A New Tool for Integrated Emissions and Controls Strategies Analysis

David C Misenheimer
U.S. Environmental Protection Agency
709 T.W. Alexander Drive (C439-02)
Research Triangle Park, NC 27711

Darryl Weatherhead
U.S. Environmental Protection Agency
709 T.W. Alexander Drive (C439-02)
Research Triangle Park, NC 27711

Larry Sorrels
U.S. Environmental Protection Agency
709 T.W. Alexander Drive (C439-02)
Research Triangle Park, NC 27711

Marc Houyoux
U.S. Environmental Protection Agency
709 T.W. Alexander Drive (C339-02)
Research Triangle Park, NC 27711

Alison Eyth
UNC Institute for the Environment
654 Bank of America Plaza
137 E. Franklin St., CB#6116
Chapel Hill, NC 27599-6116

ABSTRACT

EPA is developing the Control Strategy Tool (CoST) to allow users to generate emission inventories with additional controls applied on top of a future-year base inventory. COST will track information about control measures, their costs, and the types of emissions sources to which they apply. It will also compute control strategies that match control measures to emission sources using algorithms such as “maximum emissions reduction” and “least cost”. The result of a control strategy will contain information that specifies the estimated cost and emissions reduction achieved for each control measure-source combination. The resulting control strategy can be exported to a CSV file as a table; viewed in a graphical table that supports sorting, filtering, and plotting; or it can exported to an emissions inventory file that can be input to SMOKE.

EPA will prepare the initial version of CoST within the Emissions Modeling Framework (EMF), which is under development to solve the many long-standing difficulties of complex emissions modeling. By providing this new tool integrated within the EMF, it will facilitate a level of collaboration between control strategy development and emission inventory modeling that was not previously possible. CoST will replace AirControlNET, a software tool that EPA developed previously. The reasons for replacing AirControlNET are to provide a more flexible software platform, support multi-pollutant analyses (including criteria pollutants and precursors, HAPs, and climate change gases), improve transparency of the underlying data and assumptions, allow eased import/export and editing of the underlying data, and enhance connectivity with other related software tools and datasets.

INTRODUCTION

EPA's Health and Environmental Impacts Division (HEID) is developing a new software tool to estimate the emission reductions from emission control strategies that could be applied to sources of air pollution across geographic areas. The main purpose of the tool is to support national and regional-scale multi-pollutant analyses, such as the National Ambient Air Quality Standards, although the software may also prove useful for some urban and local-scale analyses. Note that the software is an engineering cost tool for creating controlled inventories and is not intended to model emissions trading strategies, nor is it an economic impact tool. The new software is intended to replace older software called AirControlNET (ACN), which has similar capabilities and was first released in 1999. Following its initial release, ACN was upgraded several times; but new requirements to interface with more recently developed tools and databases have made the FoxPro computing platform insufficient to meet today's needs. Therefore, this new control strategy tool is being designed using a new platform that supports the additional flexibility and functionality that is needed to support current and upcoming analysis activities at EPA's Office of Air Quality Planning and Standards. This tool will also support multi-pollutant analyses, including criteria pollutants and precursors, HAPs, and climate change gases.

PROBLEM STATEMENT

EPA and other agencies and organizations concerned with air quality management often undertake studies of various strategies for improving air quality to meet certain goals. Typical steps in such a study are as follows:

Setup

- **Step 1 - Identify Year(s) for Calculating Emission Reductions & Costs; Process Base Case Projection Emission Inventories**
- **Step 2 - Identify Candidate Control Measures**
- **Step 3 - Identify Scope of Each Control**

(e.g., geographic areas, emission source types - defined by source category codes (SCC), pollutants to which each control applies, etc.)

