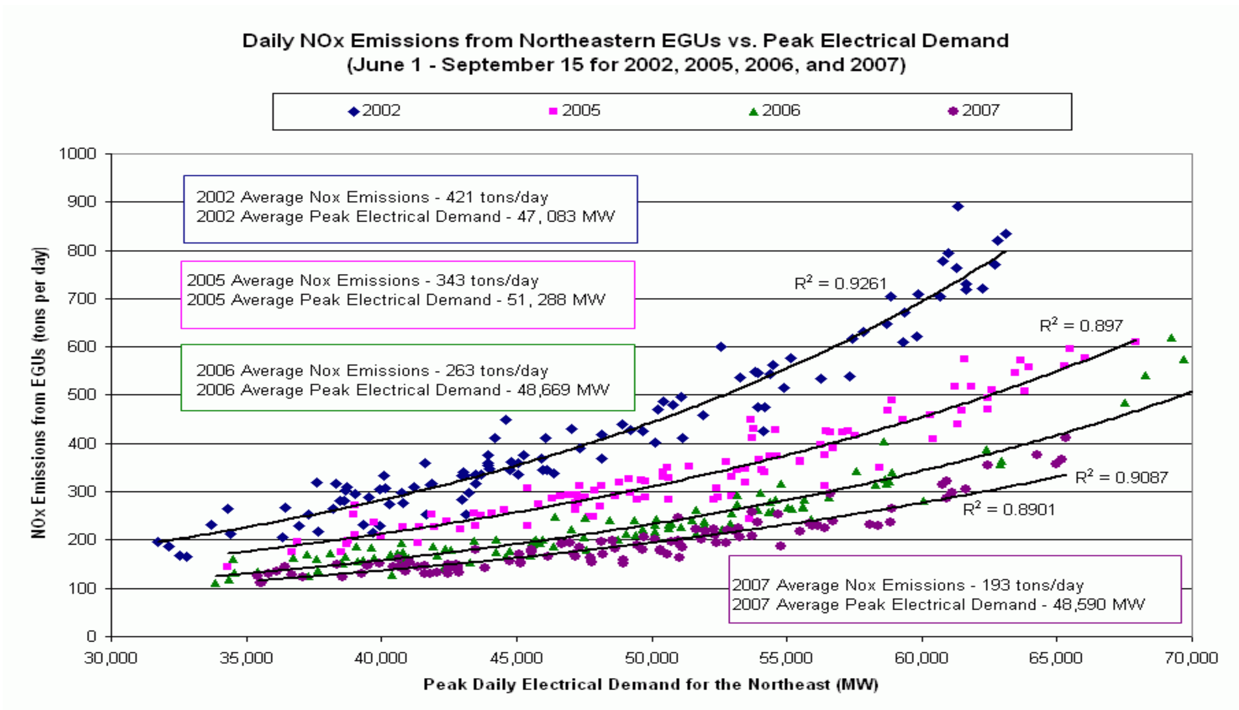
As shown in the following chart developed for Connecticut, load following??? units have two times emissions per heat input rate (lb/mmbtu) than base load units while peaking units have an order of magnitude higher emissions per heat input rate (lb/mmbtu) than base loaded units.



EGU emissions have been coming down in recent years, but emissions on peak days are roughly double average seasonal emissions (see following two graphs):

NOx Emissions Versus Peak Electricity Demand
on Ozone Days and Non-Ozone Days

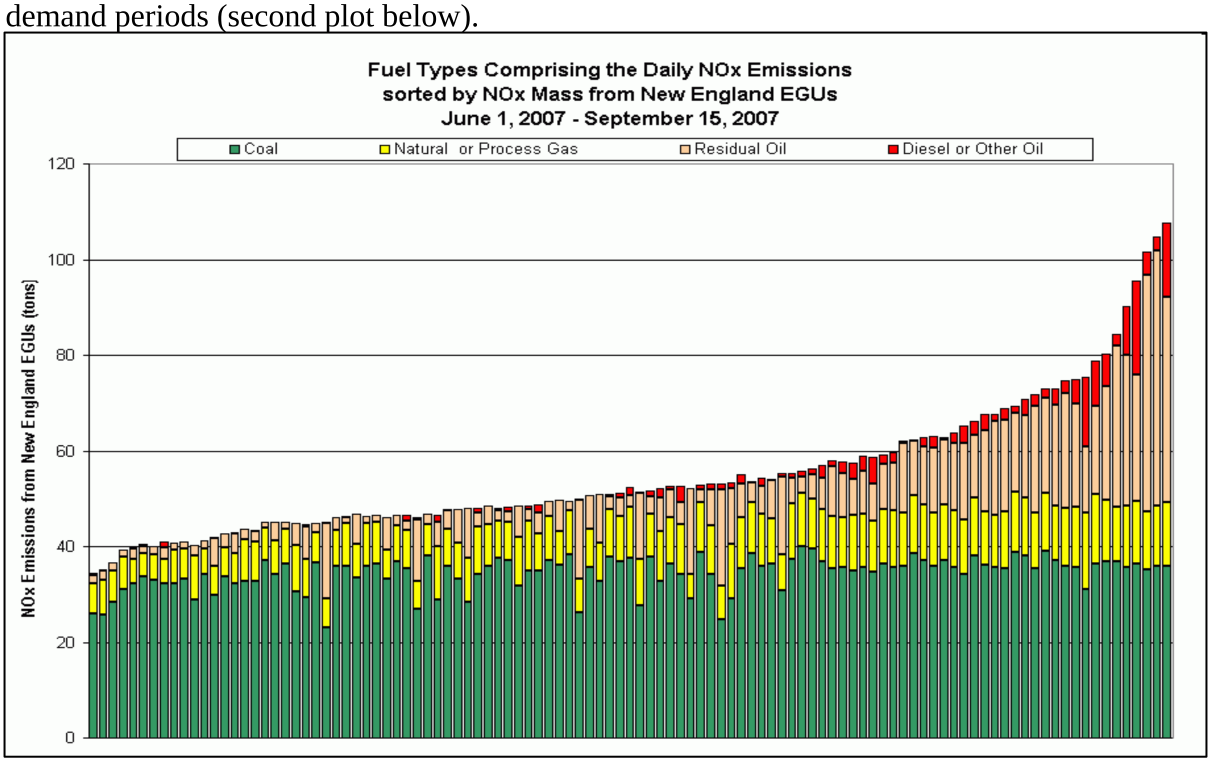


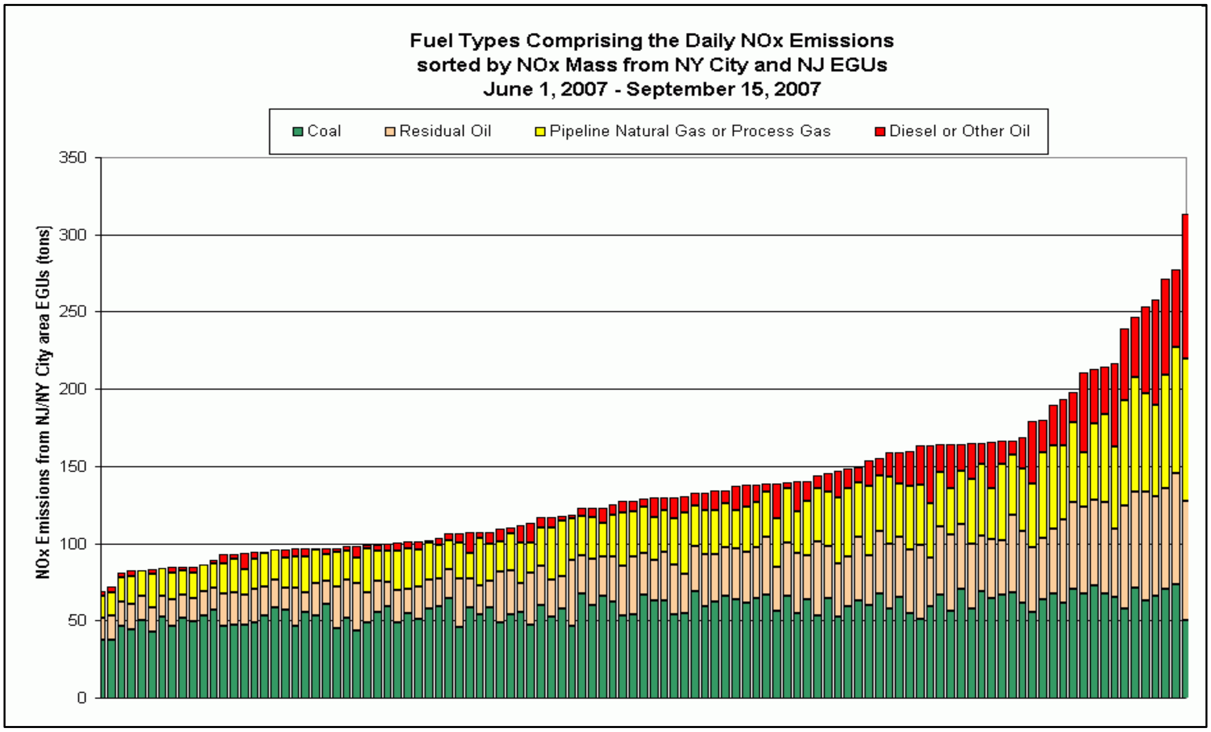


MW)

Finding 3: The fuel used by major EGUs during times of peak demand varies within the OTR region.

In New England, it is generally the residual oil and diesel based units that come online when electrical demand surges while natural gas usage only increases slightly with increasing demand (first plot below). In NY and NJ, however there is an increase in natural gas and diesel operation during peak demand periods (second plot below).



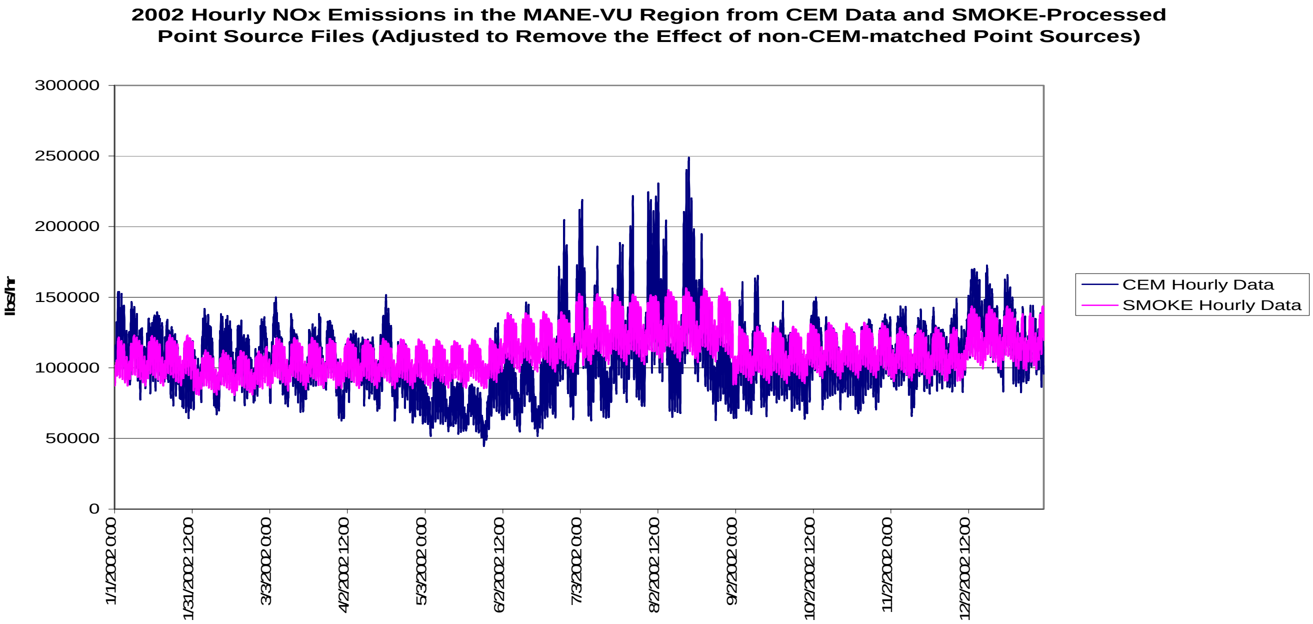


A) Major EGUs

<u>Overview</u>

Early attempts at modeling variable CEMS-based emissions has been labor intensive and fell short of fully accounting for all reported emissions. An earlier attempt with the MANE-VU 2002 modeling platform in 2004 through 2006 by MANE-VU reported the following:

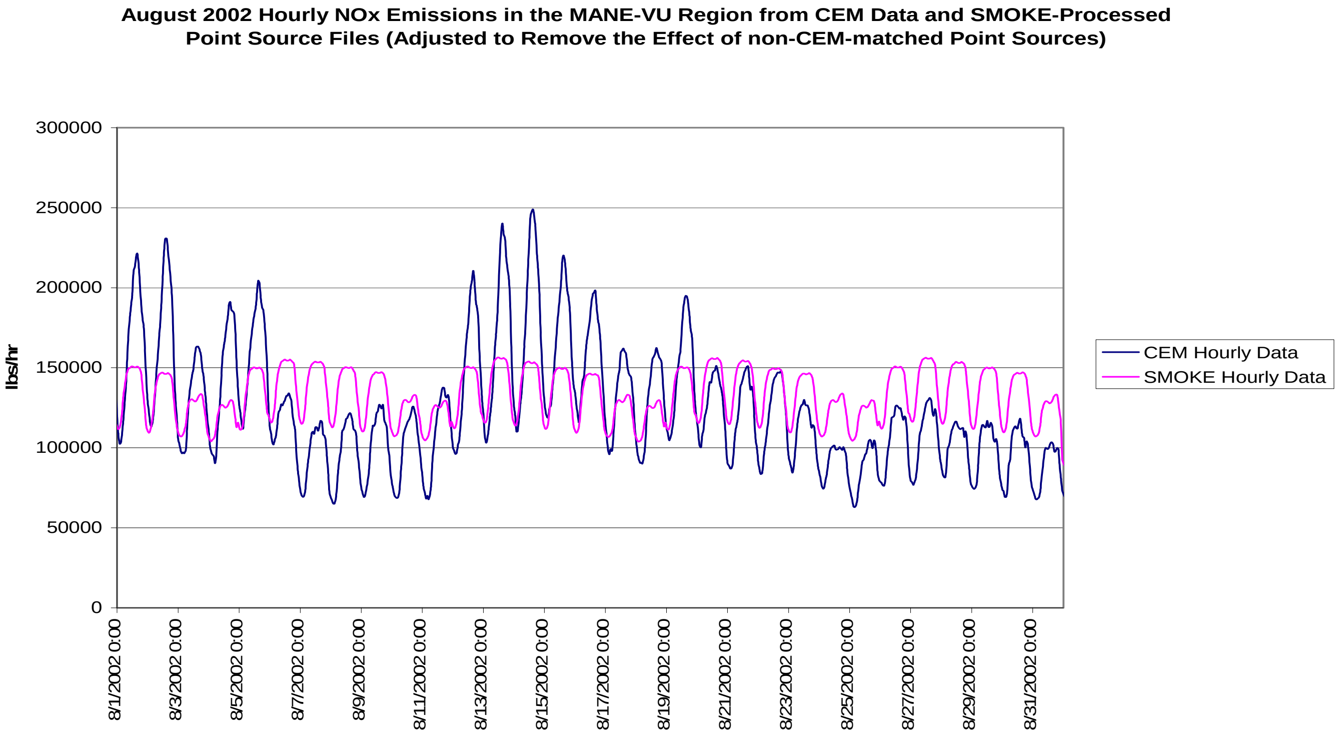
> *One particular issue was on how the temporal allocation of annual total emissions from electric generation units (EGU) should be treated. The standard approach in SMOKE is to apply month-of-year, day-of-week, and hour-of-day profiles to the annual emissions Given that some of these facilities operate the continuous emissions monitoring systems (CEMs), an alternate approach would be to override the temporal allocation for these sources in SMOKE by reading in the hour-specific data from the CEM database and matching them to the inventory data. This option was explored and several attempts were made to link the state supplied inventory information on EGUs by their ORISID to the CEMs data and often the matching was successful only to about 85% or so in accounting for emissions of NO_x over the domain. Similar efforts were made by the other RPOs, but not necessarily to a successful outcome in accounting for all of the emissions. Moreover, for the projected year there is no way to identify as to what the hourly emissions would look, given that the projection data are obtained from the IPM simulation which provides emissions information limited to the annual and summer seasons. Therefore it was decided after consulting with the OTC modeling committee to utilize the standard SMOKE approach and apply state-specific temporal profiles for allocation of emissions for both the base year 2002 and for the future year to maintain consistency in methodology. These state specific profiles were obtained from VISTAS who utilized 2002 CEMs data. Consequently, one would not expect to find close agreement between the SMOKE processed hourly point source emissions and CEMs data for individual days, especially not during episodes of high electricity demand due to hot weather which are not represented by the SMOKE temporal profile. However, on an annual total basis one would expect good agreement between CEMs data and SMOKE processed emissions for sources matched to the CEMs data since the CEMs data presumably was utilized by the states when the inventories were developed.*



In order to process emission inventories into modeling files, annual emission inventories are processed to temporally allocate emissions. The most commonly used emission processor, and the one used by the OTC modeling group, is the SMOKE model. SMOKE allocates emissions to established monthly, daily, and diurnal profiles. It is not currently designed to allow use of hourly CEMS data, however there is a module available, called CEMScan, which may be of some assistance to this process. CEMScan can read and incorporate a year's worth of unit specific hourly CAMD data and produce SMOKE readable files. The output from CEMScan is used by the SMOKE program Smkinven to allocate hourly CAMD emissions normalized to annual inventory data, NEI data.

How the emissions from these units are processed will affect modeling results. For example, CAMD hourly data shows significant NOx emission peaks on HEDDs. Processing with SMOKE emission default profiles underestimates those peaks and conversely overestimates emissions on cooler days. In the last SIP modeling exercise temporal profiles were developed by Alpine Geophysics. These profiles were based on total state generation rates in 2002. Because these profiles are the average for an entire state they do not capture short-term and local spikes in electric generation and the resulting spike in emissions. This problem is shown in the following chart of CAMD hourly emissions (blue) and SMOKE processed emissions using the state average profiles (pink). Much of the variability is lost.

If there is hourly emissions data available from CAMD why is annual data from the NEI incorporated into the hourly allocations? It is assumed that NEI is the 'gold standard' of emissions for SIP purposes. This may be EPA's way of tying the 'official' emissions into the modeling when incorporating temporal profiles based on CAMD data. The sum of the hourly CAMD data should be equal to the annual emissions reported to the NEI. However, this may not always be the case. Aberrant behavior is being investigated.



Some of these problems can be alleviated by selecting a limited period (an episode) for modeling. This reduces the amount of QA needed and the episode can be selected to avoid times of major outages or malfunction by sources. With this in mind, CAMD hourly data could be used by applying two utilities (CEMScan and Smkinven). CEMScan provides output data consisting of hourly data for NOx, SOx, Heat input, Gross load, and Steam load. Smkinven can then be used to read the CEMScan output file to estimate all other pollutants using the ratio of hourly to total annual heat input for each unit. If heat input is unavailable Smkinven will develop ratios based on steam load or gross load hourly to annual ratios.

