

Recent Applications of the Control Strategy Tool (CoST) within the Emissions Modeling Framework

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ABSTRACT

EPA is developing the Control Strategy Tool (CoST) to allow users to estimate the emission reductions and costs associated with future year control scenarios, and then to generate emission inventories with the control scenarios applied. CoST tracks information about control measures, their costs, and the types of emissions sources to which they apply. The purpose of CoST is to develop control strategies that match control measures to emission sources using algorithms such as “maximum emissions reduction”, “least cost”, and “apply measures in series”. The result of a control strategy contains information that specifies the estimated cost and emissions reduction achieved for each control measure-source combination. Control strategy results can be exported to CSV files or viewed in a graphical table that supports sorting, filtering, and plotting. The results can also be merged with the original inventory to create controlled emissions inventories that can be exported to files that can be input to the emissions model SMOKE, which is used by EPA to prepare emissions inputs for air quality modeling.

CoST is a component within the Emissions Modeling Framework (EMF), which is currently being used by EPA to solve many of the long-standing complexities of emissions modeling. By providing CoST as a tool integrated within the EMF, it facilitates a level of collaboration between control strategy development and emission inventory modeling that was not previously possible. CoST supports multi-pollutant analyses and data transparency, and provides a wide array of options for developing control strategies. Recent applications of CoST include the computation of detailed onroad and nonroad mobile source strategies, a point and area source least cost comparison study with AirControlNET, and a pilot study for greenhouse gases emitted from the cement sector.

INTRODUCTION

EPA’s Health and Environmental Impacts Division (HEID) is developing the Control Strategy Tool (CoST) to estimate the emission reductions from emission control strategies that could be applied to sources of air pollution across geographic areas [Misenheimer, 2007]. The main purpose of the tool is to support national and regional-scale multi-pollutant analyses, such as specifying the National Ambient Air Quality Standards, although the software may also prove useful for some urban and local-scale analyses. CoST 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. CoST supports multi-pollutant analyses, including criteria pollutants and precursors, HAPs, and climate change gases. It has been developed using a platform that provides the flexibility and functionality that is needed to support current and upcoming analysis activities at EPA’s Office of Air Quality Planning and Standards (OAQPS). CoST has been developed within EPA’s Emissions Modeling Framework (EMF) client-server architecture [Houyoux, 2008]. By incorporating CoST into the EMF, it was possible to take

advantage of existing software and hardware infrastructures. It has also encouraged a new level of communication and collaboration between the emissions modelers and the cost-benefit analysts that are developing strategies that emissions modelers then model.

CoST development began in 2006. It is intended to replace older software called AirControlNET (ACN) [<http://www.epa.gov/ttn/ecas/AirControlNET.htm>], which has some similar capabilities and was first released in 1999. A prototype version of CoST that established the key concepts needed was available by the end of 2006. An interim version of CoST including a database that consisted primarily of data converted from AirControlNET was available by the end of 2007. This version could run control strategies per the user's specifications, compute annualized capital and operating and maintenance costs, create controlled inventories from the results, and export these inventories for input to EPA's emissions model SMOKE.

The focus of the 2008 enhancements is to further develop the software and to confirm and refine the contents of the control measure database so that CoST can be used for meaningful analyses at OAQPS. New control strategy analysis algorithms have been added as needed to support OAQPS analyses. These include efficiently running mobile control strategies that involve over a half million control measure records and multiple emission inventories of up to three million records each. CoST has been validated against independently generated point and area source strategies and supports both cost per ton-based as well as cost equation-based cost estimates. In addition, the concept of control programs is being incorporated into the software to facilitate projection of inventories from base to future years, as well as optimization and uncertainty capabilities to deal with current-day multipollutant targets. In addition, a greenhouse gas application focusing on the cement industry is underway.

APPROACH

Components of CoST within the EMF

CoST is accessed through the EMF client user interface. The EMF client runs on a user's desktop and accesses the EMF server software running on a remote computer via web services. The EMF has the ability to read in and manage emissions inventories and other data related to the emissions modeling process and then store it in a relational database. It also provides a feature called the Case Manager that allows the user to collect the data into modeling 'cases', export the data needed for the cases, run scripts required to implement the cases, and collect their results. The EPA uses this feature to run SMOKE on a compute server [Houyoux, 2008]. The PostgreSQL (<http://postgresql.org>) relational database upon which the EMF is based is being used to develop summaries that aid in the quality assurance of the data input to and output from the modeling cases. Using the EMF server to provide centralized storage and summaries of the SMOKE modeling input files, and then exporting the data for use by a multi-processor compute server, has allowed EPA to achieve a very high throughput for their emissions modeling projects.