- **Step 4 - Gather Data for Calculating Emission Reductions & Estimated Costs, including:**
  - **Percent Reduction** for each Year/Control/SCC/Geog Area/Pollutant
  - **Rule Penetration (RP)** for each (primarily for area & mobile source controls)
  - **Rule Effectiveness (RE)** for each
  - **Estimated Costs** for each (e.g., $2,500/ton NOx reduced)

- **Step 5 - Calculate Effective Emission Reductions**
  (e.g., where multiple controls are to be combined)

Analysis

- **Step 1 - Select Candidate Controls to "Apply"**
  For each Scenario/Year/Geographic Area:
  - Identify Initial Criteria for Selecting Controls
    - Cost/ton cutoff, whether technologies are part of a likely future rule, etc
  - Select Tentative Controls, Evaluate Resulting Reductions & Costs
    - Apply controls to emission inventory
    - Look at emission reductions, benefits, costs and decide whether to include these controls in final analysis

- **Step 2 - Apply Controls**

For each Scenario/Year/Geographic Area, Apply Controls and Prepare Control Case Data Set, Including:

- Scenario
- Year
- ST/Cnty FIPS
- Pollutant
- Control (or combined controls)Base case emissions
- Emission reductions
- Reduction %
- Cost
- Cost/Ton

Results

- **Final Step - Prepare Outputs (Reports, Briefing Charts, etc)**
  Example:
  - Summary Reports
  - Briefing Charts
  - Maps

To manage resources effectively, agencies need a software tool to enable personnel to accomplish the steps above through a process that minimizes time and effort and ensures reliable results. The purpose of the CoST project is to provide a tool that supports these activities.

APPROACH

We began the project by completing the following tasks:

- Identified the needs of the user community within EPA's OAQPS
- Assessed the current performance of AirControlNET and prepared recommendations for improvements
- Prepared recommendations for a new control strategy tool, including software platform and database format
- Prepared a design document
- Created a prototype version of the software tool

The prototype is currently being used for preliminary studies to assess its effectiveness for meeting EPA's needs. The goal of the prototype is to help EPA consider how the tool will evolve so that EPA can evaluate it and determine the long-term plan for this software. Much of the planned infrastructure for the software is available in the prototype, but a number of potential enhancements have been identified and will be implemented according to recently identified priorities.

The prototype version is fully integrated with EPA's Emission Modeling Framework (EMF), which is used to manage emission inventory and modeling related data. This approach could facilitate a significantly improved level of collaboration between control strategy development and emission inventory modeling. Control measure data can be entered or viewed via the Graphical User Interface (GUI), or it can be imported from files that are provided in a specific CSV format. Control measures contain information about control technologies and programs that are available to control emissions, the source categories they apply to, the control efficiencies achieved, and their costs.

EPA is designing CoST to include information that identifies the types of emission sources (e.g., source categories, production equipment) to which each control measure can be applied. This information can be viewed and edited to ensure greater transparency and easier updates. Once a control strategy is selected for analysis, a controlled inventory can be generated from this information, which can be input to SMOKE or for other purposes. SMOKE ('Sparse Matrix Operator Kernel Emissions') is an emissions modeling system for preparing model-ready inputs. The development of the control strategy software within the EMF enables the software to take advantage of EMF's multi-user client-server-based platform. In addition, there are a number of areas in which enhancements to the EMF will benefit CoST, and vice versa.

We are currently testing the software with data from recent and ongoing air quality analyses. We are continuing to prioritize and add control strategy related enhancements to the software according to the needs of upcoming analyses. Modifications to the software are being implemented in priority order as available resources allow. An ongoing parallel effort is to enhance the control measures database for criteria pollutants. We have begun a limited effort to compile data concerning co-benefits and dis-benefits of

traditional control measures on greenhouse climate change gases. Later in 2007, we will begin populating the database for HAPs.

Use Cases and Goals

This section provides some context for the system architecture design by describing the use cases and goals for the software as discussed early in the design process. Use cases describe ways in which the new software is expected to be used, in terms that are familiar to most potential users. The use cases were developed during a series of meetings with the EPA control strategy tool development team. From the use cases, a set of high-level goals was extracted.