Currently the tool that is used by the OTC modeling committee to process emissions inventories for use in photochemical model applications is the SMOKE processor. The emissions inventories are often developed by the state agencies, and this is a collaborative modeling work requiring information from both inside and outside the OTR, the data are assembled and processed through contractor support. Currently the SMOKE processor allocates annual emissions to a temporal basis of monthly, daily, and hourly utilizing facility profiles that are provided by the user. It was decided to utilize the EPA-CAMD archives EGU sector emissions on hourly basis along with other information as part of the NOx Budget Plan (NBP) and the acid rain program (ARP). However, there are limitations in terms of what data are collected under this process

NBP sources are often 25MW capacity or above, with some exceptions. Since, NBP sources report only for a six month period (May 1 through September 30), hourly data may not be available for the non-summer season. Also, there may be other sources that are below 25MW capacity but are EGUs, for which information is to be collected. Another aspect of the CAMD data is that there is no stack information, which is needed in model application, and this is often achieved by developing a cross-walk between the CAMD inventory and the state inventory.

Base Year

Before CAMD data can be readily applied for HEDD modeling, additional coordination and analysis is needed to develop an approach to handle units that only report 6 months of data to CAMD. A number of units are only required to report emissions to CAMD from May 1 though September 30, which complicates using the hourly data for these units since the CAMD hourly emissions are normalized to the annual NEI emissions. In these examples the annual NEI total would be significantly higher than what is reported to CAMD. This could lead an overestimation of emissions during the summer months.

Future Years

Projecting HEDD units provides unique challenges in that no current modeling tool in the common domain is designed to predict what units will exist to provide peaking capacity in future years. They may be the same units or economics might drive a different collection of units into the role. To date, there is no guidance on what to assume for projecting emissions for HEDD units, however something has to be assumed. We have discussed various options for projection of HEDD units including:

Option 1

Should episodic modeling of the base case year indicate that there is not a significant difference in peak ozone between the CAMD hourly modeling and the standard (but improved) SMOKE profiled modeling, then it may make sense to not alter the modeling process for typical ozone attainment modeling (Non HEDD specific assessment) and project emissions as the states have always done.

Option 2

Applying temporal profiles to HEDD units in future year modeling could be done in a straight-forward way. Since future year modeling utilizes the exact same meteorology as the base year, the same temporal profiles for that meteorology could be utilized, i.e. the same ones used in the base year modeling. However, instead of normalizing the hourly emissions to the annual or ozone season NEI emissions, they are normalized to the projected emissions. This approach should work whether an economic forecast model is used to derive future EGU operations or growth factors are used to project future emissions. Of course, if there are new units that are projected to start operation estimated profiles will have to be generated. In addition, ozone season emissions will have to be projected for EGUs.

Option 3

EPA has been working with a version of IPM (3.0) that has the new capability of producing hourly emission forecasts based on the CAMD hourly data set and the same economic parameters IPM has always used. This would produce a projected hourly data set ready for SMOKE emission processing. While this technique holds some promise, it could prove expensive since it is unproven in public application and could take several runs of differing inputs and assumptions before acceptable final results can be achieved.

Option 3A

Same as Option 3 but replaces IPM with other modeling tools.

Conclusion
It is believed that some of the problems discussed in this section can be alleviated by selecting a limited period (an episode) for modeling. This reduces the amount of QA needed and the episode can be selected to avoid times of major outages or malfunction by sources.

B) Other EGUs and Distributed Generation Units

Emissions data for almost all DG units are not included in the CAMD database and these create a special challenge for generating hourly emissions estimates. In such cases, fuel use records, load shadowing of similar nearby units and other techniques may be the only way to reconstruct meaningful estimates of emissions. An evaluation of the mass of emissions involved with such units should be weighed against the effort required to prepare the emissions for modeling to determine if the effort is worthwhile.

Including new sources like these obviously requires an estimate of the emissions, their locations (or a surrogate for that) and a way to temporal allocate them. If this data is not available, then there in fact is no way to include their impact in any meaningful way.

If the data is available and needs to be temporally allocated, then there are the following options:

- If the temporal allocation is known, then either SMOKE temporal profiles, day-specific emissions values, or hour-specific emissions values can be used to allocate emissions. Some custom software may need to be developed to create the day-specific or hour-specific emissions values. If that isn't possible, then temporal profiles must be used.

- For a temporal profile approach, there are a couple of options. If using emissions for every week of your modeling episodes is undesirable (which is what normally happens, even with the best temporal profile approach SMOKE can offer) then the following a typical approach can be used for processing in SMOKE. In the end, the previous approach might have taken less time and would be more robust (less prone to error).

  1) Decide if all of the days will use the same total emissions or not.
  2) If so, then get model ready emissions for one day. Use Mrggrid to merge in the emissions on the days that need these emissions. This needs to be done for the planned number of days of these emissions to ensure the annual emissions from these sources end at desired levels.
  3) If not, then a "typical month" approach needs to be used, where average-day emissions are created for each month and then merge in these month-specific emissions only on the days selected. Care must be exercised to make sure the emissions add up to the targeted levels for each month and for the year, since SMOKE wouldn't do that automatically for you (normally it would, but then it produces emissions on the same days in every week).

C) Modeling of Major EGUs Hourly Emissions by other Agencies

Methods used by other agencies, including EPA OAQPS, LADCO, and VISTAS, vary to a degree, but each has taken a fairly rigorous approach toward improving emissions modeling to better represent hourly variability compared to what SMOKE automatically produces. Each has produced a form of cross-walk, matching sources with CEMS data available to sources included in modeling files.

Generally, sources with CEMS data (within a state) are used to create emission profiles for non-baseloaded sources without CEMS data. The profile is then used for the nonCEMS units while actual CEMS data is used for sources that have it.

It is noteworthy that each separates actual base year operation data from typical operations as determined by multiple years of operations data. For example, in the base year one unit may be down for service while others pick up the load. The typical condition would include the downed unit and the other units would be assigned less load. This differential needs to be considered in any emission projection work.

While the details vary, each shares similarities of more accurately reflecting hourly emission variations. However, none of the approaches are designed to isolate unit by type for closer examination or to carefully handle the on and off nature of peaking units and the incomplete data that may come with them. None specifically identify HEDD units or separate them for source specific treatment.

During the Workgroup process, EPA OAQPS made suggestions for improving the emission modeling approach for HEDD analyses. The three key improvements identified include; 1). separation of ozone season CEMS data from non-ozone season data to help reconcile annual reported emissions with actual ozone season CEMS data, 2). spatial averaging to take into account power zones rather than state-level allocations and 3). averaging done by groups of units that fall into certain categories of temporal behavior, such as base load, load following, and peaking units.

EPA also recommends keeping the future-year approach consistent with the baseline approach. However, since the starting point for the emissions is summer and non-summer IPM emissions, the approach gets applied slightly differently. So, instead of annual-to-month allocation factors used in the baseline runs, the CEM data are used to compute summer-to-month and non-summer-to-month factors. This approach ensures that the summer and non-summer IPM emissions totals are the same before and after temporal allocation. Otherwise, the temporal allocation approach (from month to day and from day to hour) are the same as in the baseline approach.

Additional detail on the EPA and VISTAS approaches is provided in Attachments B and C respectively.

Workgroup Recommendations

Modeling:
In support of the next round of State Implementation Plans (SIPs), modeling the affect of EGUs on HEDD should be conducted for either the summer ozone season or for targeted episodes. The workgroup focused it's discussions around modeling 15 to 20 episodic (and spin-up) days during the summer of 2007. EPA Region 1 recommended episode modeling for June 27 and August 3, and in specific the period of June 24 through July 11. The primary focus of the effort will be on ozone, although changes in $PM_{2.5}$ will be noted. The suggested approach consists of four simulations:

1. 2007 base case using CAMD hourly data rather than monthly, weekly and diurnal profiles to allocate annual emissions
2. 2007 base using SMOKE monthly, weekly and diurnal profiles to allocate annual emissions. These profiles are to be developed from CEM data for one or more years at the state, ISO region, and/or unit level
3. 2007 run #1 (above) with all identified Major EGU HEDD units turned off
4. 2007 run #3 (above) with displaced capacity redistributed

The difference between runs #1 and #3 will provide an indication of the contribution of Major EGU HEDD units on air quality. The difference between runs #1 and #2 will provide information on the air quality response of the use of the improved hourly methodology profiles in the allocation of emissions.

MARAMA has asked states to identify units that are Major EGU HEDD units in their states. These units could be the ones selected for elimination in model run #3. The group does not have a suggestion for how run #4 emissions will be developed, but deems such a run may be needed to be realistic in replacing capacity removed in the modeling by artificially shutting down Major EGU HEDD units. Run #4 will be designed at a later date depending on the results of Runs #1-3, and could ultimately be a suite of runs consisting of various redistribution or control strategies.

Approach:
Create two separate annual inventory files, called "summer annual" and "winter annual". This is developed as follows:

Those units that have hourly values year-round would reflect the annual totals and should be in agreement between the CAMD and the State data. However, for those units that report only summer hourly values, the 'winter annual' is the difference between the CAMD summer total and the annual State data.

For processing the "summer" months, i.e. the months when all units are reporting, one could then use the "summer annual" file in conjunction with the hourly files. Because the sum of the hourly values matches the "annual" value and SMOKE sees that hourly values are missing for the rest of the year, all hourly values should be allocated correctly.

For processing the "winter" months, i.e. the months when some of the units have no hourly information, one needs to provide plant-specific seasonal profile or some suitable temporal profile for the allocation of these emissions. The other units would utilize the hourly data and since the 'annual values' are synchronized the emissions should be allocated correctly.

Approaches for projecting future years are not yet recommended by the workgroup.

Definition of HEDD Unit:
Key to runs 3 and 4 of this study is how HEDD units, major EGU and DG units are defined in the OTR. Because some states already have rules proposed or adopted with differing definitions, we recommend that this modeling effort not override existing definitions. We recommend that states be responsible for determining which units are to be defined as HEDD units. Other units not selected as HEDD will remain assigned as a regular EGU. For modeling purposes, we recommend that HEDD and DG units be binned into three categories during the state identification process. These bins will aide in future modeling sensitivity work as it may be requested. It is easier to bin the sources in the identification process than to return later and perform another source by source evaluation.

The three bins include:

HEDD1: EGUs with available CAMD hourly data
HEDD2: EGUs without available CAMD hourly data
HEDD3: Distributed generation units associated with peak day operation. These units may or may not be in the CAMD database because of their capacity. They are also likely to be found in states' area source inventories.

For inventory purposes, these bins can be subdivided based on fuel type or boiler design. Such subdivision would prove helpful in later analyses for potential control assessments.

HEDD2 and HEDD3 bins would need additional inventory work to estimate approximate operational patterns. Temperature and operational shadowing of other nearby HEDD units was discussed, but the workgroup leaves the details to the inventory groups to work through. Substantial quality assurance will be needed for each HEDD sector before data can be modeled with confidence. DG units need additional inventory work to estimate temporal operational patterns and where their emissions are accounted for in the inventory. Therefore, these sets may not be included in the initial modeling effort.

Emissions Preparation:
MARAMA is concluding an effort to prepare a crosswalk of CAMD and NEI point sources and ensuring stack parameters are reasonable. Quality assessment of the CAMD data is needed before using it in the model.

An episode must be selected that represents HEDD for the region. For hours in the selected episode, the following quality assurance must be evaluated:

1) Are all emissions units that report for only 6 month properly characterized in the inventory?
2) Were there major outages or upsets that resulted in atypical deployment of generating units or excessive emissions outside what is permitted?
3) What CEMS units were down or was data unacceptable and therefore filled by established conventions?
4) Did the ISO request deployment of distributed generation resources and what resources were deployed?

After evaluation of these questions a decision should be made of whether the selected HEDD episode has adequate emissions data for reliance in modeling.

The HEDD Subgroup proposes MARAMA conduct further emissions analysis and develop the necessary SMOKE input files for modeling. MARAMA would hire a contractor to perform several tasks:

Task 1: Prepare work plan and QAPP

Task 2: Episode identification

1. Identify one or more appropriate episodes for analysis (This analysis would address the factors identified in EPA guidance for selection of modeling episodes and would take into account meteorology, include periods of high ozone and fine particles in nonattainment areas in the region, and seek to avoid periods when CAMD data indicate that major units are not operating. Consideration of the operation status of HEDD units and transport patterns is also needed.)
2. Prepare technical report.

Task 3: Obtain and quality assure data

1. Download 2007 NEI annual and ozone season point source and 2007 CAMD hourly files
2. Develop information to address the three bins identified above
3. Develop state specific CEMS profiles for HEDD units (HEDD1) and non-HEDD units
4. QA data files
   - CEM data flags
   - Unit upset and outage reports
   - Request of ISO for DG deployment
   - Differentiate between actual 2007 HEDD operations and typical operations based on 3 to 5 years worth of data
5. Provide files for review by state and local agencies
6. Finalize emissions information

Task 4: Prepare input files and report

1. Prepare data in form for use in SMOKE
   a. Consider applying state emission HEDD profiles for HEDD2 and HEDD3 sources
   b. Consider applying state emission profiles for nonCEMS EGUs
2. Summarize data for use in SIPs and describe results in a technical report
3. Provide output files for use in CMAQ or other regional model
4. Provide detailed emission summary reports

In December, 2008, MARAMA issued an RFP and subsequently conducted a competitive process to select a contractor to assist in developing and/or updating regional emission inventories for the northeastern United States to support required modeling analyses, control strategy assessments, and other air quality management needs. The RFP stated, “The regional inventory will be used to concurrently address national ambient air quality standard (NAAQS) requirements for the new ozone and fine particle ambient standards and to evaluate progress towards long-term regional haze goals. Because similar pollutant emissions and atmospheric processes control chemical formation and transport of fine particles, ozone, and regional haze, similar technical analyses are necessary to evaluate air quality benefits of emissions controls. The emissions inventory will support a single integrated, one-atmosphere air quality modeling platform to support state air quality attainment demonstrations.” The RFP further stated, “Inventory formatting and documentation should be adequate to facilitate evaluation of the effectiveness of control measures for relevant pollutants, averaging times, and geographic scales." The RFP described sample work assignments to be used to evaluate proposals. The RFP stated, "Actual work assignments may differ from sample tasks, and work assignments will be negotiated on an as-needed basis within available funding."

As provided in MARAMA's *Contractor Selection Manual*, MARAMA worked with a committee of technical experts from the region to select a contractor from among the three who submitted bids in response to the RFP. The committee selected MACTEC as the contractor. MARAMA executed a contract agreement that provides for development of written work assignments. Each work assignment includes a budget and schedule for preparation of specific work products.

MARAMA would propose to use the existing contract with MACTEC as a vehicle for assigning development of an HEDD emissions inventory. MARAMA's current resources are insufficient to fund this task without the award of additional funding.

Recommended Future Emission Work

Distributed generation units associated with peak day operation will need additional inventory work to define the units, determine where their emissions occur in the inventory and estimate approximate operational patterns. Temperature and operational shadowing of other nearby HEDD units was discussed, but the workgroup leaves the details to the inventory groups to work through.

Issues to be Resolved

1. Funding
2. Intensive Q&A
3. Low end size limits have not been discussed for each bin
4. While this sensitivity study is focused on a 15-20 day period, what if anything should we say for the regular seasonal and annual runs?
5. OTR only vs. full domain?
6. Base year only vs. projected future years?
    a. If future year is required, what needs to be assumed for these units?
    b. Should they be assumed to be used exactly as in the base year or the same loads but with controls?

Attachment A
Distributed Generation Units Calculation Methodology

- Uncontrolled emission rates for a 0.5 MW (500 KW) unit:

12 grams NOx/bhp-hr (emission factor from EPA 453R/93/032, Table 2.1 and Table 2.8, the ACT for IC engines, the link for which is provided below and the tables are reproduced below) * 1bhp/0.75 KW*500 KW*(1lb/453g)=17.7 lbs/hr

Therefore, a facility with 3 MW of generating capacity (a small peak shaver, for example) would have uncontrolled emissions of approximately 106 lbs/hr NOx.

- Controlled emission rates for a 0.5 MW (500 KW) unit:

Assume SCR, for 90% NOx reduction, as noted in Table 2-8 of the ACT (see below):

1.2 grams NOx/bhp-hr (Table 2-8, see below) *1 bhp/ 0.75 KW*500 KW * (1 lb/453 g) = **1.8 lb NOx/hr**

Therefore, a facility with 3 MW of generating capacity would have controlled emissions of approximately 10.6 lbs/hr NOx.

Another method to calculate controlled emission rates would be to use the rates suggested for Tier 4 engines, the nonroad emission standard which comes into effect in 2011 or so for large generation sets. The full Tier data on the nonroad standards can be found at the following link. The data sets are located in Tables 3 and 4.

http://www.dieselnet.com/standards/us/nonroad.php#tier3 The standards here suggest a controlled emission rate of 0.4 gr NOx/KW-hr is possible, so that the controlled NOx rate from a 500 KW unit is as follows:

0.4 grams NOx/KW-hr * 500 KW * (1 lb/453 gr) = **0.44 lbs NOx/hr** A 3 meg facility would emit about 2.6 lbs NOx/hr.

Link to ACT: http://www.epa.gov/ttn/naaqs/ozone/ctg_act/199307_nox_epa453_r-93-032_internal_combustion_engines.pdf

EPA 453R/93/032 – Table 2-1

TABLE 2-1. AVERAGE HEAT RATES AND UNCONTROLLED NO_x EMISSION FACTORS FOR RECIPROCATING ENGINES

Engine size, hp	No of engines	Average heat rate, Btu/hp-hr[a]	Average NO_x emissions, g/hp-hr[a]	Average NO_x emissions, ppmv @15% O_2[b]	Average NO_x emission factor, lb/MMBtu[c]	Weighted average for each engine type[d]		
						NO_x, g/hp-hr	NO_x, ppmv @15% O_2[b]	NO_x, lb/MMBtu
RICH-BURN SI ENGINES								
0-200	8	8140	13.1	880	3.54	15.8	1060	4.64
201-400	13	7820	16.4	1100	4.62			
401-1000	31	7540	16.3	1090	4.76			
1001-2000	19	7460	16.3	1090	4.81			
2001-4000	10	6780	15.0	1000	4.87			
4001 +	2	6680	14.0	940	4.62			
LEAN-BURN SI ENGINES								
0-400	7	8760	7.9	580	1.99	16.8	1230	5.13
401-1000	17	7660	18.6	1360	5.35			
1001-2000	43	7490	17.8	1300	5.23			
2001-4000	30	7020	17.2	1260	5.40			
4001 +	25	6660	16.5	1200	5.46			
DIESEL ENGINES								
0-200	12	6740	11.2	820	3.66	12.0	880	3.95
201-400	8	6600	11.8	860	3.94			
401-1000	22	6790	13.0	950	4.22			
1001-2000	14	6740	11.4	830	3.73			
2001-4000	6	6710	11.4	830	3.74			
4001 +	6	6200	12.0	880	4.26			
DUAL-FUEL ENGINES								
700-1200	5	6920	10.0	730	3.18	8.5	620	2.72
1201-2000	3	7220	10.7	780	3.26			
2001-4000	5	6810	8.4	610	2.72			
4001 +	4	6150	4.9	360	1.75			

[a]Calculated from figures corresponding to International Standards Organization (ISO) conditions, as provided by engine manufacturers.