Through CoST, two major concepts were added to the EMF: control measures and control strategies. Control Measures are devices or practices that reduce emissions of criteria pollutants, hazardous air pollutants (HAPS), and/or greenhouse gases. Control Measures in CoST and the EMF have a list of efficiency records that specify what pollutants are controlled by the measure and the cost of applying the controls. Control Measures also have a list of SCCs to which the measures apply. The inventory sources are matched to the control measures based on their SCC. The list of available control measures is shown in the EMF via the Control Measure Manager, which can be accessed by choosing Control Measures from the Manage menu on the EMF client main window. An example of the Control Measure Manager is shown in Figure 1.

Control Strategies within CoST and the EMF take as input the emission inventories stored within the EMF along with the Control Measures in the database. When a control strategy is run, it associates the measures with the sources according to an algorithm. For example, the maximum emissions reduction algorithm will associate with the source the measure that provides the most reduction to the specified target pollutant. Prior to running a control strategy the user must specify a set of parameters including the type of analysis algorithm to use, the target pollutant, and the cost year for results. In addition, the user must select one or more emissions inventories and the types of (or the specific) control measures to include in the run. Optionally, the user may specify a filter for the emissions inventory, a set of counties to process, and a set of constraints (e.g., maximum cost per ton) for the strategy run. Once the strategy is configured, the user may click 'Run' to start running the strategy on the EMF server. The primary output of a control strategy run is a "detailed result" which specifies the control measures that were applied to the inventory sources for the controlled sources only. A controlled inventory output that includes all sources in the original inventory can then be created from the detailed result and can then be used for emissions modeling or inventory-wide analysis. The outputs for the control strategy are stored as datasets within the EMF and are accessible from the strategy. A sketch of this process is shown in Figure 2.

The control strategies, their configuration settings, and their outputs are stored within CoST until they are deleted by the user that created them. The list of available strategies in the system and useful summary information about the strategies is shown in the Control Strategy Manager, which is accessed through the Manage menu on the EMF client main window. An example of the Control Strategy Manager is shown in Figure 3.

Figure 1. Control Measure Manager

#	Select	Name	Abbreviation	Pollutant	Avg CPT	Avg CE	Min CE	I
1	<input type="checkbox"/>	SNCR; External Combustion Boilers, Elec Gen, Sub/Bit Coal (2)	NSNCRECBE2	NOX	1136.00	40.00	40.00	▲
2	<input type="checkbox"/>	SNCR; External Combustion Boilers, Elec Gen, Sub/Bit Coal (3)	NSNCRECBE3	NOX	1136.00	40.00	40.00	■
3	<input type="checkbox"/>	Coal Washing; Utility Boilers - Coal Fired	BCWSHUBCF	SO2	320.00	35.00	35.00	■
4	<input type="checkbox"/>	Fuel Switch - High to Low S Content; Utility Boilers - High Sulfur ...	SFWHLUBHS	SO2	140.00	60.00	60.00	■
5	<input type="checkbox"/>	SNCR; Utility Boiler - Cyclone	NSNCRUBCY	NOX		35.00	35.00	■
6	<input type="checkbox"/>	SNCR; Utility Boiler - Coal/Wall	NSNCRUBCW	NOX		35.00	35.00	■
7	<input type="checkbox"/>	SCR; Utility Boiler - Cyclone	NSCR_UBCY	NOX		90.00	90.00	■
8	<input type="checkbox"/>	SCR; Utility Boiler - Coal/Wall	NSCR_UBCW	NOX		90.00	90.00	■

26 rows : 23 columns [Filter: None, Sort: Avg CPT(-)]