High Priority Use Cases

The following use cases were identified to have a high priority:

1. **Add new and edit existing control measures:** EPA users must be able to input new control measures (e.g. control devices and in some cases control programs), and relevant information about them such as expected control efficiencies. Additionally, they must be able to edit existing control measure information to correct erroneous data and update data where newer information is available.
2. **Add emission inventories:** EPA users must be able to add new emission inventories to the system and develop control strategy analyses using these.
3. **Examine information about a control measure:** EPA users must be able to see information about a control measure, including control efficiencies, the SCCs to which the measure applies, and how the costs are computed for the measure. Other important information to view is documentation regarding the source of data that was used to populate information about the control measure.
4. **Perform a least-cost analysis:** A very important control strategy analysis to perform is a least-cost analysis. For example, if a 25% reduction in NOx is required to meet ambient air quality targets, the new tool needs to estimate the least cost strategy to meet this target. In some cases, it is desirable to specify a constraint that all sources of a particular type are controlled in the same way, or that controls cannot be applied to a specified sector. Note that the percent reduction should be specified in terms of the total emissions in the inventory, as opposed to the controllable emissions specification that was used in AirControlNET. It may be useful to specify a subset of sources in the inventory to consider for an analysis, such as considering only a specific sector, set of SCCs, or geographic region (e.g. a non-attainment area or MSA).
5. **Perform a broad scale analysis of controls:** In this case, the air quality planner would pick an industry or sector within a region and apply the same controls to it and assess the resulting cost. For example, “What is the estimated cost and emissions reduction achieved to install scrubbers on all power plants that don’t have them?”

6. **Export data for input to SMOKE:** The results of the strategy need to be exported in a form usable by SMOKE as a controlled inventory. Currently, the "One Record per Line" (ORL) format is used by SMOKE for both toxics and criteria inventories and should be the initial format that is supported. Exporting a controlled inventory with information on which measures are applied to which sources is preferred to a control packet approach because the use of control packets leaves more room for inconsistencies in implementation between the control strategy software and SMOKE regarding which sources are controlled and to what extent. In addition, the development of a full controlled inventory facilitates analyses of that inventory in its entirety, which is difficult to accomplish using a control packet-based approach.

7. **Develop graphs, maps, or tables of strategy results:** It is useful to present the results of the analysis including the emissions reductions and costs using various types of tables, graphs, and plots. The data may be summarized at different levels (e.g. state, county, SCC prior to displaying the tables, maps, or plots. It is also important to be able to export the result of the analysis so that available commercial plotting or mapping program can be used for further analysis or for preparation of presentation materials.

8. **Perform a sensitivity analysis:** A planner wants to see the impacts on the cost [and emission reduction] of modifying parameters such as discount/interest rate (e.g., 3% vs. 7%), energy costs, labor costs, and uncertainty levels in the control efficiencies or emissions estimates.

9. **Develop cost curve plots, tables, and equations:** It would be very useful to develop a cost curve that shows the least cost possible to achieve various levels of control. It is also useful to parameterize the cost curve to minimize storage of the cost points and facilitate review of results for different points other than those explicitly computed when the curve was generated.

10. **Analysis across sectors:** In some cases, it may be useful to perform analyses across sectors. For example, when running the Response Surface Model (RSM), there is a factor which groups non-EGU point with area. Therefore, there is a need to compute total reductions for sectors, total controllable emissions, total cost, and total sector emissions. In addition, it may be required to consider information from both sectors simultaneously in a least cost analysis. It will be helpful if area fugitive dust (afdust), fires, and other area sources (oarea) can be incorporated into the same least cost analysis, and if pfdust and non-EGU can be grouped together (note that they both have plant, point, stack, segment, and pollutant(s) for keys). Ideally these sources would be in a single inventory file and would be exported to individual data files as part of export prior to modeling.

11. **PM NAAQS Case Study:** During our design discussions, some steps that were taken by team members to implement the recently completed PM NAAQS analysis were discussed. The steps were described as follows:

    a. Choose design values that exceed proposed standard (e.g., 15ppm for PM)
    b. Find a county that appears to exceed the standard
    c. Determine if the county is part of an MSA/CBSA?

d. If so, what other counties are in the MSA/CBSA?
e. Run a strategy analysis on this region to see if the target air quality objective was achieved.
f. Generally, look at counties in the region. It is desirable to visually see counties already included in the analysis and see the level of emissions for various pollutants/sectors in nearby counties. It would be very helpful to be able to easily identify counties that are likely to contribute significantly to nearby air quality monitor exceedences based on their proximity to the exceeding county, position up-wind according to prevailing wind direction, and level of emissions for pollutants/sectors suspected of contributing to the exceedence.
    1. It is useful to see emission densities (e.g., tons/sq mile, tons/person, or total tons for the county) computed for various major emissions sectors in neighboring counties.
    2. It is often useful to pick counties with high emissions for certain combinations of sectors and pollutants.
g. It is sometimes helpful to define sub-regions that cover a larger area for more of a regional strategy.