[b]Calculated from g/hp-hr figures using the conversion factors from Chapter 4.

[c]lb/MMBtu = (g/hp-hr) x (lb/454g) x (1/Heat Rate) x (1,000,000).

[d]Weighted average is calculated by multiplying the average NO_x emission factor by the number of engines for each engine size and dividing by the total number of engines. For example, for dual-fuel engines, the weighted average is calculated as:

$$[(5 \times 10.0) + (3 \times 10.7) + (5 \times 8.4) + (4 \times 4.9)]/17 = 8.5 \text{ g/hp-hr}$$

EPA 453R/93/032 – Table 2-8

TABLE 2-8. EXPECTED RANGE OF NO_x EMISSION REDUCTIONS AND CONTROLLED EMISSION LEVELS FOR CONTROL TECHNIQUES APPLIED TO DIESEL AND DUAL-FUEL ENGINES

Control technique	Average uncontrolled NO_x emission level[a]		Achievable NO_x reduction, %	Expected controlled NO_x emission levels	
	g/hp-hr	ppmv		g/hp-hr	ppmv
DIESEL ENGINES					
IR	12.0	875	20 - 30	8.4 - 9.6	610 - 700
SCR	12.0	875	80 - 90[b]	1.2 - 2.4	90 - 175
DUAL-FUEL ENGINES					
IR	8.5	620	20 - 30	6.0 - 6.8	430 - 500
SCR	8.5	620	80 - 90[b]	0.8 - 1.7	600 - 125
L-E	8.5	620	75	2.0[c]	150

[a]The uncontrolled emission rates shown are representative averages for diesel and dual-fuel engines. The actual uncontrolled emission rate varies from engine to engine.
[b]Guaranteed NO_x reduction available from most catalyst vendors.
[c]Guaranteed controlled NO_x emission level available from engine manufacturers.

DieselNet.com Nonroad Diesel Engines – Table 3

Table 3
Tier 4 Emission Standards—Engines Up To 560 kW, g/kWh (g/bhp-hr)

Engine Power	Year	CO	NMHC	NMHC+NO_x	NO_x	PM
kW < 8 (hp < 11)	2008	8.0 (6.0)	-	7.5 (5.6)	-	0.4[a] (0.3)
8 ≤ kW < 19 (11 ≤ hp < 25)	2008	6.6 (4.9)	-	7.5 (5.6)	-	0.4 (0.3)
19 ≤ kW < 37 (25 ≤ hp < 50)	2008	5.5 (4.1)	-	7.5 (5.6)	-	0.3 (0.22)
	2013	5.5 (4.1)	-	4.7 (3.5)	-	0.03 (0.022)
37 ≤ kW < 56 (50 ≤ hp < 75)	2008	5.0 (3.7)	-	4.7 (3.5)	-	0.3[b] (0.22)
	2013	5.0 (3.7)	-	4.7 (3.5)	-	0.03 (0.022)
56 ≤ kW < 130 (75 ≤ hp < 175)	2012-2014[c]	5.0 (3.7)	0.19 (0.14)	-	0.40 (0.30)	0.02 (0.015)
130 ≤ kW ≤ 560 (175 ≤ hp ≤ 750)	2011-2014[d]	3.5 (2.6)	0.19 (0.14)	-	0.40 (0.30)	0.02 (0.015)

a - hand-startable, air-cooled, DI engines may be certified to Tier 2 standards through 2009 and to an optional PM standard of 0.6 g/kWh starting in 2010
b - 0.4 g/kWh (Tier 2) if manufacturer complies with the 0.03 g/kWh standard from 2012
c - PM/CO: full compliance from 2012; NOx/HC: Option 1 (if banked Tier 2 credits used)—50% engines must comply in 2012-2013; Option 2 (if no Tier 2 credits claimed)—25% engines must comply in 2012-2014, with full compliance from 2014.12.31
d - PM/CO: full compliance from 2011; NOx/HC: 50% engines must comply in 2011-2013

DieselNet.com Nonroad Diesel Engines – Table 4

Table 4
Tier 4 Emission Standards—Engines Above 560 kW, g/kWh (g/bhp-hr)

Year	Category	CO	NMHC	NO_x	PM
2011-2014	Generator sets > 900 kW	3.5 (2.6)	0.40 (0.30)	0.67 (0.50)	0.10 (0.07)
	All engines except gensets > 900 kW	3.5 (2.6)	0.40 (0.30)	3.5 (2.6)	0.10 (0.07)
2015	Generator sets	3.5 (2.6)	0.19 (0.14)	0.67 (0.50)	0.03 (0.022)
	All engines except gensets	3.5 (2.6)	0.19 (0.14)	3.5 (2.6)	0.04 (0.03)

Attachment B
EPA OAQPS Hourly Methodology

EPA OAQPS approaches for temporal allocation of "EGUs" for modeling

EPA's Office of Air Quality Planning and Standards (OAQPS) has used a specific methodology for base and future-year temporal allocations for both its 2002 and 2005 modeling platforms. This approach is divided into three parts: (1) model performance evaluation and (2) baseline runs for Relative Response Factor (RRF) calculations, and (3) future-year runs (also for RRFs). These approaches affect OAPQS's sector called "ptipm", which represents all of the sources that it has been able to match from the base-year inventory to the units included in the IPM model. These units are primarily electric generating utilities (EGUs), but also include co-generating units at industrial facilities.

For model performance evaluations, OAQPS uses the hourly Continuous Emissions Monitoring (CEM) data for NOx, SO2, and heat input to allocate the annual emissions from the National Emission Inventory (NEI). Since the CEM data do not contain stack-level details (such as stack characteristics and coordinates) needed for air quality modeling, it is necessary to map the unit-level data from the CEMs to the individual stacks and processes in the NEI for allocating those emissions. To do this, OAQPS uses CEM hourly NOx to allocate NOx emissions, CEM hourly SO2 to allocate SO2 emissions, and CEM heat input to allocate all other pollutants from those units. There are some units in the ptipm sector that are not CEMs. For these units, OAQPS uses the same approach as is used in the baseline approach, described next.

For the baseline approach, the same annual NEI emissions are allocated using allocation factors that are averaged across multiple years of CEM data. There are three parts to this allocation: year-to-month, month-to-day, and day-to-hour. The averaging approaches help to alleviate potential problems caused by unplanned downtime at some facilities for any given year, month, or facility. For the year-to-month allocations, the CEM data are used to create state-specific allocation factors by averaging three years of CEM data, with the base year for modeling the central year of the three. For example, the three years for a 2005 baseline are 2004, 2005, and 2006. CEM emissions are summed by month and state across the three years, and the allocation factors are created by dividing these sums by annual sums by state across those same years. As with the model performance run, the NOx data are used to create NOx-specific profiles, the SO2 data is used to create SO2-specific profiles, and the heat input is used to allocate all other pollutants.

Also for the baseline approach, the month-to-day factors are computed using CEM data from only the base year of interest, but the factors are still create by state. For a 2005 baseline, the 2005 CEM data would be used. The sum of the CEM emissions in 2005 for the state is computed by day and the factor is the sum by day and state divided by the sum by month and state. The same approach is used with the NOx CEM data allocating NOx, the SO2 CEM data allocating SO2, and the heat input data allocating all other pollutants.

Finally for the baseline approach, the day-to-hour factors are computed using 3 years of CEM data to compute state-specific day-to-hour profiles. For the modeling done by OAQPS, the hourly allocation was less critical than for HEDD modeling. In this approach, the annual CEM data are averaged for each hour of the day by state across the three years of CEM data and then divided by the daily average by state across the three years. The NOx CEM data allocate the NOx emissions, the SO2 CEM data allocate the SO2 emissions, and the heat input CEM data allocate all other pollutants.

EPA OAQPS has already identified improvements to these approaches. There are two key improvements. First, the spatial averaging could take into account power zones rather than state-level allocations. Second, the averaging could be done by groups of units that fall into certain categories of temporal behavior, such as base load, load following, and peaking units. In addition, other improvements may be needed for better support of HEDD control evaluation.

Finally, for the future-year approach, the primary goal was to keep consistent with the baseline approach. However, since the starting point for the emissions is summer and non-summer IPM emissions, the approach gets applied slightly differently. So, instead of annual-to-month allocation factors used in the baseline runs, the CEM data are used to compute summer-to-month and non-summer-to-month factors. This approach ensures that the summer and non-summer IPM emissions totals are the same before and after temporal allocation. Otherwise, the temporal allocation approach (from month to day and from day to hour) are the same as in the baseline approach.

To implement the model performance case, EPA uses the SMOKE model that supports using the CEM data directly. For the non-CEM sources in the ptipm sector, EPA creates day-specific data files for input to SMOKE uses custom software tools. These tools are also used to create day-specific SMOKE inputs for the baseline and future-year cases, which apply the annual-to-month (or season-to-month) factors and the month-to-day factors by state and pollutant. The day-specific emissions are fed to SMOKE as an input inventory, and SMOKE applies the day-to-hour factors.

DETAILED INFORMATION

2002-based Platform: Methodology for temporal allocation of ptipm sector data for evaluation (2002aa) and average year (2002ba) case.

I. 2002aa_cembased - model performance methodology

For 2002aa, the ptipm sector temporal allocation will include

A) 2002 CEM data for sources in the 2002 NEI ptipm sector that match 2002 CEM data
B) Precomputed daily emissions derived from sources in the 2002 NEI ptipm sector do not match 2002 CEM data.

The matching of 2002 NEI ptipm sources to 2002 CEM data is done by SMOKE (within Section A below) which utilizes the ORIS facility and BOILER IDs in the ORL file. (ORIS_BOILER_ID & ORIS_FACILITY_CODE)

A. Use Hourly CEM data emissions for sources in ptipm that match CEM

CSC will input the 2002 CEM data (which they already have) with ptipm sector into SMOKE. CSC will be using the Cemscan utility program and the Smkinven program with the option to read the hourly and day-specific inventory files.

This process will ensure that the hourly CEM data are used for all sources matching the CEM data. The SO2 and NOX CEM emissions will be used directly from the CEM data file and the heat input will be used to allocate all other pollutants, including mercury pollutants in the hg_ptipm sector and the other HAPs (however, for the shakeout, we will not be processing the Hg and other HAPs).

Key issues for CSC to check are that all CEM data are matched to sources in ptipm sector and that for each source that matches, the CEM hourly NOX and SO2 values sum to the same NOX and SO2 annual values provided ptipm sector file. CSC will use the report generated by the Cemscan program to help with this task.

B. Develop and use of pre-computed daily emissions for sources in ptipm that do not match CEM

For sources not matching the CEM data, we will be using precomputed daily emissions that will be created by CSC. The daily-to-hourly allocation will be performed by SMOKE using hourly profiles by state based on the 2002 CEM data averaged over the whole year into a single hourly profile for each state. The daily emissions will be created by applying to the annual data temporal profiles (as described next) to go from annual to month and then from month to day. The temporal profiles will be created outside of SMOKE using the CEM data.

1. Create monthly temporal profiles that will allow computation of day-specific emissions from the annual emissions in ptipm (outside of SMOKE)

- Create State-specific monthly temporal profiles based on 2001, 2002, and 2003 CEM data. Note that the 2003 CEM data is in a different format than the CEM data for the other years. CSC will re-format (eventually, all years will use new format, but for now we will use older format) The monthly profiles will be based on the average of 2001, 2002, and 2003 CEM data for each month. There will be NOx profiles used for NOx, SO2 profiles for SO2, and "all other" profile developed from the CEM heat input data. They will not be SCC-specific and will be applied to all ptipm sources (other than those in Section A) based on state and pollutant.

Internal SQL code was written to generate month-to-day emissions (item 3, 2nd bullet). Guidance/steps for generating these are not available.

2. Create diurnal profiles that will allow be used in SMOKE to temporally allocate the day-specific emissions

- Create state-specific diurnal profiles based on the 2002 CEM data by summing for each of 24 hours, the emissions of all EGUs for each month in each state and dividing by the number of months*EGUs for that hour to get an average hourly value. Then normalize to compute an hourly diurnal profile. NOTE: the CEM data hourly time stamps are in local time, so there is no need to shift the hourly data before making this computation, since hourly profiles must also be in local time and SMOKE will adjust them to GMT when they are applied.

Here is the guidance and steps based on what was done for the 2001 platform.

THREE SETS OF STATE-SPECIFIC DIURNAL PROFILES NEED TO BE CREATED BASED ON THE HOURLY STATE SPECIFIC CEM DATA FOR THE YEAR 2002

1. load data by month. Each month is a 49*24 matrix (49 states * 24 hours)
2. sum across all hours for each state and for each month
3. Get percent of total for each hour (diurnal profile) for each month
4. average (mean) across the 12 months
5. Renomalize the %s by the total percent (which should be close to 1) since there may be rounding errors in the averaging. Convert the profiles from fractions to integers for the SMOKE format by multiplying by 1000 or 10000.

6. Assign hourly profile IDs that do not overlap any other IDs, by State. Pick a set of unique numbers that has the state code as the last 2 digits e.g., for NOX, 32001 thru 32055, for SO2, 33001 thru 33055 and for heat input 34001 thru 34055.
7. Then make sure the field width is accurate and export to the SMOKE format for the /WEEKDAY DIURNAL/ and /WEEKEND DIURNAL/ packets. Please remember to add to both packets.

A PTIPM-SPECIFIC TEMPORAL CROSS REFERENCE THAT HAS ONLY THREE ENTRIES PER STATE HAS TO BE CREATED

1. Monthly and weekly profiles set to uniform profile IDs since these will be ignored -can keep previous monthly and weekly temporal profiles in 2001 platform for ptipm
2. NOX-specific put into xref as state-polllutant specific; SO2-specific as state-pollutant specific and Heat input is the overall default (zero for SCC, state code filled in, and county code is zero). Could probably use current xref and change the profile codes.

3. Create day-specific emissions, in SMOKE-ready day-specific format

- Create monthly emissions by applying the monthly temporal profiles created in step 1 above to the annual emissions. (This step does not use SMOKE)

- Compute day-specific emissions from monthly emissions using 2002 CEM data only, by state and by pollutant (NOX, SO2, or other).

Internal SQL code was written to do this, but needs revision to include computation of the monthly temporal profiles and diurnal temporal profiles.

- If 2002 does not have any CEM data for a state for a given month (but does have emissions in the nonCEM part), then the monthly-to-daily allocation will be uniform for that month. This case can happen when the 3-year monthly profiles put emissions into a month, but for the year-specific monthly-to-daily data, there were actually no emissions in that month.

Internal SQL code handles this.

4. Process day-specific ptipm emissions through SMOKE

When running SMOKE, CSC will use the Smkinven program with the options for reading the hourly and daily data files created in step 3, above. When running the Tempoeal program, CSC will use the settings to use the hourly and daily intermediate files. The run script will also be configured to use the diurnal profiles created in steps 3, above.

ADDITIONAL NOTES:

The CEM data will include additional fields that should be ignored as follows:

In all cases, the difference between data that is “filled in” versus measured will be ignored. Additionally, data from facilities that are shut down is not dropped, but the 3-year averaging approach for the monthly profiles partially accounts for this.

II. 2002ba- “average year” methodology

- All sources will get the approach described above for non-CEM sources (Section B)

III. 2010ba (using 2002 platform) - Future-year methodology

- All sources will get the approach described above for non-CEM sources; however, the calculation will be different because data are provided as summer average-day and winter average-day.

The logic and formulas needed for this approach are as follows:

If month ≥ May and month ≤ September:
Emissions$_m$ (tons/month) = annualized_summer_emissions * (5/12) * summer_monthly_fraction$_m$

Otherwise:
Emissions$_m$ (tons/month) = annualized_winter_emissions * (7/12) * winter_monthly_fraction$_m$

Where:
m = month of the year

Annualized_summer_emissions = the emissions value in the summer SMOKE input file from post-processed IPM data provided by CAMD

Annualized_winter_emissions = the emissions value in the winter SMOKE input file from post-processed IPM data provided by CAMD

summer_monthly_fraction, $$f_m = \frac{D_m}{\sum_{n=May}^{September} D_n}$$

winter_monthly_fraction, $$f_m = \frac{D_m}{\sum_{n=January}^{April} D_n + \sum_{n=October}^{December} D_n}$$

Where:
D = NOx monthly CEM fractions for allocating NOx emissions,
SO2 monthly CEM fractions for allocating SO2 emissions,
Heat input monthly CEM fractions for allocating CO, VOC, PM10, PM2.5, and NH3 emissions

The above formulas provide the monthly emissions for all pollutants. Using this information, the same approach is used to allocate the monthly emissions to day-specific emissions as were used for the base year. Namely, we apply monthly-to-daily emissions factors using 2002data only by state. The NOx data are used for the NOx emissions, SO2 data for the SO2 emissions, and Heat Input for all other pollutants.

NOTE: this approach will require post-processing the IPM data from CAMD each time we get a new dataset. This step will need to be automated by CSC.

Attachment C
VISTAS Hourly Methodology Select Portions of:

Draft Final Report

Technical Support Document for VISTAS Emissions and Air Quality Modeling to Support Regional Haze State Implementation Plans

November 14, 2007

2.2.1 Processing of Point Source Emissions

Stack parameters are often more important to the reliability of the air quality modeling results than the emissions rates themselves. Stack parameter data are frequently incorrect, especially in some of the current regional modeling inventories and careful QA is required to assure that the point source emissions are properly located both horizontally and vertically on the modeling grid. To screen for simple, but potentially serious inventory errors such as these, the study team has modified procedures originally developed by EPA[3] to quality assure, augment, and where necessary, revise, stack parameters to examine the accuracy of the point source emissions, as well as standardize procedures to identify and correct stack data errors. These procedures were implemented in the NIF to IDA conversion step of the inventory development. Additionally, SMOKE has a number of built-in QA procedures designed to catch missing or out-of-range stack parameters. These procedures were also invoked in the processing of the point source data.

For the final baseline modeling, we separated the point source emissions into EGU and non-EGU categories. The non-EGU category was not processed using any day or hour-specific emissions inputs. All non-EGU point source emissions were temporally allocated to month, day, and hours using annual emissions and source category code (SCC) based allocation factors. These factors were based on the cross-reference and profile data supplied with the utilized SMOKE version and were supplemented with relevant data provided to the study team by VISTAS and its contractors.

For EGU sources with EPA reported continuous emissions monitoring (CEM) data for 2000-2004 or with hourly emissions provided by stakeholders, actual hourly data were used. For those sources where EPA CEM data are utilized, NOx, SO2, and heat input-based hour-specific profiles were developed and applied to NOx, SO2, and all other emissions, respectively. This ensured that the annual emission values provided by the EI contractor were maintained, but distributed using hourly to annual profiles. For sources providing hour-specific data and where they were approved by the State in which they operated, those data were substituted for EPA CEM-based emissions and distributions.

To temporally allocate the remaining EGU point sources (those which do not report under the CEM program), the NOx, SO2, and heat input data were collected from the 2000-2004 CEM datasets, and used to develop unit-level typical temporal distributions. CEM data from 2002 were used to develop comparable profiles and emission distributions during the actual 2002 model validation runs. The hour, day of week, and monthly specific temporal profiles were used in conjunction with the EI supplied emissions data to calculate hourly EGU emissions by unit.