View Edit Copy New Find Pollutant: MAJOR Cost Year: 2006 Import Export Close

Figure 2. Setting up a Control Strategy within the EMF

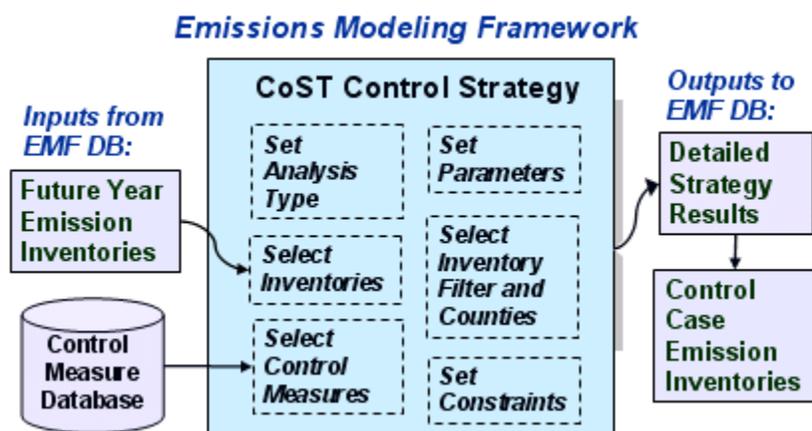


Figure 3. Control Strategy Manager

#	Select	Name	Last Modified	Region	Target	Total Cost	Reduction	Strategy Type
1	<input type="checkbox"/>	Annotate Inventory	2008/05/24 10:47		NOX			Annotate Inventory
2	<input type="checkbox"/>	Apply Measures in Series	2008/05/24 10:47		NOX	109800.00	101.10	Apply Measures In Series
3	<input type="checkbox"/>	Maximum Emissions Reduction	2008/05/24 10:47		NOX	282200.00	95.51	Max Emissions Reduction
4	<input checked="" type="checkbox"/>	Least cost curve	2008/05/24 10:45		NOX	2023000.00	828.10	Least Cost Curve
5	<input type="checkbox"/>	Limited Area Local Controls (C...	2007/05/14 15:14	NC, SC, VA	NOX	0.00	160.40	Max Emissions Reduction
6	<input type="checkbox"/>	Limited Area Local Controls	2007/05/14 15:08	NC, SC, VA	NOX	0.00	505.30	Max Emissions Reduction
7	<input type="checkbox"/>	Statewide Local Controls	2007/05/14 14:41	NC, SC, VA	NOX	71470000.00	18290.00	Max Emissions Reduction

7 rows : 13 columns [Filter: None, Sort: Last Modified(-)]

Buttons: View, Edit, New, Remove, Copy, Close

Reproducing Mobile Analyses from the Ozone NAAQS RIA

A major effort began in the fall of 2007 to use CoST to replicate an independently generated analysis of mobile source controls for the Ozone NAAQS Regulatory Impact Assessment (RIA), and to perform additional related analyses. This effort was different from previously completed analyses in that the EPA wanted to apply a series of control measures to the same emission sources in a specified order. The order of application was significant because the estimated costs of the measures were computed based on emissions reduced by each measure, and this is a function of the emissions remaining after each successive measure has been applied. The control measures that were considered for onroad sources were:

- Plug-In Hybrids
- Aftermarket Catalyst
- Eliminate Long Duration Idling
- Lower Reid Vapor Pressure (RVP)
- Onroad Scrapage and Retrofit
- Continuous Inspection and Maintenance Programs
- Commuter Programs

- Tier 3 Standard

The measures (including aircraft, locomotive, and marine measures) that were considered for nonroad sources in the analysis were:

- Lower RVP
- Bond Rule (CA and non-CA)
- Nonroad Retrofits
- Diesel Marine National Rule
- Ocean Going Vessel Standards
- Commercial Aircraft Standards
- Diesel Locomotive Standards

Another unique characteristic of this analysis was the volume of the control measure data and the volume of the emissions inventory data. The control measure data was provided specific to each SCC, each county, and to each affected pollutant, including some mode-specific pollutants, such as evaporative VOC versus exhaust VOC. The total amount of control measure data exceeded 500,000 records for each of the nonroad and onroad source sectors. An example of this data for one measure is shown in Figure 4. In addition, for some types of measures, including Lower Reid Vapor Pressure, Onroad Retrofits, and Nonroad Retrofits, the data volume was further increased because seasonally varying control measure data was provided (e.g., different measures and control efficiencies for spring, summer, and fall).