Medium Priority Use Cases

The following use cases were identified to have a medium priority, and will be targeted later in the development of the tool:

1. Perform a multi-pollutant least cost analysis, in which more than one pollutant is targeted for reduction.
2. Perform an uncertainty analysis on results of a cost analysis using Monte Carlo or other methods.
3. Analyze a large number of control strategies at one time using a command line or batch mode, or at a minimum the ability to start running multiple strategies from the GUI.
4. Simulate a scenario for which a emissions trading program is in place.
5. Prepare standard reports as needed based on control strategy results.
6. Examine metadata for a cost analysis.
7. Examine an audit trail for multiple control strategy analyses.
8. Conduct analyses at more disaggregated industry levels than in current version, such as by individual SCC.
9. Perform a sensitivity analysis in which specific inventory records are adjusted (e.g., information regarding emissions or existing controls).
10. Export cost analysis data in a form usable by EMPAX.
11. Support for innovative measures. For example, if a public or public interest, or even private, entity spent X $ on an outreach effort, and that effort led to a Y % reduction in consumer natural gas usage, what would be the effect on emissions?

If we spent X$ on an outreach effort to promote aqueous solvents, and that reduced solvent usage by Y%, what are the resulting emission reductions. What percent of the inventory do these reductions represent?

12. Source level controls. It would be useful to be able to develop source by source percent reduction level application. If an SCC- or POD-based (i.e., group of related SCCs) control level is unachievable, the tool should select the next highest or lowest value for an individual source, while retaining the more generic application hierarchy of control measures within that POD
13. Import IPM control information & mobile source information. For example, bring in controlled emissions and control information for those sectors and then be able to apply additional controls to those, especially given that for EGUs in particular, the ability to be able to apply additional emissions control measures is very useful. Jim: Do you want to say anything about measures for future automotive technologies such as duel-fueled vehicles, alt-fueled vehicles, hybrids and the like?

High Level Goals for the New Software

The following high-level goals for this control strategy tool were based on the use cases:

- The software will be able to apply additional controls to a base case inventory to prepare. a future year inventory that contains the best estimates of growth and control programs expected to be in place in that year based on programs currently "on the books".
- The software will estimate the cost (when all required information is available) – both annualized capital and operating, along with the emissions reductions achieved from applying additional controls to the inventory.
- The future year base inventory to which the additional controls will be applied, will be read in from the extended ORL format, although other formats such as NIF may be supported later.
- Inventories with both toxics and criteria must be supported initially at least for emissions reductions, whereas cost computations for toxics will be supported later as more cost data becomes available.
- A future year inventory that implements the derived strategy (i.e., the future year "control case" inventory) will be output in an extended ORL format for processing by SMOKE (other formats may be supported later).
- The software should support national, regional, and urban scale analyses.
- The software should eventually support all source sectors (e.g., non EGU-point, EGU-point, stationary area, mobile), although it will first be used for non-utility point and stationary area.
- The software should have the option of running on a single desktop computer, or in a client-server mode.
- The software should interface with the EMF.

- Instructive and clarifying plots and tables should be produced.
- In order for the software to be able to properly determine which additional controls can be added to a source, the input inventories used for the analyses will need to explicitly specify detailed information about existing controls. [Note: This is not a software requirement but rather is a data requirement of the emission inventory that will impact the effective application of the software.]
- Cost equations should be easily visible to users.
- The software should support the specification of limits of capacities (e.g., maximum boiler capacity) to which a control measure applies.
- It would be useful for the new control strategy software to run both as a desktop tool and as a client-server system.
- Eventually, the new software may also apply growth factors so that the future year base case inventory could be generated directly by the software using the NEI as the input.
- A method for including estimates of emission reductions of elemental carbon (EC) and organic carbon (OC) will likely be needed and allow consideration for these data which are not stored in currently available inventories.