All point sources were spatially allocated in the domain based on the stationary source geographic coordinates. If a point source was missing its latitude/longitude coordinates and data could not be found to properly site the unit within the domain, the source was placed in the center of its reported county.

3 ftp://ftp.epa.gov/EmisInventory/2002finalnei/documentation/point/augmentation_point/2002nei_qa_augmentation_report0206.pdf

2.3.1 Temporal Allocation

VISTAS 2002 and 2018 annual emissions modeling were configured to generate point, area, nonroad mobile, on-road mobile, and biogenic source emissions. In addition, certain subcategories, such as fires and EGUs were maintained in separate source category files in order to allow maximum flexibility in producing alternate strategies. With the exception of biogenic and on-road mobile source emissions that are generated using the BEIS and MOBILE6 modules in SMOKE, pre-computed annual emissions were processed using the month, day, and hour specific temporal profiles of the SMOKE model. Area and nonroad sources were modeled as a block of Thursday, Friday, Saturday, Sunday, and Monday one per month (total of 60 days modeled). On-road motor vehicle sources were modeled for one seven-day week per month.

Point sources and biogenics were modeled for each day of the annual period.

VISTAS based its temporal profiles and source category cross-reference files on the EPA CAIR/CAMR/CAVR modeling platform with files located on EPA's CAIR file transfer website[6]. Modifications were made to reflect State specific profiles or updated state of knowledge application of these profiles. Some of these changes included the reallocation of North Carolina NONROAD generated emission categories to a regional set of temporal profiles more consistent with the operation of these source types in the State. Additionally, EGU CEMbased temporal profiles and onroad emissions modeling were prepared in manners deviating from EPA's original CAIR platform.

As noted previously, on-road mobile modeling in SMOKE was done for selected weeks (seven days) of each month - using these days as a "representative week" of the entire month. This selection allows for the representation of day-of-the-week variability in the on-road motor vehicles, and models a representation of the meteorological variability in each month. VISTAS executed sensitivity tests to examine this "representative week" methodology versus an everyday on-road mobile modeling method[7]. VISTAS determined that the use of representative week onroad mobile emissions produced ozone and particulate matter concentrations (and thus regional haze) that were nearly indistinguishable from the "everyday" mobile method. VISTAS determined that the difference in the modeled air quality - resulting from the on-road mobile modeling methods - was insignificant.

2.3.1.1 CEM-Based Temporal Profile Development and Application

Two sets of monthly profiles were developed for processing EGU emissions with CEM data:

1. Profiles based solely on actual 2002 CEM-based data at the state level. The 2002-only profiles are intended to be used by VISTAS in developing model performance evaluation metrics necessary for configuring air quality models in attainment demonstration analyses.

2. Profiles based on historical averages of 2000 through 2004 CEM-based data. These historical 2000-2004 average profiles were developed and are recommended to be used to represent consistent "typical" operating conditions at EGUs in the VISTAS domain for the base year and future year emission estimates.

6 ftp://www.airmodelingftp.com/
7 http://www.epa.gov/ttn/chief/conference/ei15/session9/abraczinskas.pdf

Analyses conducted by the modeling team[8] indicate an added benefit to the modeling results with the application of CEM-based day-of-week and diurnal profiles, in addition to the monthly profiles for each state. As part of this analysis, specific day-of-week (Monday, Tuesday, Wednesday, etc.) and diurnal profiles were developed for each month and State to better represent operating conditions at units within each State. The day of week and diurnal profiles were developed from averages of CEM-based emissions and heat input activity occurring on that day-of-week or during that hour-of-day.

These profiles are intended to be applied to units were CEM matches cannot be made to VISTAS emission inventories.

Data Obtained

Five years (2000 through 2004) of hourly CEM information from EPA's CAMD website were obtained for each unit in the VISTAS states[9]. The "Prepackaged Data" option allows the download of files containing emissions data for a specific state, quarter or month, and year. Each prepackaged data file is in .csv (comma delimited) format and contains the following fields:

State, Facility Name, Facility ID (ORISPL), Unit ID, Date, Hour, SO_2 Emissions (lbs), CO_2 Emissions (tons), NO_x Emissions Rate (lb/mmBtu), NO_x Emissions (lbs), Heat Input (mmBtu), Operating Time (hours), Gross Load (MW), and Steam Load (1000 lb/hr).

For this analysis, we obtained the prepackaged monthly unit-level hourly emissions data by state and year. Using these data, we reformatted the files and quality assured for applicability to this analysis.

File Contents

The reformatted files were prepared as identified in Table 2-2.

Quality Control / Quality Assurance

Each file was reviewed to determine if NOx, SO2 and heat input values were represented for each hour of every day for each unit in the obtained data. Zero values were considered to be valid if operating time identifiers indicated no operation during that hour (e.g., data value of zero but operating hours greater than zero).

Using the measurement flags and field values in the reformatted files, numerous spot checks were made of anomalous or missing variable data to ensure that data corruption was not impacting the statistical analyses. Additionally, each year's hourly total of NOx, SO2, and heat input (per state) were summed and compared to EPA annual summaries of the same data elements.

When there were facilities or units with no emissions data or unit characteristics, we verified that these sources are not required to report emissions data or had not yet reported emissions data to EPA. In some cases, certain months or quarters of the year were blank for individual units or facilities and using EPA data caveat reports, we verified these units were not in operation during those times.

8 http://www.epa.gov/ttn/chief/conference/ei14/session11/stella.pdf
9 http://cfpub.epa.gov/gdm/index.cfm?fuseaction=prepackaged.select

Inventory Matching

Prior to the development of the unit-specific SO2, NOx, and heat input ratios for each hour, the step of matching CEM units to the VISTAS 2002 modeling inventory started. Because naming convention and facility or unit numbering can be unique at the Federal, State, local, or facility level, the step of matching existing units from an emissions inventory to the CEM data base proved to be more complicated than anticipated.

The VISTAS EGU emission inventory accounted for approximately 3.7 million tons of SO2 and 1.5 million tons of NOx in calendar year 2002. There were 861 units reporting to the CEM database in 2002 for the ten VISTAS States. The primary objective of the inventory matching steps was to account for as many units and tons as possible allowing for the unit-specific application of hourly temporal distribution profiles.

Table 2-2. CEM data file format.

Column	Description
State	State in which the facility is located.
Facility Name	The name given by the owners and operators to a facility.
Facility ID (ORISPL)	The unique six-digit facility identification number, also called an ORISPL, assigned by the Energy Information Administration, a component of the Department of Energy.
Unit ID	Each unit at a facility has a unique identification number. It is alphanumeric and may be from one to six characters in length. For utility units and other units that generate energy for sale, the unit ID used for Part 75 reporting is the same unit ID that appears in the National Allowance Database (NADB) (for Acid Rain Program units) or in the State's allowance allocation list.
Day	Day on which a unit was operating.
Hour	Hour on which a unit was operating.
Operating Hours	Percent of hour in which a unit was operating.
Gross Load (MW)	Gross load is the output of the unit as measured in megawatts.
Steam Load (1000 lb/hr)	Steam load is the output of the unit as measured in 1000 lb/hr of steam.
SO_2 Mass (lbs)	SO_2 released for the hour in pounds.
SO_2 Mass Measurement Flag	Indicates whether the value for SO_2 mass was measured or derived due to missing data.
SO_2 Rate (lbs/mmBtu)	SO_2 emissions rate in pounds per million British thermal units (lbs/mmBtu).
SO_2 Rate Measurement Flag	Indicates whether the value for SO_2 rate was measured or derived due to missing data.
NO_x Rate (lb/mmBtu)	NOx emissions rate in pounds per million British thermal units (lbs/mmBtu).
NO_x Rate Measurement Flag	Indicates whether the value for NO_x rate was measured or derived due to missing data.
NO_x Mass (lbs)	NO_x released for the hour in pounds.
NO_x Mass Measurement Flag	Indicates whether the value for NO_x mass was measured or derived due to missing data.
CO_2 Mass (lbs)	CO_2 released for the hour in pounds.
CO_2 Mass Measurement Flag	Indicates whether the value for CO_2 mass was measured or derived due to missing data.
CO_2 Rate (lbs/mmBtu)	CO_2 emissions rate in pounds per million British thermal units (lbs/mmBtu).
CO_2 Rate Measurement Flag	Indicates whether the value for CO_2 rate was measured or derived due to missing data.
Heat Input (mmBtu)	Heat per hour as calculated by multiplying the quantity of fuel by the fuel's heat content.

Under the direction of VISTAS, emissions inventory contract staff prepared comparisons of the VISTAS 2002 emission inventory of EGU sources to that of CEM-based emissions, heat input, and operating characteristics. For each unit identified as an EGU source in the VISTAS inventory, an attempt was made to match it to a CEM unit and associated data.

Automated facility (ORIS) and unit identification was made for a majority of units who maintained the same numbering and nomenclature between the two data sets. This first computerized step captured the majority of emissions by matching some of the largest units in the VISTAS domain. The remaining steps were followed in order to match the outstanding facilities and emissions as reported by VISTAS States in the 2002 emission inventory.

Inventory contractors developed county-level reports of the remaining unmatched facilities and units from the VISTAS inventory and made comparisons of annual emissions of SO2 and NOx to the CEM-based SO2 and NOx for sources also identified within the same county. This step of the matching process allowed an incremental amount of emissions and units to be accounted for and assigned unit-specific profiles for model performance evaluation.

Finally, remaining VISTAS inventory and CEM sources were manually compared to each other in an effort to determine if reporting errors in State or county codes or facility or unit identification codes accounted for this reminder of unmatched sources. These manual matches were confirmed or revised with VISTAS State and stakeholder participation and input. With this step, a few sources were identified to have facility identification changes or misreported county codes preventing automated matching from occurring and corrected for the final application of factors.

Once all methods of comparison were exhausted, the remaining unmatched VISTAS emission inventory of EGU sources was excluded from the unit-specific profile assignment steps and was allocated more generalized facility or State temporal profiles as described in the following section.

This inventory comparison process allowed for the match of over 650 of the 861 CEM identified units (76%) to the VISTAS EGU emission inventory for 2002. More importantly, however, was the match of 99.95 percent of the SO2 emissions and over 99.4 percent of the NOx emissions from these sources in the VISTAS domain.

Profile Calculations

Two sets of profile types have been developed for modeling EGU emissions within the VISTAS domain. The first set are to be applied to individual units able to be matched to CEM data, the second are to be applied to EGU sources within the VISTAS domain where CEM-based matches could not be identified.

The first set of temporal profiles have been developed for specific hour-of-date periods based on historical actual 2002 or average NOx, SO2, and heat input data for sources reporting under EPA's CEM program between 2000 and 2004. These profiles are based on the actual or statistical average of the CEM data variables (NOx, SO2, and heat input) for each hour-of-date (e.g., Hour 12 of March 3) during the year. In the typical profile calculation, variables are calculated for each hour when the operating time of the CEM is greater than 0 (e.g., the unit is in operation during that hour). In the case of 2002-only calculations, all reported NOx, SO2, and heat input data were used in the averaging, including those identified as non-operating hours. This allowed for the best representation of actual 2002 conditions for the expected use of these profiles for model validation studies.

In the second set of profiles, NOx, SO2, and heat input values were averaged over each unit to allow for the calculation of State level monthly, day-of-week, and diurnal profiles for VISTAS States.

For the 2000-2004 averaging period, representation of typical operating conditions was desired, so in the averaging calculation only valid operating hour NOx, SO2, and heat input values were used. This prevented the introduction of equipment shutdown because of power outages, control installation, or planned maintenance into the temporal profile calculation.

Actual 2002 Profiles

Through the EPA's Clean Air Market's Data and Maps website, quarterly unit-level hourly emissions data by State and calendar year 2002 were obtained for purposes of developing temporal allocation factors applicable to EGU sources within the VISTAS domain. Key elements in these data sets include the State where the unit is located, facility name, facility identification (ORISPL) code (assigned by the Department of Energy at the Energy Information Administration), unit identification code, date of record, hour of record, SO2, CO2, and NOx mass (in lbs per hour), heat input (million British thermal units [MMBtu]), and NOx emission rate (lbs/MMBtu).

SO2 and NOx mass and heat input values were summed for each unit to an annual level to allow for the calculation of an hour of date-to-annual ratio estimation. Equation 2-1 provides this calculation for heat input. Table 2-2 provides an example result of the ratio calculation.

Equation (2-1)
$$hi_{ratio,hr,date} = hi_{hr,date} / \sum_{Dec31}^{Jan1} hi$$

where hi = heat input (MMBtu)

Since it was assumed that all sources in the VISTAS EGU inventory would not be matched to individual CEM-based units, the same calculations were performed for each State so that a hierarchical application of ratios (unit first, State second) could be assigned as necessary. Table 2-3 shows example ratios calculated for each month by State. Table 2-4 reflects an example of the State-month-day of week ratio calculation and Table 2-5 shows a State-month-diurnal ratio calculation example. Each of these ratios were calculated for each State in the VISTAS domain emissions inventory.

Three parameter values (SO2 mass, NOx mass, heat input) were calculated at each aggregation as NOx and SO2 emissions vary due to fuel blend, sulfur content, or seasonal control and are not necessarily representative of the other variables' seasonal, daily, or even hourly variation. The monthly variation in relative distribution of SO2, NOx, and heat input differs enough to justify calculating each parameter value set of temporal profiles with CEM data.

Table 2-3. Application of Calculated Ratios for Actual 2002 by Unit.

				Actual Reported Values [2002]			Calculated Ratios		
ORISPL	UnitID	Date	Hour	SO2 Mass	NOx Mass	Heat Input	SO2	NOx	Heat Input
3	2	01-01-2002	0	15.563	10.294	13.3	1.417E-06	1.915E-06	1.372E-06
3	2	01-01-2002	1	14.977	8.338	12.5	1.364E-06	1.551E-06	1.289E-06
3	2	01-01-2002	2	14.93	9.286	12.6	1.360E-06	1.728E-06	1.300E-06
3	2	01-01-2002	3	14.774	9.677	12.8	1.346E-06	1.800E-06	1.320E-06
…	…	…	…	…	…	…	…	…	…
3	2	07-01-2002	0	1084.017	717.467	995.1	9.873E-05	1.335E-04	1.026E-04
3	2	07-01-2002	1	1102.47	750.04	1012.2	1.004E-04	1.395E-04	1.044E-04
3	2	07-01-2002	2	1109.41	768.55	1016.6	1.010E-04	1.430E-04	1.049E-04
3	2	07-01-2002	3	1102.598	772.614	1012.6	1.004E-04	1.437E-04	1.044E-04
3	2	07-01-2002	4	1087.909	736.967	998.6	9.909E-05	1.371E-04	1.030E-04
3	2	07-01-2002	5	1099.375	731.888	1009.5	1.001E-04	1.362E-04	1.041E-04
3	2	07-01-2002	6	1127.007	693.779	1026.3	1.026E-04	1.291E-04	1.059E-04
3	2	07-01-2002	7	1203.814	644.008	1114.2	1.096E-04	1.198E-04	1.149E-04
…	…	…	…	…	…	…	…	…	…
3	2	12-31-2002	21	712.26	503.505	835	6.487E-05	9.367E-05	8.612E-05
3	2	12-31-2002	22	716.983	587.419	850.1	6.530E-05	1.093E-04	8.768E-05
3	2	12-31-2002	23	521.311	430.787	647.8	4.748E-05	8.014E-05	6.681E-05
3954	**3**	**Annual Sum**		**10979533.36**	**5375215.80**	**9695608.12**	**1.000**	**1.000**	**1.000**

Table 2-4. Application of Calculated Ratios for Actual 2002 by Example State and Month.

		Actual Reported Values [2002]			Calculated Ratios		
State	Month	SO2 Mass	NOx Mass	Heat Input	SO2	NOx	Heat Input
FL	Jan	67,755,539	42,004,513	113,531,981	0.0726	0.0813	0.0733
FL	Feb	56,516,278	34,145,451	91,969,840	0.0605	0.0661	0.0594
FL	Mar	69,997,283	39,244,669	107,685,763	0.0750	0.0759	0.0695
FL	Apr	73,678,638	40,824,242	118,170,997	0.0789	0.0790	0.0763
FL	May	88,889,603	48,974,695	142,351,045	0.0952	0.0948	0.0919
FL	Jun	79,736,153	44,027,147	138,648,667	0.0854	0.0852	0.0895
FL	Jul	94,401,559	50,007,339	157,075,598	0.1011	0.0968	0.1014
FL	Aug	93,041,423	50,077,048	160,601,359	0.0996	0.0969	0.1037
FL	Sep	93,349,234	49,183,990	155,433,110	0.1000	0.0952	0.1003
FL	Oct	84,214,449	46,837,495	146,347,289	0.0902	0.0906	0.0945
FL	Nov	60,374,969	33,098,684	105,854,682	0.0647	0.0641	0.0683
FL	Dec	71,853,245	38,331,463	111,702,695	0.0769	0.0742	0.0721
FL	**Total**	**933,808,373**	**516,756,735**	**1,549,373,024**	**1.0000**	**1.0000**	**1.0000**

Table 2-5. Application of Calculated Ratios for Actual 2002 by Example State and Month and Day of Week.

State	Month	Day of Week	Actual Reported Values [2002] SO2 Mass	NOx Mass	Heat Input	Calculated Ratios SO2	NOx	Heat Input
GA	Mar	Sun	13,057,959	4,005,097	10,089,522	0.1467	0.1437	0.1458
GA	Mar	Mon	11,937,355	3,841,172	9,564,295	0.1341	0.1378	0.1382
GA	Mar	Tue	11,860,749	3,766,317	9,351,652	0.1332	0.1351	0.1352
GA	Mar	Wed	12,020,458	3,764,653	9,232,574	0.1350	0.1351	0.1334
GA	Mar	Thu	11,560,778	3,677,100	9,056,011	0.1299	0.1319	0.1309
GA	Mar	Fri	14,572,757	4,616,042	11,368,579	0.1637	0.1656	0.1643
GA	Mar	Sat	14,005,730	4,197,929	10,522,180	0.1573	0.1506	0.1521
GA	**Mar**	**Total**	**89,015,786**	**27,868,311**	**69,184,812**	**1.0000**	**1.0000**	**1.0000**

Table 2-6. Application of Calculated Ratios for Actual 2002 by Example State and Month and Hour of Day.