Figure 4. Multi-pollutant, County-specific Control Measure Data

#	Select	Pollutant	Locale	Effective Date	Cost Year	CPT	Ref Yr CPT	Control Efficiency
1	<input type="checkbox"/>	CO	37013		1999		0.00	51.88
2	<input type="checkbox"/>	EXH_VOC	37013		1999		0.00	20.50
3	<input type="checkbox"/>	NOX	37013		1999	9850.00	9850.00	46.44
4	<input type="checkbox"/>	PM2_5	37013		1999		0.00	43.86
5	<input type="checkbox"/>	VOC	37013		1999		0.00	20.50
6	<input type="checkbox"/>	CO	37003		1999		0.00	51.88
7	<input type="checkbox"/>	EXH_VOC	37003		1999		0.00	20.50
8	<input type="checkbox"/>	NOX	37003		1999	9850.00	9850.00	46.44
9	<input type="checkbox"/>	PM2_5	37003		1999		0.00	43.86
10	<input type="checkbox"/>	VOC	37003		1999		0.00	20.50
11	<input type="checkbox"/>	CO	37001		1999		0.00	51.88
12	<input type="checkbox"/>	EXH_VOC	37001		1999		0.00	20.50

In addition to the large volume of control measure data, the emissions inventory data is also quite large. Each complete onroad emissions inventory is approximately two million records, and each nonroad inventory is approximately three million records. Also, because the mobile inventories for emissions modeling are different for each month of the year, all twelve of the monthly onroad and

nonroad inventories have to be processed for each control strategy. This resulted in almost 60 million inventory records that need to be processed for each annual strategy run. Some other special requirements were the desire to apply each kind of control measure to a different set of counties, and to temporarily override the rule penetration values as a sort of sensitivity analysis.

A number of enhancements to CoST were required to make these strategy runs manageable and efficient. The enhancements to CoST that were implemented are the following:

1. A list of applicable months attribute was added to the control measures so that measures that were specific to certain months could be specified. An example of the user interface for this is shown in Figure 5.
2. A feature was added to find all control measures that apply to a specified list of SCCs.
3. The transfer of control measure data from the server to client was streamlined so that the control measure manager could display the list of measures in a reasonable amount of time.
4. By default, the control measure manager shows only the name, abbreviation, and major pollutant. A 'Show Details' checkbox was added to allow users to view additional information such as the average cost per ton, and the minimum, maximum, and average control efficiency.
5. A new "Apply Measures in Series" strategy analysis type was added to support the application of multiple measures to the same source.
6. When adding a set of specific measures to a control strategy, the ability to specify the order in which they should be applied, the rule effectiveness, the rule penetration, and the set of counties to which they should apply was added. An example of this is shown in Figure 6.
7. The ability to process average day inventories for various months of the year (in addition to annual) was added, an example of which is shown in Figure 7.
8. Control strategy results were updated to accommodate multiple controls on the same source.
9. The processing of the control strategies was moved from Java into SQL to achieve better performance.
10. A number of SQL indices had to be added to achieve efficient processing performance.