System Architecture

Software Development Platform

The system architecture describes how the software will be deployed on target computers, and the overall development platform to be used. As part of Task 2, a consensus was reached that the best development platform for the new software is Java. Some advantages of using Java are as follows:

- Java has built-in tools to support both desktop and client-server computing;
- Java DataBase Connectivity (JDBC) can be used to access various types of full-featured relational databases;
- interoperability with ASAP, the EMF, PHOENIX, and MIMS could be achieved;
- Java's object-oriented nature makes it easy to extend as the software requirements grow over time;
- Java has a full-featured GUI development library;
- Java applications run on Windows, Linux, and other platforms without recompilation;
- There are many open source libraries written in Java that are available for data formatting, scientific computing, and optimization;
- Java has support for multi-threading so that different lines of processing can be followed simultaneously within the software;
- Existing Java-based EmisView/EMF emission inventory importer code can be reused; and
- MIMS Analysis Engine Java code would prove useful for tables and plots.

CONCLUSION

This software tool will provide an effective, efficient means for assessing the impact and cost of various control strategy analyses and will allow comparison across multiple pollutants and objectives. It will also provide greater transparency of the underlying data and assumptions and eased editing and import/export of input data.

KEY WORDS

Emission control strategies
Emissions modeling
Emission reductions
Engineering cost
Control measures
Control technologies