State	Month	Hour	Actual Reported Values [2002] SO2 Mass	NOx Mass	Heat Input	Calculated Ratios SO2	NOx	Heat Input
SC	Dec	0	1,356,270	556,321	1,309,476	0.0399	0.0399	0.0398
SC	Dec	1	1,332,499	540,268	1,279,485	0.0392	0.0387	0.0389
SC	Dec	2	1,324,618	536,330	1,275,732	0.0389	0.0384	0.0388
SC	Dec	3	1,330,924	538,908	1,284,514	0.0391	0.0386	0.0391
SC	Dec	4	1,335,158	545,819	1,296,880	0.0392	0.0391	0.0394
SC	Dec	5	1,385,906	565,695	1,340,759	0.0407	0.0405	0.0408
SC	Dec	6	1,436,829	586,536	1,387,329	0.0422	0.0420	0.0422
SC	Dec	7	1,488,961	611,648	1,440,753	0.0438	0.0438	0.0438
SC	Dec	8	1,491,509	613,176	1,444,956	0.0438	0.0440	0.0440
SC	Dec	9	1,501,425	618,516	1,447,916	0.0441	0.0443	0.0440
SC	Dec	10	1,484,685	610,879	1,431,441	0.0436	0.0438	0.0435
SC	Dec	11	1,459,697	593,638	1,395,938	0.0429	0.0426	0.0425
SC	Dec	12	1,423,246	578,669	1,365,957	0.0418	0.0415	0.0415
SC	Dec	13	1,391,851	570,939	1,345,091	0.0409	0.0409	0.0409
SC	Dec	14	1,352,161	557,078	1,319,068	0.0397	0.0399	0.0401
SC	Dec	15	1,344,643	551,497	1,312,670	0.0395	0.0395	0.0399
SC	Dec	16	1,369,024	559,569	1,333,589	0.0402	0.0401	0.0406
SC	Dec	17	1,449,587	595,765	1,398,917	0.0426	0.0427	0.0426
SC	Dec	18	1,493,742	621,423	1,438,833	0.0439	0.0445	0.0438
SC	Dec	19	1,473,502	611,050	1,427,712	0.0433	0.0438	0.0434
SC	Dec	20	1,479,504	608,223	1,424,664	0.0435	0.0436	0.0433
SC	Dec	21	1,475,680	608,049	1,421,202	0.0434	0.0436	0.0432
SC	Dec	22	1,450,119	597,906	1,401,208	0.0426	0.0429	0.0426
SC	Dec	23	1,391,087	573,310	1,351,539	0.0409	0.0411	0.0411
SC	**Dec**	**Daily**	**34,022,628**	**13,951,210**	**32,875,627**	**1.0000**	**1.0000**	**1.0000**

When viewed on a State by State basis, the differences in monthly variation are even more pronounced as individual facilities within each State may be affected during any calendar year by extreme temperature variation, shutdowns, or regular maintenance or installation of equipment. As an example, Figure 2-3 represents CEM data from the State of Mississippi during calendar year 2002 and reveals that SO2 emissions increase throughout the year, NOx emissions stay relatively high during the summer months, and heat input peaks during the month of July. In Mississippi's case, close to thirteen percent of the State's CEM-based heat input occurs in July. This compares to the VISTAS average of just over ten percent of CEM-based heat input in July.

Finally, when these data are reviewed at a unit level, the differences become incrementally more distinct due to the unique nature of individual facilities, their operating schedules, pollution regulation, fuel characteristics, and applied technologies. For example, a facility that is complying with summertime NOx regulation may have selective catalytic reduction (SCR) installed on its boiler(s) which in practice may only be run during ozone season months. During this period of time, heat input and SO2 emissions may remain consistent with State or regional monthly profiles, but the NOx emissions may drop significantly relative to the rest of the year.

Figure 2-4 represents an extreme unit-specific case for monthly differences from State or regional temporal allocation. The unit presented is a Mississippi baseload coal-fired boiler which in 2002 emitted over 4,000 tons of NOx and over 11,000 tons of SO2. This unit would typically run at consistent levels during the entire period, but due to a planned maintenance outage was not in operation in late January through the middle of April in 2002. Given the unique operation of this boiler during this year, the use of a regional or even State-level monthly temporal distribution would introduce significant inaccuracy to air quality modeling in the immediate or downwind area associated with this facility. While this may not be significant at great distance downwind of the source or for annual concentration estimates, more locally, and especially over shorter time scales (daily or weekly), such simplifications would have a noticeable effect on air quality model predictions.

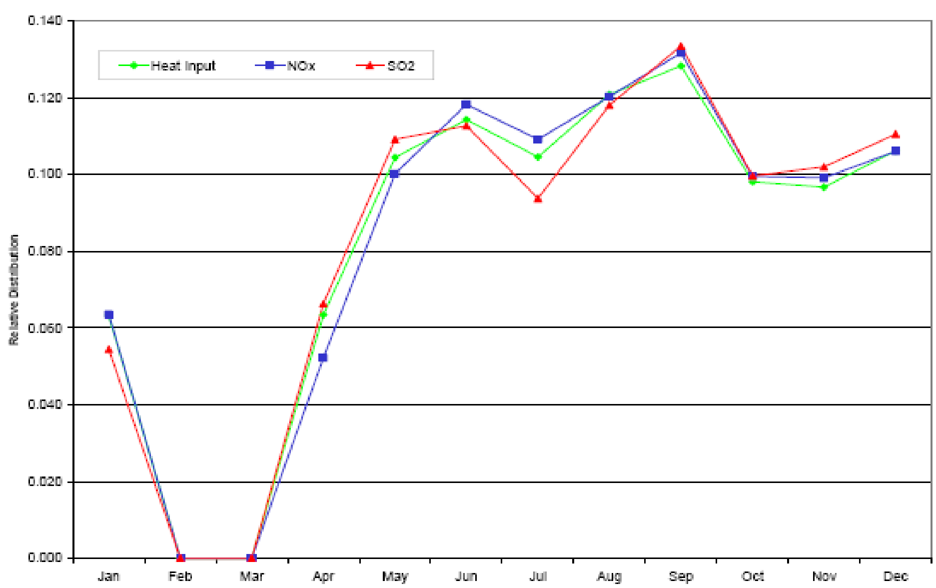


Figure 2-4. Monthly variation in 2002 of CEM reported heat input, NOx mass, and SO2 mass for specific baseload coal-fired unit in Mississippi with planned outage in late January through mid April.

Thus, while improving the representativeness of unit-specific monthly temporal profiles is desirable, providing day and hour-specific values are clearly better. For this reason, during the model performance evaluation process in the VISTAS modeling, hour-specific temporal ratios were developed for every CEM reporting unit in the VISTAS domain. These ratios allowed for the hour-by-hour accounting of emissions released at each unit at each facility within the VISTAS domain that reported output under the CEM guidelines.

Figure 2-5 represents the actual daily distribution of SO2 and NOx emissions and heat input from the Mississippi baseload unit from the above example. As can been seen in this figure, not only is the planned January through April outage represented correctly, there are significant peaks and valleys throughout the calendar year which could not be accurately represented with the application of average monthly, day-of-week, or hourly distribution factors. In reality, only the actual operating characteristics of this unit could capture the differences from hour to hour which are potentially quite important in terms of correctly modeling the impact of the source on downwind oxidant and fine particulate concentrations[10].

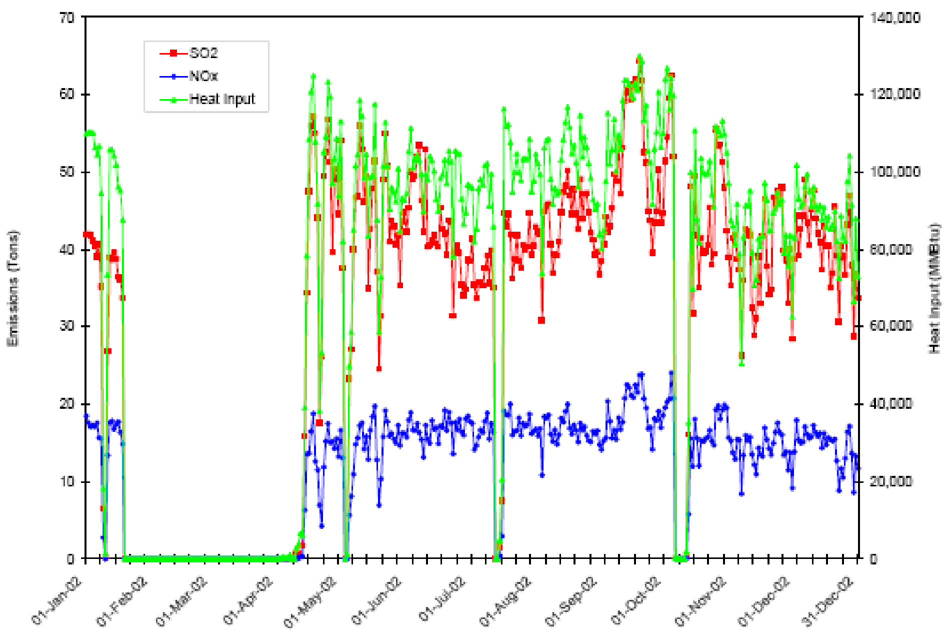


Figure 2-5. Actual daily unit-specific 2002 SO2 (tons), NOx, (tons), and heat input (MMBtu) distribution from CEM data.

Typical EGU Profiles

Hour of day of month specific temporal profiles were developed by calculating the arithmetic mean of each unit's NOx, SO2, and heat input by specific hour of day per month (e.g., Hour 21 of Wednesdays in July) from the data obtained from 2000 through 2004. In order to accomplish this calculation, each record of CEM data was first assigned a day of week. This assignment was based on the actual CEM's date of record and day of week of that record. An example of this assignment is shown in Table 2-7.

10 http://www.epa.gov/ttn/chief/conference/ei14/session11/stella.pdf

Table 2-7. Example Day-of-Week per Month Assignment.

Date	Day of Week
08/01/02	Thu
08/02/02	Fri
08/03/02	Sat
08/04/02	Sun
08/05/02	Mon
08/06/02	Tue
08/07/02	Wed

Once days of week were assigned to each record in the CEM data base, the arithmetic mean of each unit's NOx, SO2, and heat input were calculated for the ORISPL-UNITID-MONTH-DAY OF WEEK-HOUR combination. Only records where the CEMs were operating for more than half the recorded hour (OPTIME > 0.5) were used in the averaging calculation. An example of the averaged results can be seen in Table 2-8.

Table 2-8. Arithmetic Mean of CEM-based Variables for Temporal Profile Calculation.

							Calculated Average Values [2000 – 2004]		
State	Facility	ORISPL	UnitID	Month	Day of Week	Hour	SO2 Mass	NOx Mass	Heat Input
WV	Mount Storm Power Station	3954	3	1	Tue	0	406.0526	3384.074	5196.11
WV	Mount Storm Power Station	3954	3	1	Tue	1	389.6474	3287.845	5103.06
WV	Mount Storm Power Station	3954	3	1	Tue	2	395.2737	3342.848	5175.95
...	...	...	...	...	...	...	...	...	...
WV	Mount Storm Power Station	3954	3	7	Mon	4	524.7864	2505.9391	4654.34
WV	Mount Storm Power Station	3954	3	7	Mon	5	690.5636	2602.9887	4795.64
WV	Mount Storm Power Station	3954	3	7	Mon	6	912.4227	2572.0275	4727.08
WV	Mount Storm Power Station	3954	3	7	Mon	7	1060.3	2664.8686	4914.25
WV	Mount Storm Power Station	3954	3	7	Mon	8	850.2364	2678.231	5029.58
WV	Mount Storm Power Station	3954	3	7	Mon	9	415.3455	2716.8	5042.55
WV	Mount Storm Power Station	3954	3	7	Mon	10	408.8591	2876.5008	5123.71
WV	Mount Storm Power Station	3954	3	7	Mon	11	371.9909	2776.0361	5147.85
WV	Mount Storm Power Station	3954	3	7	Mon	12	327.2045	2785.5325	5129.66
WV	Mount Storm Power Station	3954	3	7	Mon	13	316.0364	2826.901	5172.29
WV	Mount Storm Power Station	3954	3	7	Mon	14	317.1136	2816.1328	5146.07
WV	Mount Storm Power Station	3954	3	7	Mon	15	329.6455	2789.0962	5121.75
WV	Mount Storm Power Station	3954	3	7	Mon	16	332.7773	2818.5379	5147.05
...	...	...	...	...	...	...	...	...	...
WV	Mount Storm Power Station	3954	3	12	Tue	21	806.7	3432.001	5375.49
WV	Mount Storm Power Station	3954	3	12	Tue	22	806.5778	3447.709	5377.68
WV	Mount Storm Power Station	3954	3	12	Tue	23	795.4667	3419.069	5359.43

These values were then applied to each unit and hour based on the 2002 calendar to match the meteorological data used in the emissions processing. An example of this application can be seen in Table 2-9. The date specific hourly averages were then summed to a unit summer (May – Sept) and winter months total and ratios were developed based on each daily hour's average value divided by the average sum total depending on the season of the day. This permitted the appropriate allocation of summertime NOx (as forecasted by IPM) when summer control only was predicted. Using the annual average ratios instead of the seasonal distributions would produce summertime emissions different than what was output from the model.

Table 2-9. Application of Calculated Ratios to Day of Year by Unit.

					Calculated Average Values [2000 – 2004]			Calculated Ratios		
ORISPL	UnitID	Date	Day of Week	Hour	SO2 Mass	NOx Mass	Heat Input	SO2	NOx	Heat Input
3797	4	09/30/02	Mon	19	2591.95	381.78	1527.26	2.899E-04	2.396E-04	2.863E-04
3797	4	09/30/02	Mon	20	2596.81	379.88	1525.60	2.904E-04	2.385E-04	2.860E-04
3797	4	09/30/02	Mon	21	2569.03	370.50	1506.74	2.873E-04	2.326E-04	2.824E-04
3797	4	09/30/02	Mon	22	2547.62	367.24	1498.66	2.849E-04	2.305E-04	2.809E-04
3797	4	09/30/02	Mon	23	2483.88	360.66	1465.68	2.778E-04	2.264E-04	2.747E-04
3797	4	10/01/02	Tue	0	1968.94	478.47	1170.76	1.587E-04	1.517E-04	1.604E-04
3797	4	10/01/02	Tue	1	1942.47	480.28	1160.68	1.565E-04	1.522E-04	1.590E-04
3797	4	10/01/02	Tue	2	1858.54	462.44	1122.29	1.498E-04	1.466E-04	1.537E-04
3797	4	10/01/02	Tue	3	1988.43	486.07	1187.56	1.602E-04	1.541E-04	1.627E-04
3797	4	10/01/02	Tue	4	2125.96	528.59	1263.00	1.713E-04	1.676E-04	1.730E-04
3797	4	10/01/02	Tue	5	2255.22	562.18	1325.40	1.818E-04	1.782E-04	1.815E-04
3797	4	10/01/02	Tue	6	2267.27	558.77	1337.81	1.827E-04	1.771E-04	1.832E-04
3797	4	10/01/02	Tue	7	2313.00	579.94	1370.73	1.864E-04	1.838E-04	1.878E-04
3797	**4**	**Summer**				**8941480.78**	**1593123.80**	**5334723.17**		
3797	**4**	**Winter**				**12408352.17**	**3154758.40**	**7300596.69**		
3797	**4**	**Annual Sum**				**21349832.95**	**4747882.21**	**12635319.86**		

Equation 2-2 reflects this calculation for heat input for a summer hour. Ratios were calculated for NOx, SO2, and heat input values. These ratios were then applied to each unit's seasonal (summer or winter) emission value for NOx, SO2, and all other pollutants, respectively.

Equation (2-2) $$hi_{ratio,hr,date,sum} = hi_{hr,date,sum} / \sum_{Sep30}^{May1} hi$$

where hi = heat input (MMBtu)

The actual hour-of-day-of-month averages calculated from the CEM data were not used directly as emissions for that hour, but were used only in the calculation of the ratios to be applied to a pre-calculated seasonal (summer or winter) emission value. This allowed for the retention of emission estimates calculated using means other than CEM data, if a State or local agency found them to be more appropriate or if it were derived by other means (e.g., IPM) but an improved distribution of emissions using CEM-based ratios.

As in the actual 2002 profiles calculations, these same calculations were additionally performed for each State so that a hierarchical application of ratios (unit first, State second) could be assigned as necessary. Instead of having variables at the unit level, however, State level values were used. These State value calculations were based on the sum of the unit-level variable averages to the level of aggregation required by the calculation (e.g., State-month. State-month day-of-week, or State-month-hour). Table 2-10 shows example ratios calculated for each month by State. Table 2-11 reflects an example of the State-month-day of week ratio calculation and Table 2-12 shows a State-month-diurnal ratio calculation example. Each of these ratios were calculated for each State in the VISTAS domain and used in instances where CEM unit matches could not be made to the VISTAS base year emissions inventory.

Again, three parameter values (SO2 mass, NOx mass, heat input) were calculated at each aggregation as NOx and SO2 emissions vary due to fuel blend, sulfur content, or seasonal control and are not necessarily representative of the other variables' seasonal, daily, or even hourly variation.

Table 2-10. Application of Calculated Ratios for Typical Operation by Example State and Month.

State	Month	Calculated Average Values [2000 – 2004]			Calculated Ratios		
		SO2 Mass	NOx Mass	Heat Input	SO2	NOx	Heat Input
FL	Jan	116,011,253	62,989,958	198,751,048	0.0858	0.0875	0.0831
FL	Feb	93,958,786	50,831,818	164,949,702	0.0695	0.0706	0.0690
FL	Mar	111,505,553	60,285,972	196,705,697	0.0824	0.0838	0.0822
FL	Apr	107,015,438	59,071,792	195,338,204	0.0791	0.0821	0.0817
FL	May	118,589,361	61,811,604	207,803,996	0.0877	0.0859	0.0869
FL	Jun	116,068,987	59,801,640	202,716,214	0.0858	0.0831	0.0848
FL	Jul	123,868,749	62,500,169	212,478,437	0.0916	0.0868	0.0888
FL	Aug	125,384,940	64,572,843	214,637,218	0.0927	0.0897	0.0897
FL	Sep	113,080,789	59,913,723	206,712,956	0.0836	0.0832	0.0864
FL	Oct	109,960,828	61,551,310	206,924,170	0.0813	0.0855	0.0865
FL	Nov	101,781,383	55,861,718	186,984,665	0.0752	0.0776	0.0782
FL	Dec	115,588,740	60,566,444	197,592,133	0.0854	0.0841	0.0826
FL	Total	**1,352,814,807**	**719,758,990**	**2,391,594,439**	**1.0000**	**1.0000**	**1.0000**

Table 2-11. Application of Calculated Ratios for Typical Operation by Example State and Month and Day of Week.

State	Month	Day of Week	Calculated Average Values [2000 – 2004]			Calculated Ratios		
			SO2 Mass	NOx Mass	Heat Input	SO2	NOx	Heat Input
GA	Mar	Sun	15,495,089	4,641,883	12,167,666	0.1455	0.1403	0.1319
GA	Mar	Mon	14,334,901	4,513,847	13,362,335	0.1346	0.1365	0.1449
GA	Mar	Tue	14,420,895	4,532,750	13,463,600	0.1354	0.1370	0.1460
GA	Mar	Wed	14,170,345	4,489,531	13,057,182	0.1331	0.1357	0.1416
GA	Mar	Thu	14,004,649	4,446,853	12,249,119	0.1315	0.1344	0.1328
GA	Mar	Fri	17,177,952	5,357,920	14,842,639	0.1613	0.1620	0.1609
GA	Mar	Sat	16,881,455	5,096,281	13,100,433	0.1585	0.1541	0.1420
GA	**Mar**	**Total**	**106,485,284**	**33,079,065**	**92,242,973**	**1.0000**	**1.0000**	**1.0000**

Table 2-12. Application of Calculated Ratios for Typical Operation by Example State and Month and Hour of Day.