Figure 5. Specifying Month-Specific Control Measures within the EMF

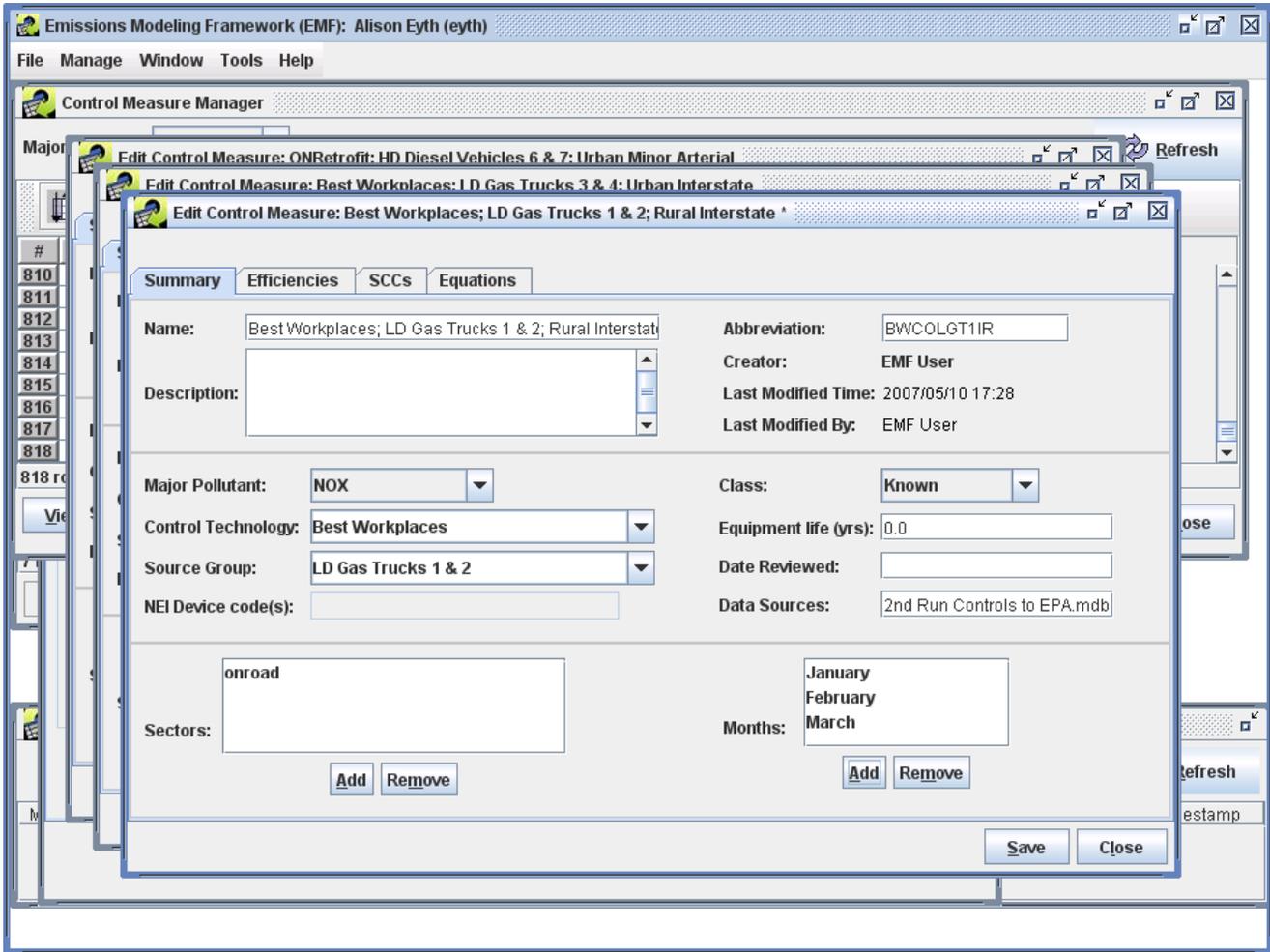


Figure 6. Specifying a Set of Measures for Strategy with Order and Rule Penetration Overrides