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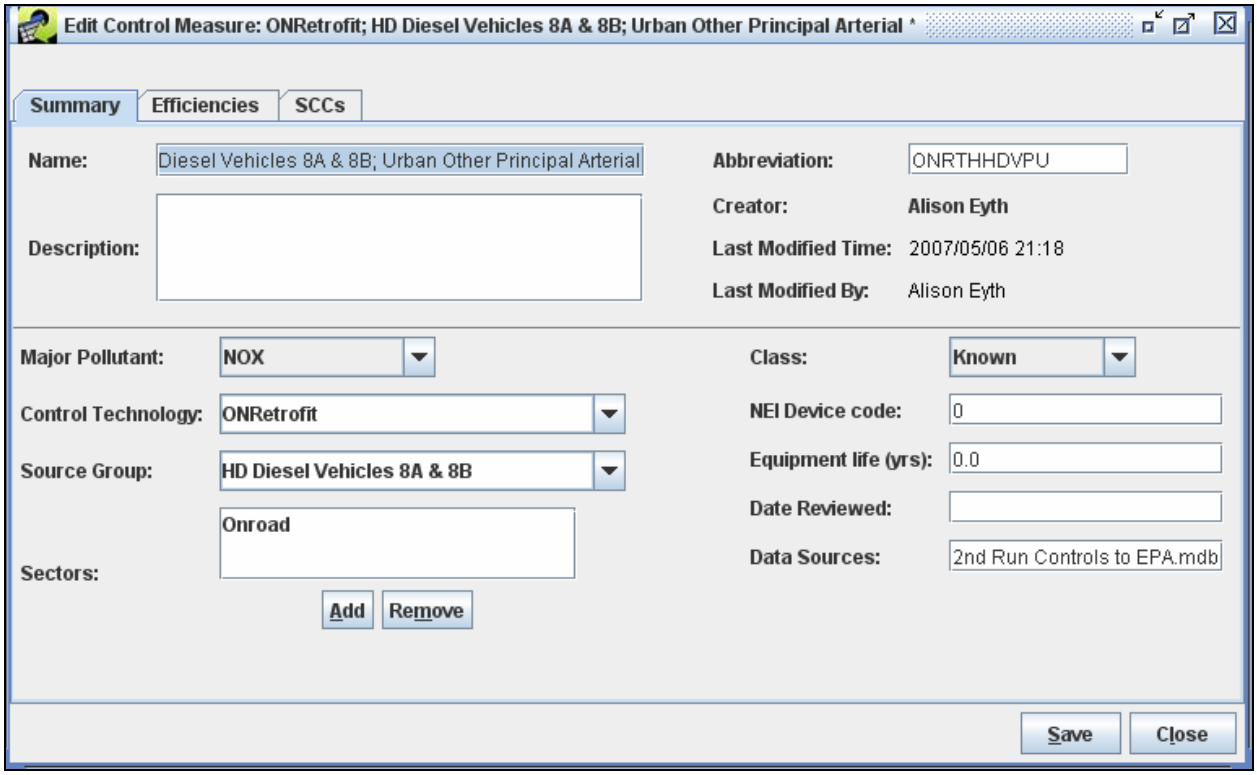
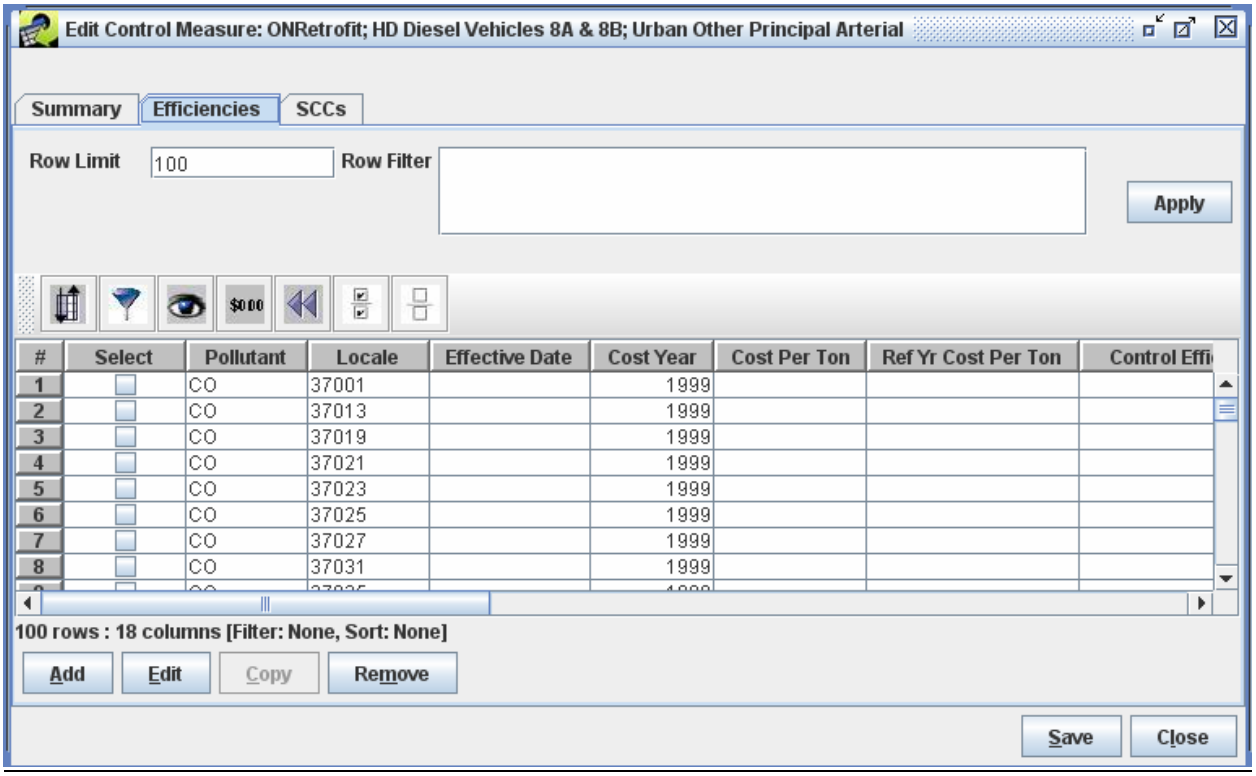
SAMPLE SCREEN SHOTS