			Calculated Average Values [2000 – 2004]			Calculated Ratios		
State	Month	Hour	SO2 Mass	NOx Mass	Heat Input	SO2	NOx	Heat Input
SC	Dec	0	1,790,705	674,127	1,908,284	0.0401	0.0395	0.0375
SC	Dec	1	1,760,847	659,279	1,877,399	0.0395	0.0386	0.0369
SC	Dec	2	1,766,498	660,719	1,890,957	0.0396	0.0387	0.0372
SC	Dec	3	1,766,455	664,407	1,922,535	0.0396	0.0389	0.0378
SC	Dec	4	1,788,023	677,882	2,005,041	0.0401	0.0397	0.0394
SC	Dec	5	1,839,136	708,796	2,193,779	0.0412	0.0415	0.0431
SC	Dec	6	1,903,431	736,781	2,379,535	0.0427	0.0432	0.0468
SC	Dec	7	1,957,422	760,608	2,504,498	0.0439	0.0446	0.0492
SC	Dec	8	1,958,923	768,669	2,515,860	0.0439	0.0450	0.0494
SC	Dec	9	1,974,624	767,392	2,419,052	0.0443	0.0450	0.0475
SC	Dec	10	1,944,825	751,207	2,264,252	0.0436	0.0440	0.0445
SC	Dec	11	1,888,552	723,857	2,140,166	0.0423	0.0424	0.0421
SC	Dec	12	1,833,408	694,261	2,022,036	0.0411	0.0407	0.0397
SC	Dec	13	1,781,162	673,316	1,936,841	0.0399	0.0395	0.0381
SC	Dec	14	1,755,403	663,791	1,911,001	0.0393	0.0389	0.0376
SC	Dec	15	1,743,443	660,042	1,897,088	0.0391	0.0387	0.0373
SC	Dec	16	1,775,717	669,264	1,937,000	0.0398	0.0392	0.0381
SC	Dec	17	1,877,548	713,920	2,099,275	0.0421	0.0418	0.0413
SC	Dec	18	1,948,165	753,627	2,255,923	0.0437	0.0442	0.0443
SC	Dec	19	1,940,185	753,123	2,258,417	0.0435	0.0441	0.0444
SC	Dec	20	1,941,859	750,942	2,221,568	0.0435	0.0440	0.0437
SC	Dec	21	1,930,605	743,880	2,182,689	0.0433	0.0436	0.0429
SC	Dec	22	1,909,077	732,480	2,140,416	0.0428	0.0429	0.0421
SC	Dec	23	1,841,457	702,464	2,003,560	0.0413	0.0412	0.0394
SC	**Dec**	**Daily**	**44,617,469**	**17,064,833**	**50,887,170**	**1.0000**	**1.0000**	**1.0000**

Application of Factors

VISTAS chose to prepare its air quality modeling inventories with Version 2.1 of the Sparse Matrix Operating Kernel Emissions (SMOKE) model. For this reason, all emissions were required to be converted to SMOKE's data formats. In particular, because hour specific temporal profiles for each day of a year are not accepted directly by the model, it was necessary to develop a set of hourly emissions inputs to circumvent this limitation. These were generated in the EMS PTHOUR format as described in SMOKE input file documentation[11].

The CEM format for individual hour-specific data files as available in SMOKE was not utilized for VISTAS emissions processing as the emissions allowable by hour would have been limited to NOx, SO2, and CO2. If this file format and optional run configuration were exercised, the NOx, SO2, and CO2 emissions processed by the model would have been accurate for CEM reported emissions, but the remaining pollutants coupled with each CEM unit would have received the monthly, daily, and diurnal temporal profiles associated with the source category codes from the unit. This could lead to potentially displaced emissions if a unit were operating at different times than the default profiles indicated. Additionally, in cases where States may not have reported annual emission estimates directly based on CEMs, these emissions would be slightly different that the original annual inventory.

11 University of North Carolina at Chapel Hill, *Sparse Matrix Operator Kernel Emissions (SMOKE) Modeling System*, http://cf.unc.edu/cep/empd/products/smoke/index.cfm.

In VISTAS modeling, for those EGU sources where CEM data were utilized, NOx, SO2, and heat input-based hour-specific profiles were developed and applied to annual NOx, SO2, and all other emissions, respectively, for both the actual and typical 2002 modeling. Heat input was chosen as a surrogate for non-CEM reported pollutants as the majority of remaining compounds are not as significantly impacted by controls or fuel content, yet the distribution of these emissions would occur during the same times CEM reported pollutants were emitted.

The application of hourly ratios to annual emissions ensured that the annual values provided by States under the CERR were maintained, but distributed using actual hourly to annual profiles. Additionally, for stakeholder sources providing hour-specific data approved by the State in which they operated, data were substituted for State provided emissions and CEM-based distributions.

To temporally allocate the remaining EGU point sources, the NOx, SO2, and heat input data were collected from the 2002 or 2000-2004 CEM datasets, and used to develop State-level temporal distributions. These month-specific hour and day of week temporal profiles were used in conjunction with the emissions inventory to calculate hourly EGU emissions by unit. Although not as accurate a distribution as the unit-specific factors, the State-based temporal distribution provided improved results to the default profiles provided with the emissions model. Figure 2-6 represents the monthly distribution comparisons of VISTAS State heat input to the default monthly distribution from Version 2.0 of SMOKE for source category code (SCC) 10100201, representing External Combustion Boilers; Electric Generation; Bituminous/Subbituminous Coal; Pulverized Coal: Wet Bottom (Bituminous Coal), a relatively common boiler type and fuel configuration in the VISTAS domain. This example is for the actual 2002 modeling exercise.

Much like the distinction in month to month variation of the profiles, day of week and diurnal patterns based on CEM data vary from unit to unit. Again, if one were to assign the same day of week or diurnal profile to every unit in the inventory, emissions from these sources would inappropriately be distributed during the episode of interest. In addition to the unique distribution provided by the unit-specific factors based on CEM data, aggregate State level daily and diurnal temporal distribution factors were developed and applied during this process. Figure 2-7 shows the variance in diurnal distribution from Tennessee’s average CEM-based NOx emissions data for each of the twelve months of calendar year 2002 as would have been applied to units unmatched to CEM sources.

The work conducted in this process had the main objective of developing temporal profiles for VISTAS EGUs necessary to apply in the generation of SMOKE PTHOUR formatted emissions. Additionally, State-level monthly, day-of-week, and diurnal profiles were developed for application to non-CEM matched units in the VISTAS emissions inventory. These temporal distributions represent a significant improvement over the EPA defaults.

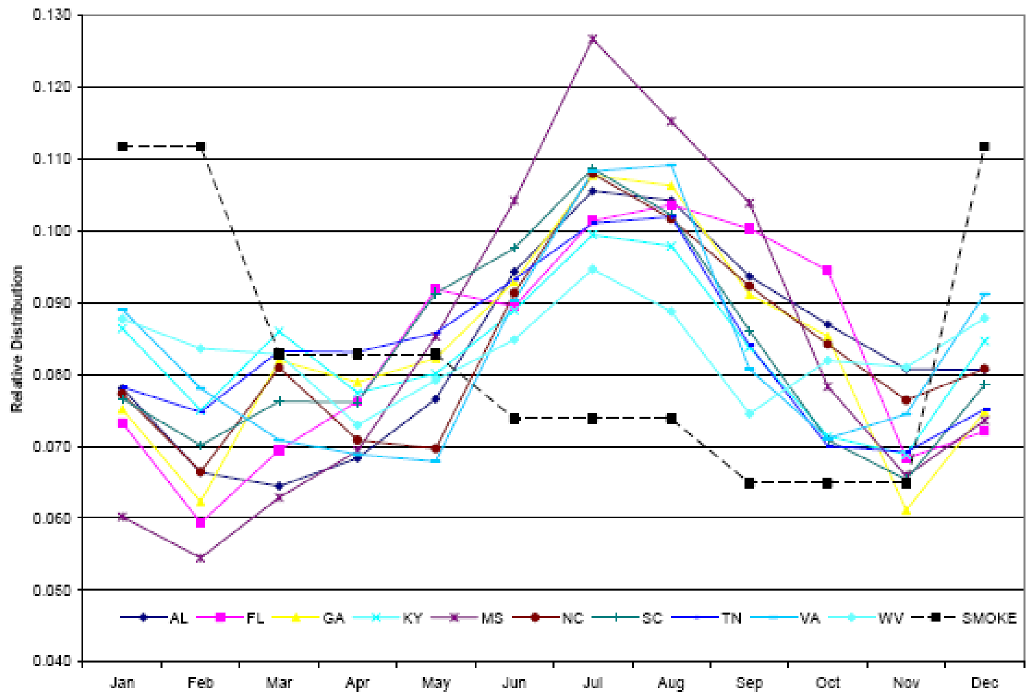


Figure 2-6. Relative distribution of actual 2002 monthly VISTAS State CEM-based heat input.

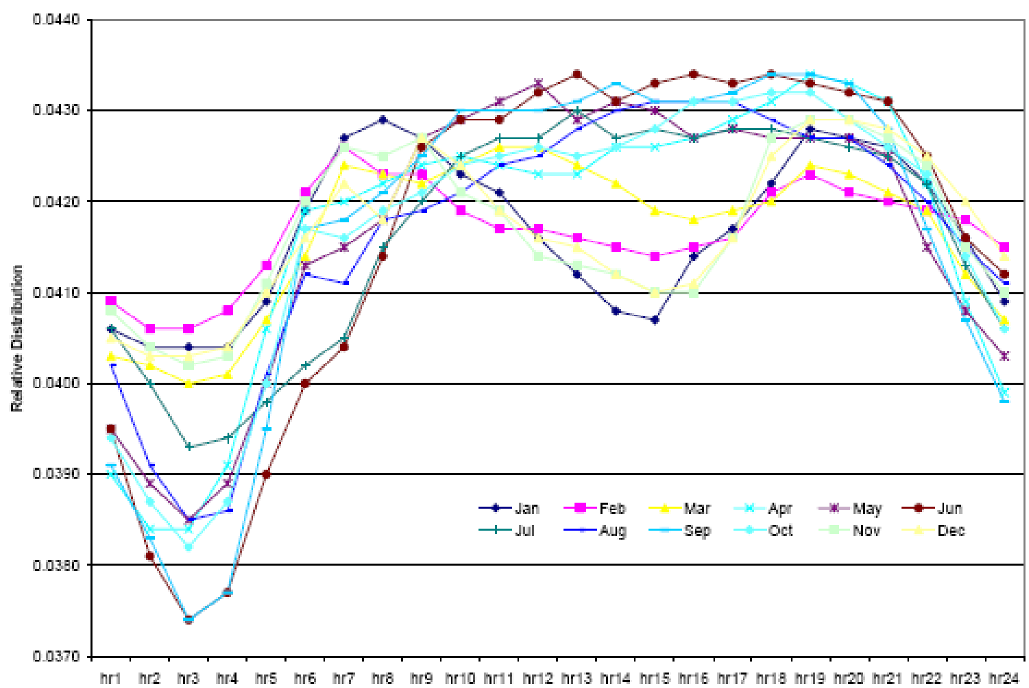


Figure 2-7. Relative distribution of diurnal actual 2002 CEM-based NOx emissions for Tennessee.

Attachment D
LADCO Hourly Methodology:

Temporally Allocating Emissions with CEM Data for Chemical Transport and SIP Modeling

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ABSTRACT

This paper describes how Continuous Emissions Monitoring (CEM) data were used to generate temporal profiles based on median CEM heat input values by month, day of week and hour of day for individual National Inventory Format (NIF) emission units, how the profiles were used to generate typical hourly emission records for base and future modeling years, and how emissions temporally allocated by use of these profiles differ quantitatively from the results of more traditional methods.

INTRODUCTION

Continuous Emissions Monitoring (CEM) data has much to recommend it for use in emissions and atmospheric modeling, as it contains directly measured emissions with hourly temporal resolution for a significant fraction of the point source inventory.

CEM data can be challenging to integrate into a modeling inventory. The high-resolution data sets grow large very quickly as the temporal or geographic domain expands. Pollutant coverage is incomplete. Deriving data that is properly representative of a period, e.g. a typical summer day, from the highly resolved CEM data is problematic. Establishing accurate correspondence between CEM reporting units and NIF emission units or release points is a major challenge.

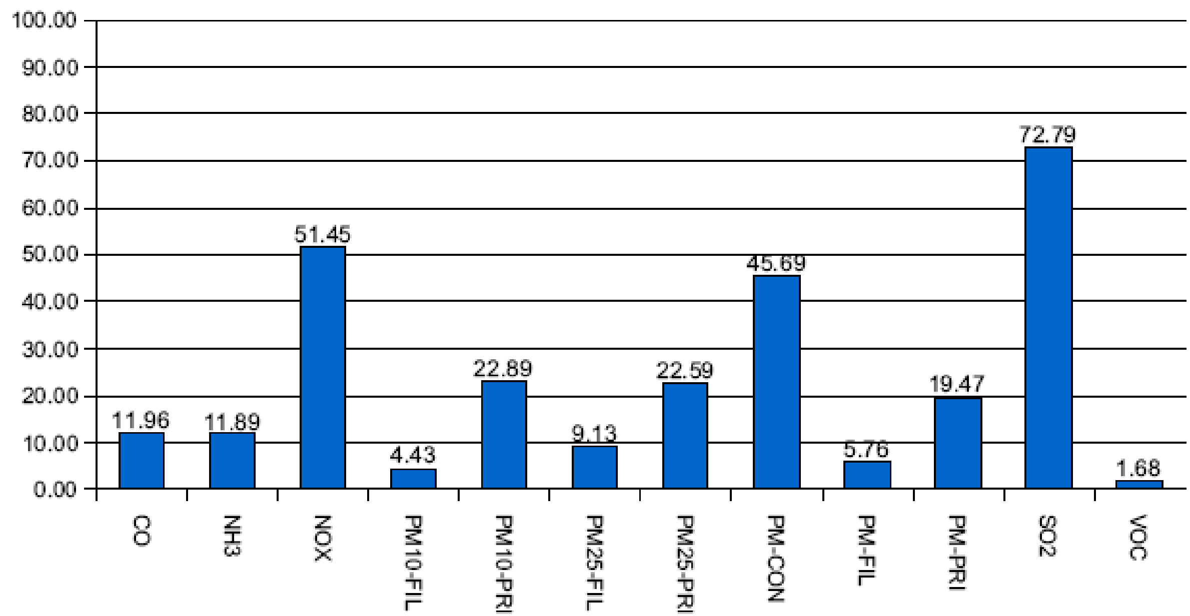
This paper describes how 2001 through 2003 CEM heat input data were used to generate unit-specific NIF emissions records for each hour of a weekday, a Saturday and a Sunday for each month of 2002 for approximately nineteen hundred NIF emission units nationwide, and it describes how the procedure was modified for future year inventories to use the summer and non-summer, rather than annual, emission records derived from output of the IPM model. We review how the above challenges were addressed, how the heat input-based approach compares to unit-specific allocation based on CEM reported SO2 or NOx emission data, and how emissions temporally allocated based on unit-specific CEM heat inputs differ quantitatively from the results of more traditional methods.

APPROACH

A desired improvement, long outstanding[1], to the temporal allocation of emission inventories for atmospheric modeling has been to incorporate improvements based on CEM data. Rather than a direct application of CEM data that would result in an inventory reflective of a specific, historic episode, the goal here was to perform temporal allocations representative of a typical period, which could be applied to base and future year inventories. It was also considered essential that the methods developed be highly automated. This last requirement was dictated by available resources, but also has the virtue of making the methods developed reproducible and readily modified and improved over the inevitable iterations of modeling inventory development.

LADCO recently contracted with E.H. Pechan for development of IPMTOOL, software which can be used to convert IPM model output data to NIF-formatted emission data. One of the results of this project was to make available a cross-reference between the key identifiers for CEM boilers and NIF emission units. This cross-reference provided an opportunity to develop a highly automated application of CEM data to modeling inventories. Figure 1 below shows the fraction of the total 2002 base year inventory that can be matched by the cross-reference, hence the fraction of the total 2002 point source inventory that can be temporally allocated by the approach described below.

Figure 1. Percentages of pollutants in the 2002 point source inventory matched to CEM heat input.



The compiled quarterly CEM data files from Clean Air Markets Division (US EPA) covering the years 2001 through 2003 (bracketing the 2002 base year) were selected for use. This data set contains just over eighty eight million records. The data elements in these tables include facility and unit identifiers, date and hour of the record, CO2 and SO2 emissions, NOx emission rates and heat inputs.

To develop the temporal allocation factors, the approach taken was based on selecting median heat input values corresponding to a given unit/temporal period combination. The rationale here is that the middle of the range of operating values will be typical of the period it represents, and uninfluenced by extremes of operation or upset events. Middle values were selected for each combination of unit, month of year, day type (weekday, Saturday, or Sunday) and hour of day.

The term middle value is used here because we chose to deviate from the definition of median in two ways. First, we chose to assume that null heat input values and missing records indicated no operation. Therefore, it was determined how many records *should* exist for each month and day type over the 2001 through 2003 period, and the middle position of that range was determined based on that number. Second, where an even number of values was expected, rather than taking the mean of the two values nearest the middle, we simply chose the lower of the two.

As an example of how the middle values were selected, note that there were sixty nine January weekdays in 2001 through 2003, hence for any given hour of the day sixty nine opportunities for a unit to report January weekday heat input values. The January weekday middle value for a given hour and unit is taken by sorting the corresponding reported values in descending order, and selecting the value in the thirty fifth slot as the desired middle value. If there are fewer than thirty five values reported, consistent with our assumptions about missing data, the middle value is set to zero.

Once the middle values have been selected, normalizing values are generated. This is accomplished by calculating what the total annual heat input for each unit would be if it operated every hour of the 2002 base year at the middle value appropriate for each hour, day type and month throughout the year.

To this point, all processing has been done on CEM data with its facility and unit identifiers. To integrate this data with a NIF inventory, NIF emission unit identifiers have to be matched to the profiling factors via the cross-reference table described earlier. While this cross reference matches CEM boilers to NIF emission units, the correspondence is not always one-to-one. Addressing this issue is straightforward in the case of one CEM boiler with multiple corresponding NIF emission units; simply duplicate the CEM-based profile data for each corresponding NIF emission unit identifier. In the case of multiple CEM boilers corresponding to a single NIF emission unit, the middle values of each month, day type and hour of day for all corresponding boilers were aggregated, as were the normalizing values. The aggregate values result in a composite profile, weighted by heat input, which is then matched to the NIF emission unit identifier.

Each of these matched NIF emission units now has has one annual normalizing value and a total of eight hundred sixty four middle values (12 months x 3 day types x 24 hours), each of which is specific to a combination of month, day type and hour of day. Generating an hourly emission record is now a relatively straightforward exercise in data matching. Given an annual emission record for a cross-referenced NIF emission unit, the fraction of the annual emissions allocated to a given hour is determined by multiplying the annual emission value by the middle value appropriate to the hour, day type, month and emission unit for which the record is being generated, and dividing by the emission unit's normalizing value.

The hourly NIF emission records generated this way are then appended to the original NIF point source file, and generation of the modeling inventory proceeds as usual, relying on the emission processor's temporal allocation routines to give priority to hourly records over records covering longer periods.

From the outputs of the IPM model, future year emissions can be derived for electrical generation units (EGUs) in both annual and summer/non-summer period emissions. To use the shorter period emission records, rather than the annual records as for the base inventory, the middle values are chosen as above, but two sets of normalizing values are calculated for each unit. One set reflects operation at the heat input middle values appropriate for each hour, day type and month over the summer period, the other set reflects operation over the non-summer period. Emissions are calculated as before, using the period-specific emission records and normalizing values rather than their annual counterparts.

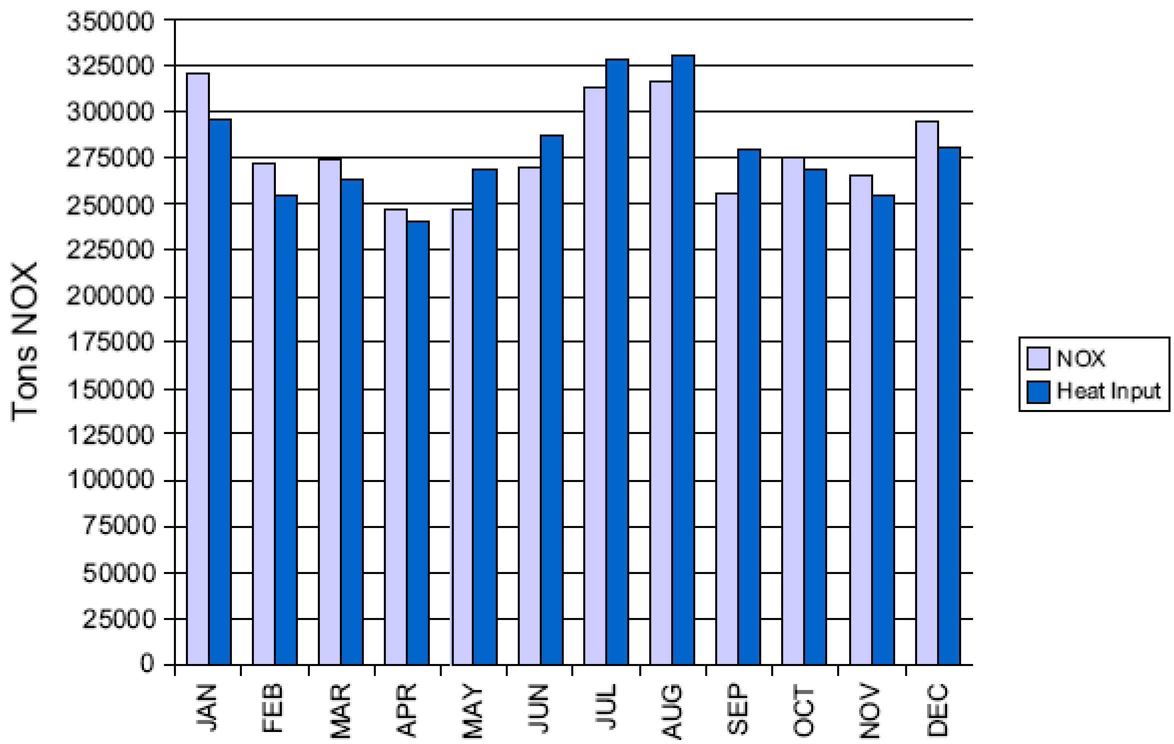
ANALYSIS OF SEASONAL EFFECTS

Other work with CEM-based data[2] has shown that, particularly when aggregated to the state or regional level, monthly CEM heat inputs do not correlate well with CEM SO2 and NOx data. Individual units have also been shown to exhibit this behavior.

To determine the extent of this problem under the median-based, unit-specific approach, the same process of developing unit, month, day and hour specific temporal profiles was performed using the CEM reported SO2 and NOx data in place of heat input. The comparison was performed on units which reported both heat and emissions data, and which could be matched to NIF data via the cross reference table.

2002 CEM reported NOx and SO2 emissions were allocated by unit using both the heat input based profile and the appropriate emissions based profile. Figures 2 and 3 below show the monthly comparisons aggregated to the national level.

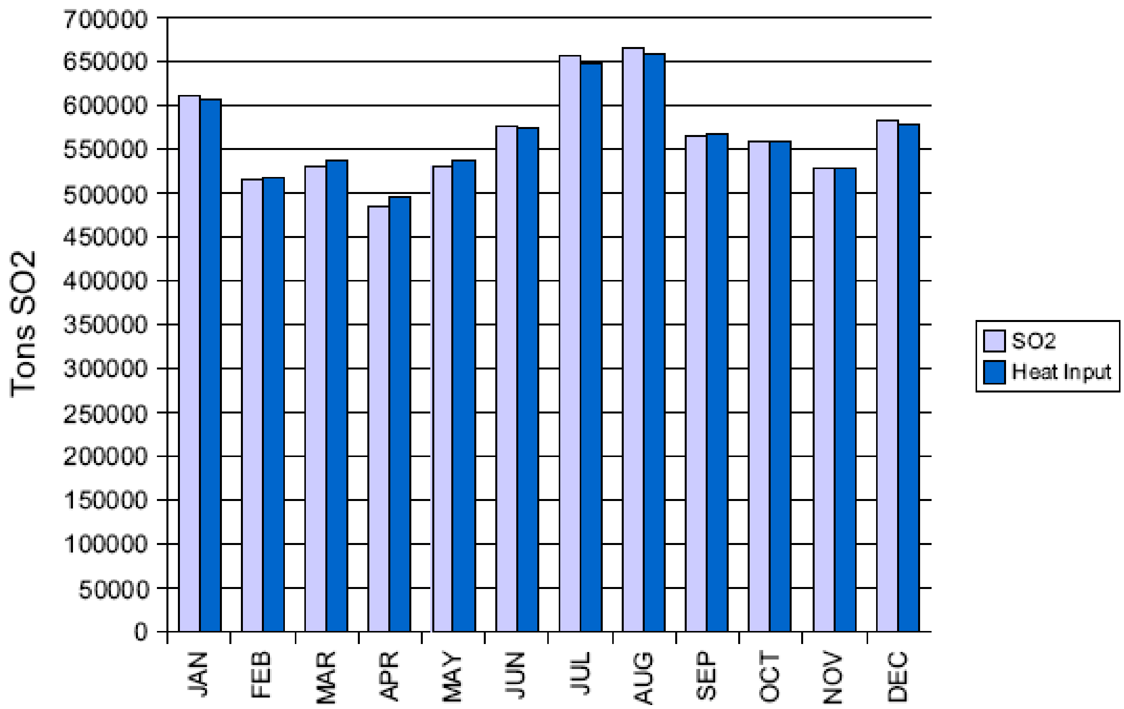
Figure 2. Temporal distribution of 2002 CEM NOx emissions by CEM heat input vs. CEM NOx.



Temporal allocation by heat input, rather than CEM reported NOx, does result in NOx levels that are higher from May through September and lower the rest of the year. This is not surprising, given May through September NOx emission trading budgets and the seasonal application of NOx controls. Witl the implementation of the CAIR rules and year-around NOx trading budgets, the expectation is for more year-around operation of controls and a resulting attenuation of the seasonal differences in evidence above.

Also, as mentioned earlier, future year emissions for EGUs are generated for summer and non-summe periods, and these summer and non-summer period emission records are what is processed for future years. To the extent that the seasonal emission variation is addressed by these periodic emissions records, normalizing to, and allocating within, these periods will propagate those corrections.

Figure 3. Temporal distribution of 2002 CEM SO2 emissions by CEM heat input vs. CEM SO2.



For SO2, the effect of temporal allocation using heat input is to moderate SO2 emissions slightly. The fact that the summer deviation between heat input and SO2 is generally in the opposite direction of that between heat input and NOx suggests that further improvements would require per-pollutant temporal activity surrogates or improvements in modeling of emission controls.

As another indicator of how well the heat and pollutant based profiles track one another, the fraction of the total 2002 CEM emissions that would be reallocated by unit from one month to another when switching between heat input basis and pollutant basis was calculated according to Equation 1 below.

Equation (1)

$$\sum_{u \in units} \sum_{m=Jan}^{Dec} \frac{|ht_{u,m} - poll_{u,m}| * E_u}{2}$$

where

$ht_{u,m}$ is the heat-based temporal profile for unit u, month m
$poll_{u,m}$ is the emissions-based temporal profile for unit u, month m
E_u is the total 2002 CEM-reported emissions for unit u

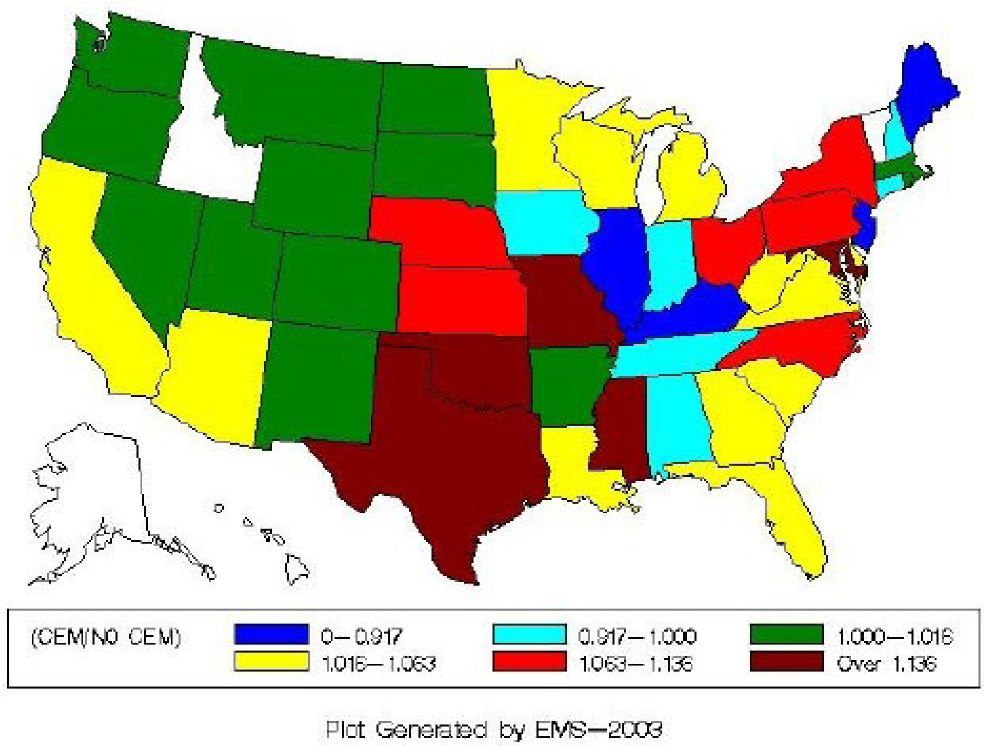
Note that variation is calculated per unit then aggregated to prevent canceling effects of compensating variations across units. For SO2, approximately 2.8% of the total 2002 emissions would be reallocated by switching between heat input and emissions based profiles. For NOx that value is 5.0%.

For each pollutant, examining the differences between heat and pollutant-based profiles for individual units does reveal a small number of units with significant variation. Most of these have relatively low emissions, however there are some units with both significant emissions and significant variation between heat and pollutant based profiles. Further investigation is planned to try to identify the source of these discrepancies.

RESULTS

The figure below shows how EGU NOx emissions at the state level change for a July weekday when applying the CEM-based unit-specific temporal profiles. Note that the temporal allocation scheme used as a basis for comparison reflects changes made several years ago when LADCO modified the default EGU temporal profiles to better reflect aggregated CEM data, and assigned certain base load EGUs a profile reflecting 24x7 operation.

Figure 4. Ratio of July 12, 2002 EGU NOx with and without CEM-based temporal allocation



Figures 5 through 8 below compare diurnal allocation of emissions in several states for a July weekday according to three different methods. The method designated EPA_DEFA applies the default single set of temporal profiles to all EGUs. The NO_CEM method is the LADCO modifications to the defaults as described above. The WITH_CEM method applies the unit-specific temporal allocation based on the CEM data.