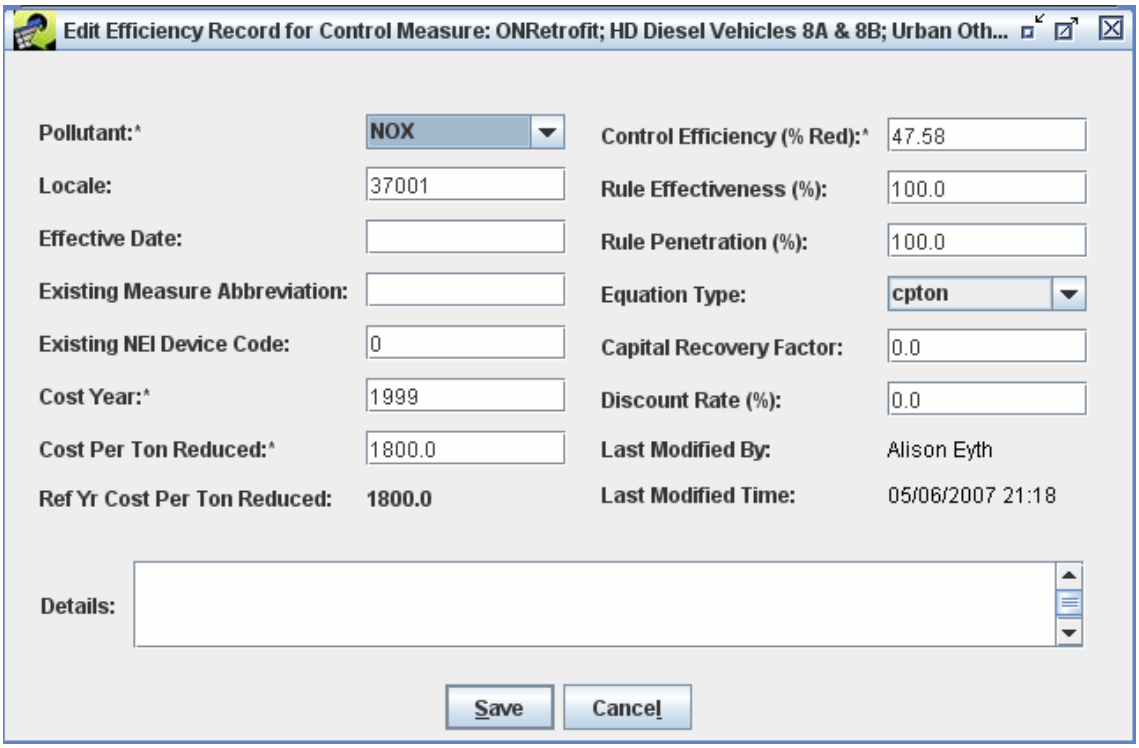
Control Measure Editor – Summary Tab



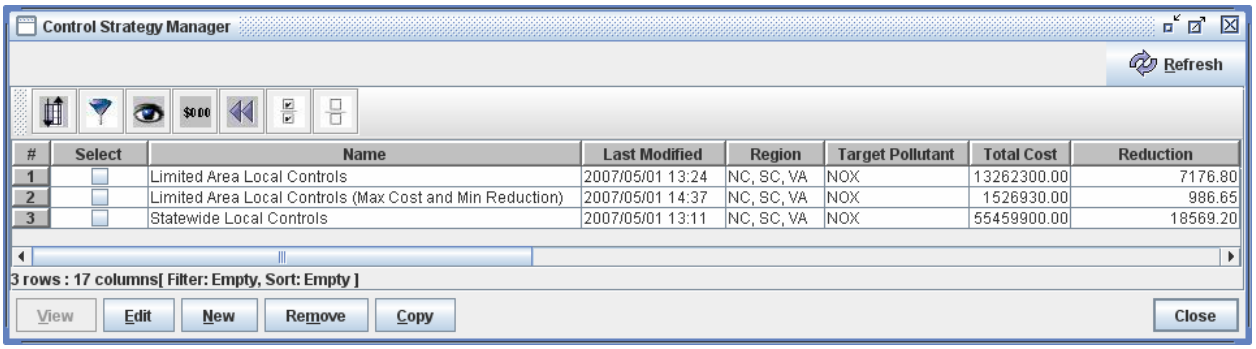
Control Measure Editor – Efficiencies Tab