Figure 5. July 12, 2002 hourly NOx for Georgia EGUs

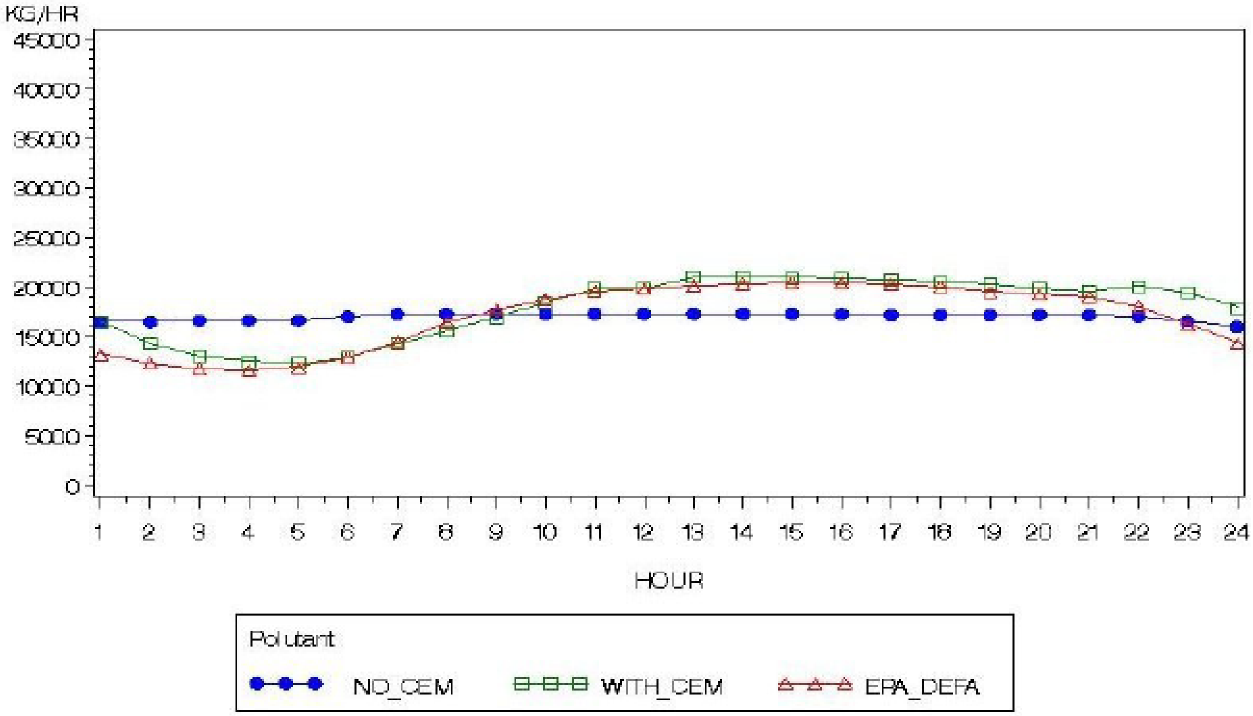


Figure 6. July 12, 2002 hourly NOx for Illinois EGUs

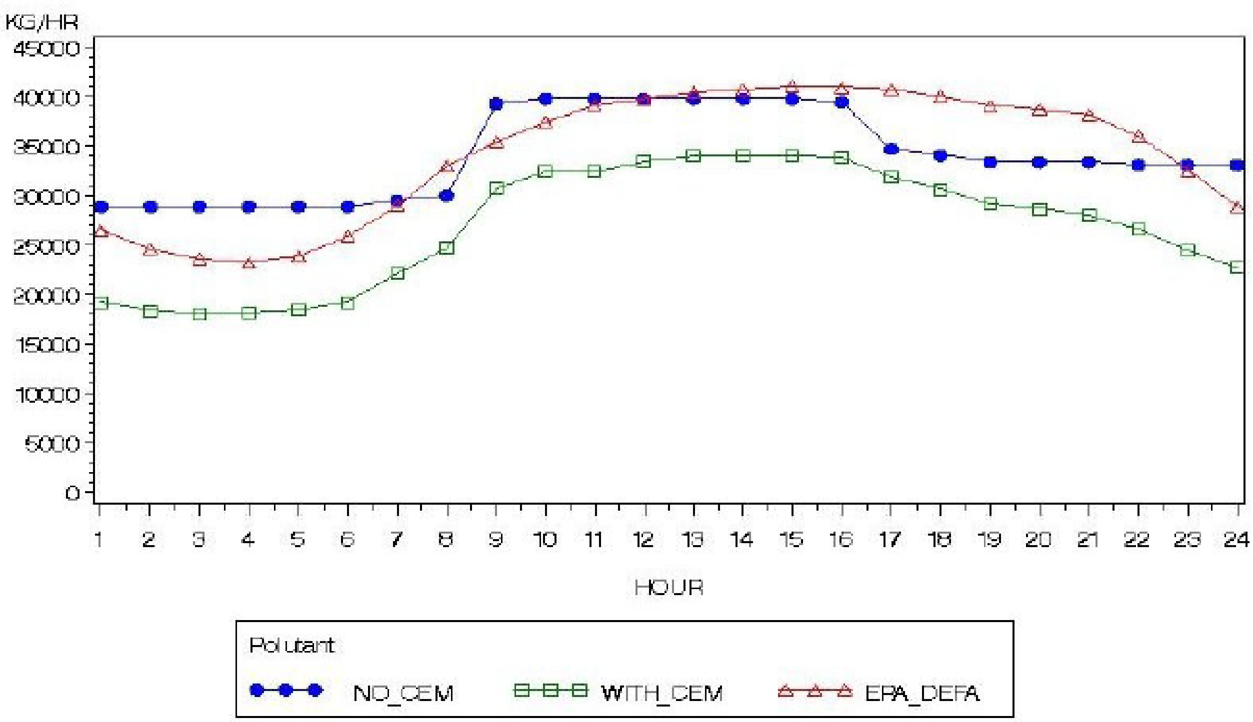


Figure 7. July 12, 2002 hourly NOx for Michigan EGUs

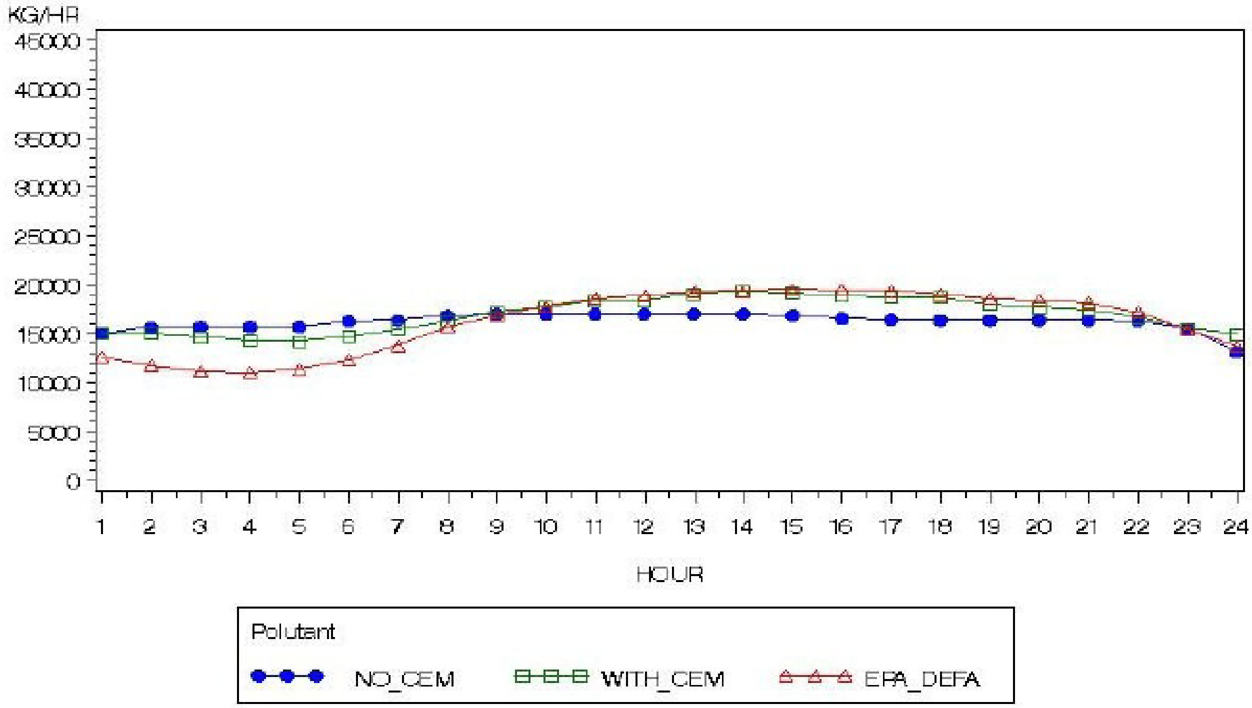
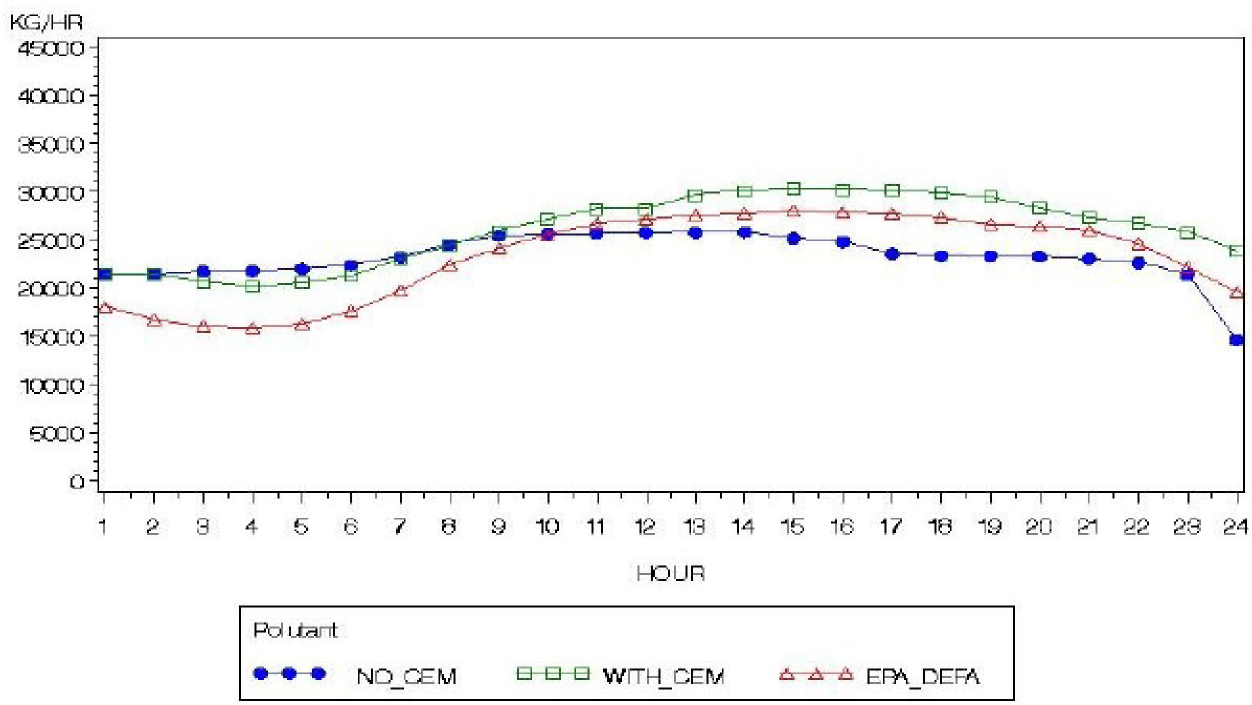


Figure 8. July 12, 2002 hourly NOx for Pennsylvania EGUs



Figures 9 through 12 below show monthly weekday, Saturday and Sunday daily NOX totals for 2002 and 2009 for individual facilities with and without CEM based temporal allocation.

Figure 9. Despite a reasonable overall correspondence, differences between temporal allocation schemes of 10 TPD for weekdays and 20 TPD on weekends are common for this large source in 2002.

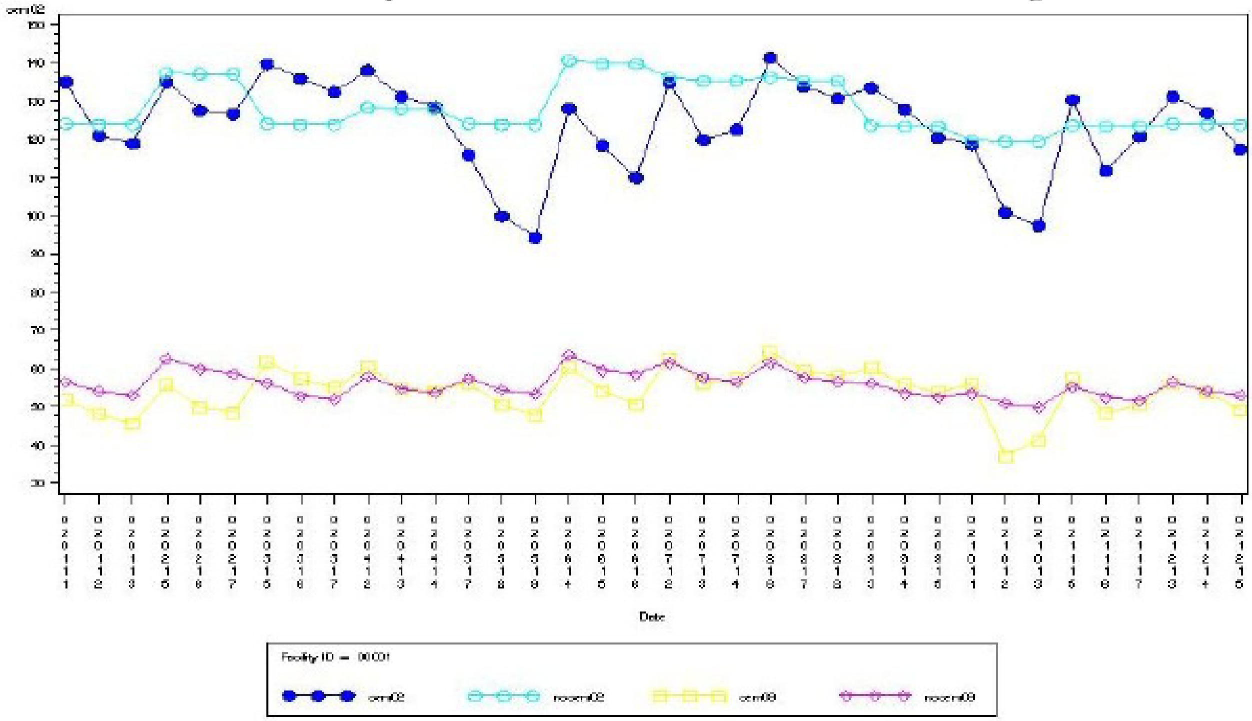


Figure 10. Significant weekday/weekend variability is apparent when allocated with CEM data.

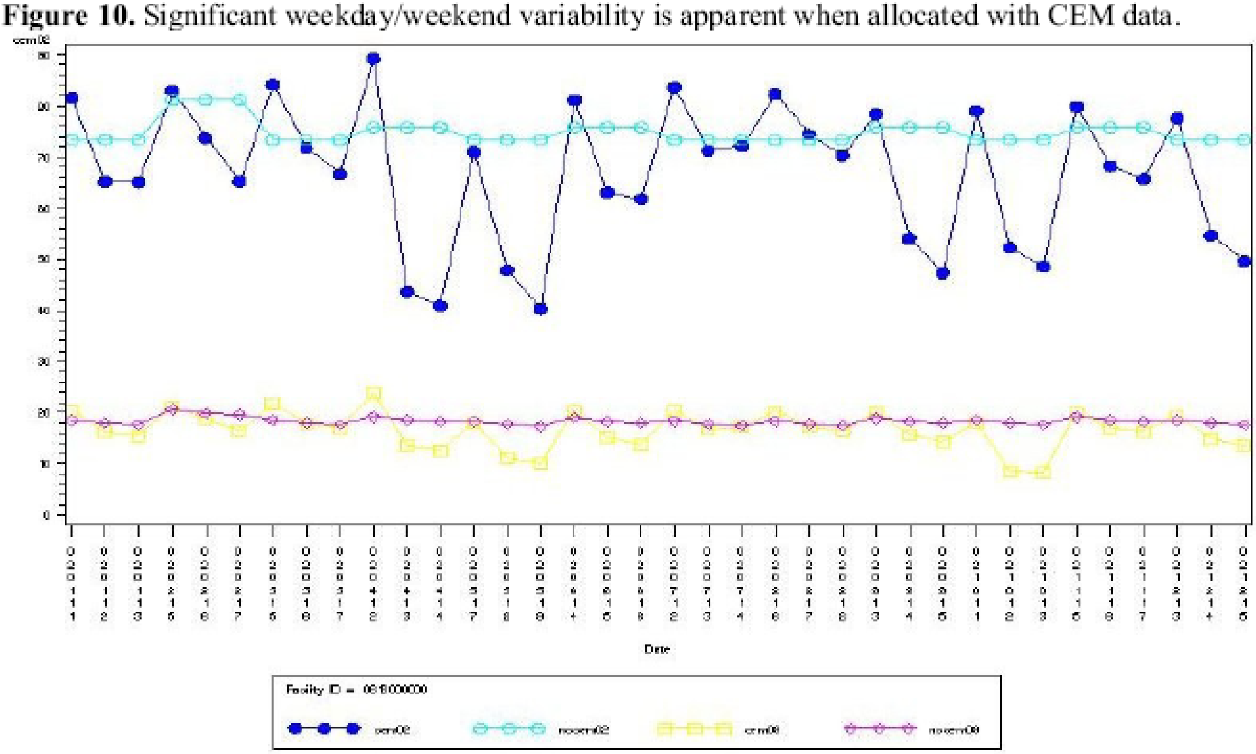


Figure 11. With a median-based approach over three years, the April drop cannot be due to a single outage, but is strongly suggestive of a maintenance pattern.

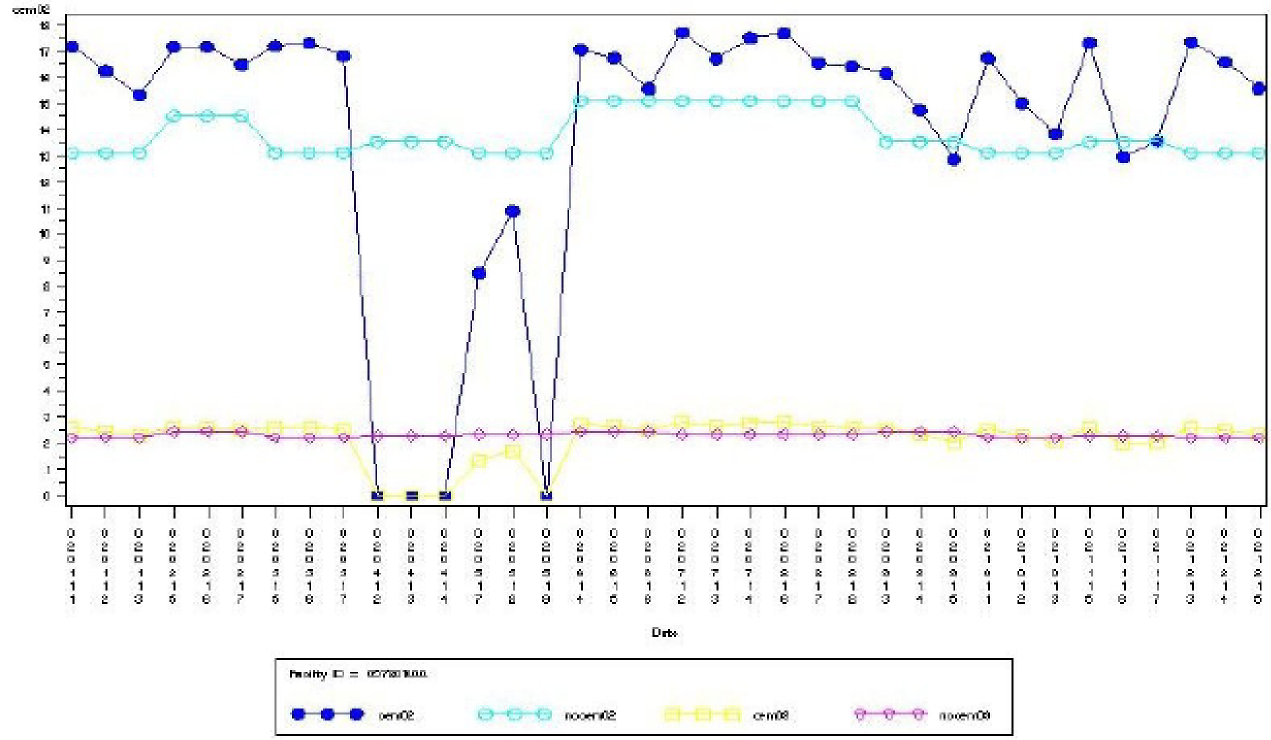
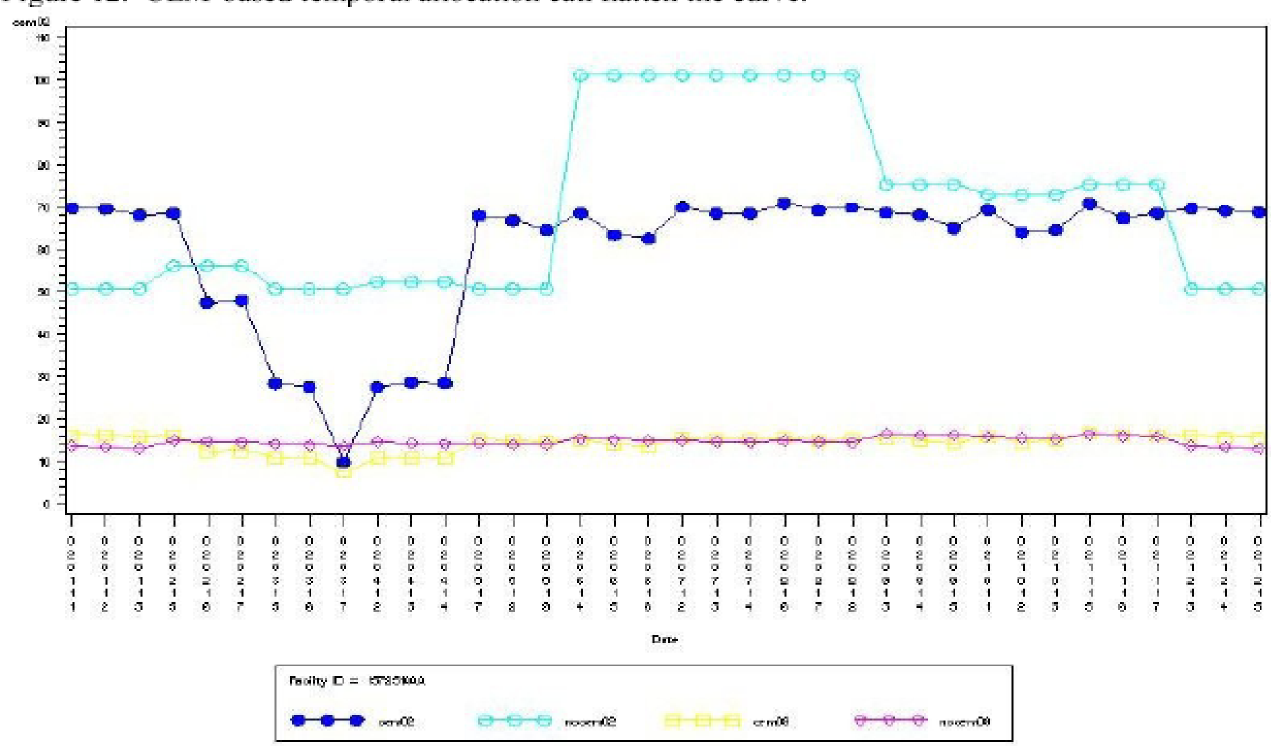


Figure 12. CEM-based temporal allocation can flatten the curve.



CONCLUSIONS AND RECOMMENDATIONS

As a proof of concept for automated application of CEM data to national emission inventories, several significant success can be noted. Starting with the load of eighty eight million CEM records, through generation of unit-specific temporal profiles and matching to a nationwide NIF point source inventory, and finishing with the output of 13.7 million NIF-format hourly emission records, the run takes well under a week on a sub-$1000 computer. Most of the processing time is spent developing the unit-specific temporal profiles, processing which need not be repeated unless the underlying CEM data, the normalizing period(s), or the CEM-to-NIF cross reference changes. Applying the profiles to an updated national inventory and generating updated hourly emissions records takes less than a day. Future year emissions data generated from alternative nationwide IPM runs has been processed in a couple hours.

Given the relatively modest resource requirements, the fraction of the modeling inventory for ozone precursors and particulates that can be matched to CEM data, and the observed quantitative differences between CEM-based and traditional temporal allocation methods, a strong case exists for more widespread adoption of a CEM based approach to temporal allocation.

Heat input is the best available single surrogate for multiple pollutants, though improvement might be realized via a CEM reported emissions-based approach for SO2 and NOx, or improvements to modeling of emission controls.

The median-based approach minimizes the effects of upset events or extremes of operation, and generally results in temporal profiles that can be considered representative of typical operating patterns. The exceptions are units used so infrequently as to rarely or never give non-zero middle values. We have reverted to traditional methods for these units. While the total annual emissions from these infrequently used units is not large, the correlation between days with high electric demand and high ozone potential suggests this as an area for further improvement.

The most obvious opportunity for improvement lies in improving the cross-reference between CEM and NIF data. Improved temporal allocation is only one of many aspects of inventory development and modeling that would benefit from improved integration of the high-quality, high-resolution CEM data with emission inventories. Though it is the best currently available, the cross reference used in this project must be seen as an independent, one-time effort. Provision should now be made for a CEM to NIF cross-reference to be developed and maintained as a cooperative effort among the interested parties.

One possible approach would be to add fields for CEM unit identifiers to the NIF emission unit and release point records (the cross reference used in this project matched data at the emission unit level, but much of the CEM data corresponds better to a release point). Incorporating the cross-reference into the NIF data would make data matching more direct and transparent for users of inventory data, and it would provide opportunity and motivation for emitting facilities and inventory developers to review and improve the correlation between CEM and NIF data.

It is hoped this demonstration of the improvements currently available from integrating high-resolution CEM data with emission inventories, and the low resource requirements for doing so, will provide further impetus for process changes that will allow better utilization of CEM data by inventory developers and modelers.

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KEYWORDS

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