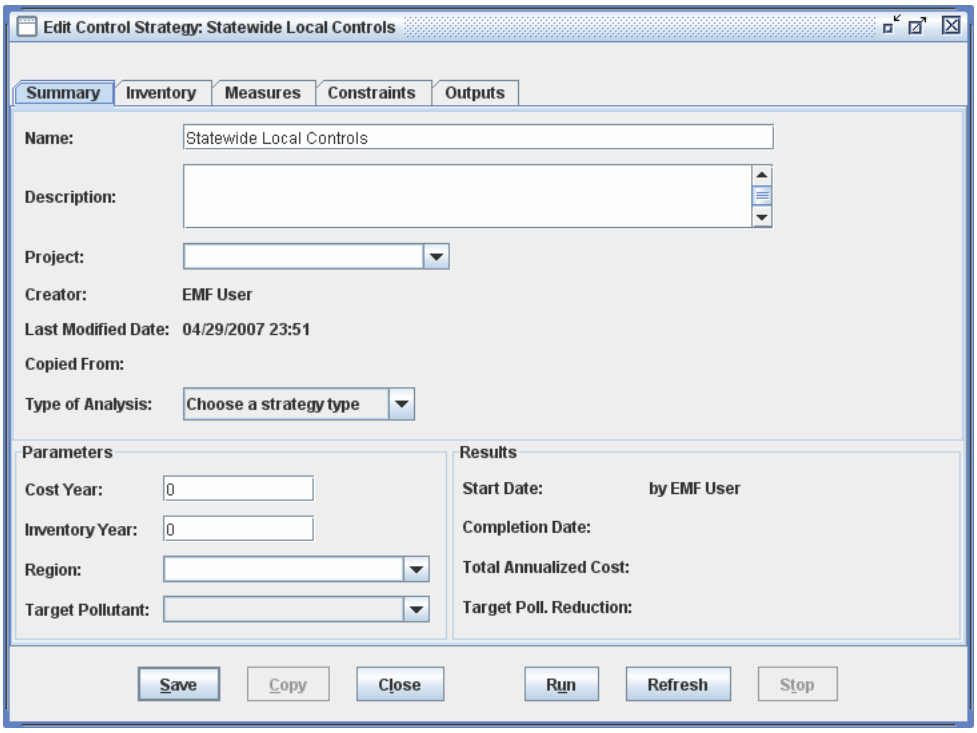
Control Measure Editor – Editing Data



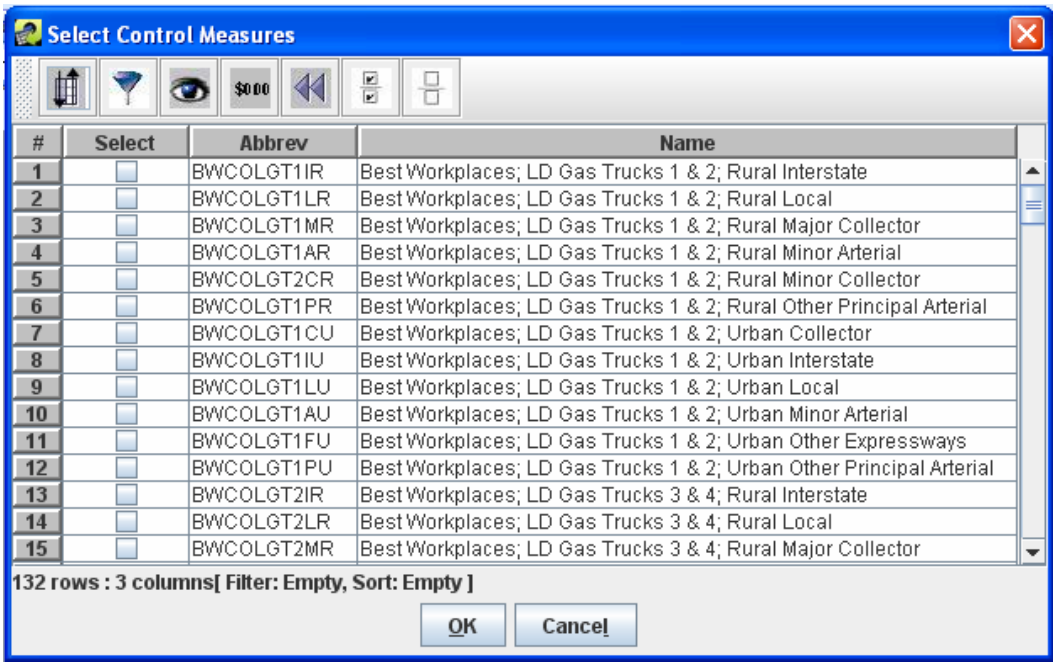
Control Strategy Manager – Selecting a Strategy



Control Strategy Manager – Input Summary Information



Control Strategy Manager – Select Control Measures



Control Strategy Manager – View Strategy Results