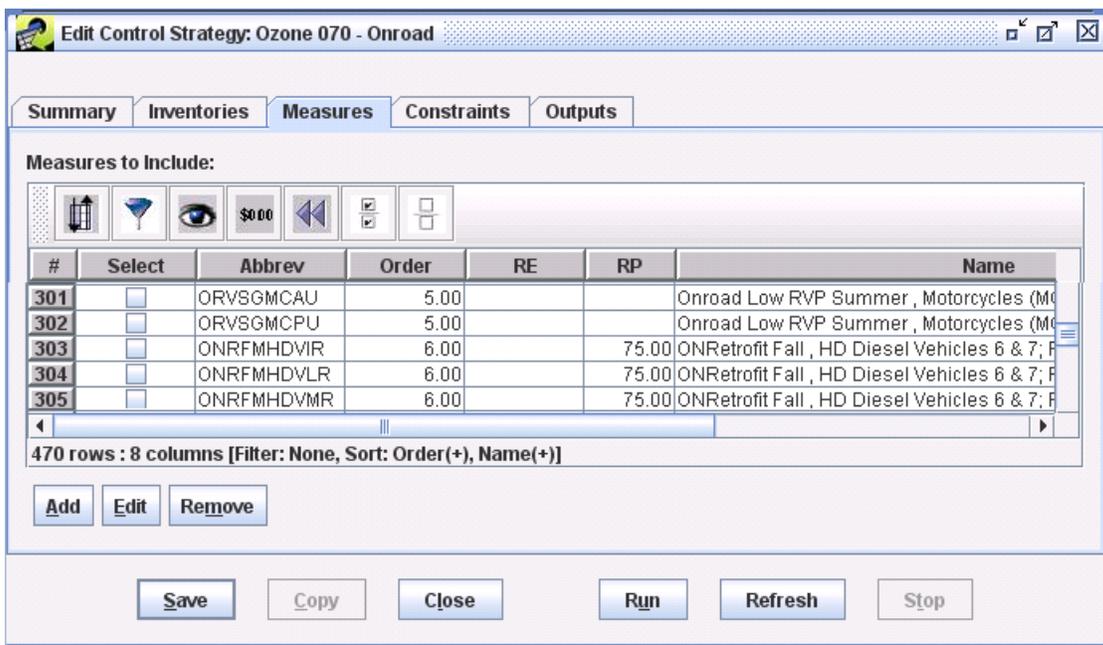
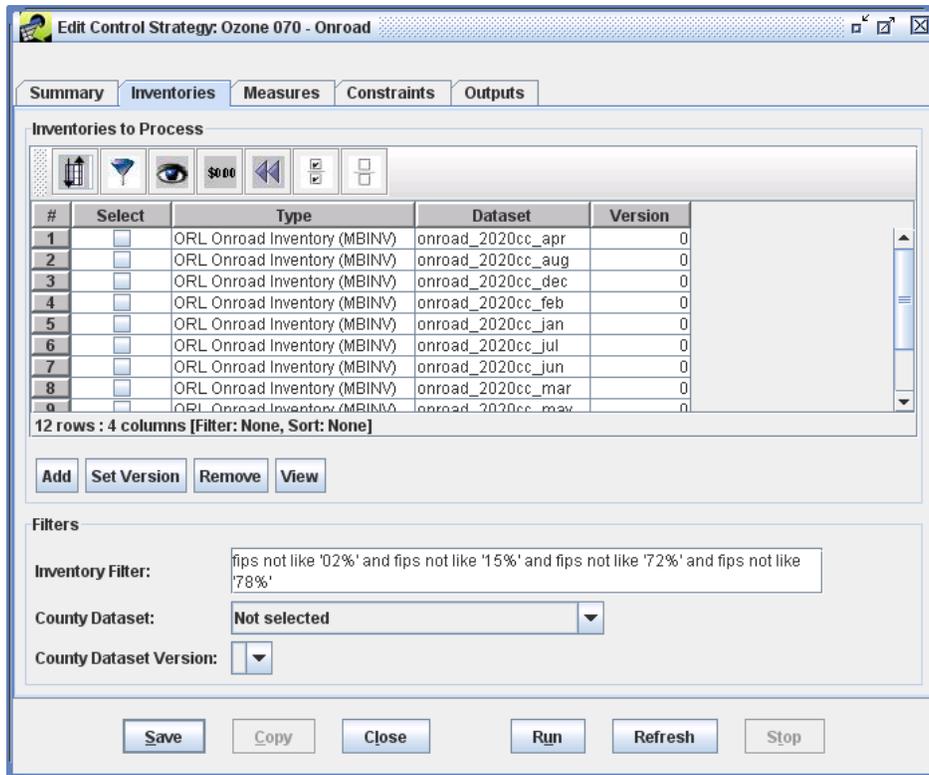


Figure 7. Processing Multiple Month-Specific Inventories within the EMF



The result of this mobile analysis was that the results from the independent analysis were in large part reproduced for all the months in the modeled year. The situations in which the results were not reproduced were traced to be the result of missing data, or data that was used in the original analysis that did not meet EPA’s specifications. Several reports were generated from the resulting data via the EMF quality assurance reporting subsystem, which can summarize inventories and strategy results in many different ways. From these reports, it was possible to see how each of the control measures impacted each pollutant. Some examples of the resulting emissions reductions from the various types of measures are shown in Table 1. Note that both emissions reductions and cost estimates were computed for multiple pollutants and appropriately summarized, and also that emissions reductions for some lesser impacted pollutants are not shown here. A screenshot of the tab that shows the outputs from the control strategy for each input inventory is shown in Figure 8.

Table 1. Onroad Mobile Strategy Emissions Reductions (tons/yr)

	VOC	NOX	PM10	CO
Aftermarket Catalysts	51,513	65,936		
Commuter Programs	2,578	4,687	360	146,043
Continuous Inspection	32,696	22,850		557,618
Eliminate Long Duration Idling		8,351	160	
Retrofits	9,302	101,059	2,259	39,180
Lower RVP	22,014	1,181		78,849
Plug-In Hybrids	56,888	20,833		
Tier-3 Standards	104,168	73,036		

Figure 8. Outputs from a Mobile Strategy Run

Output Datasets

#	Select	Result Type	Record Count	Input Inventory	Result
1	<input type="checkbox"/>	Strategy Summary	2091465		Summary_1473_VO_20080117
2	<input type="checkbox"/>	Detailed Strategy Result	1326631	onroad_2020cc_sep	Strategy_1484_VO_20080118
3	<input type="checkbox"/>	Detailed Strategy Result	1171303	onroad_2020cc_oct	Strategy_1483_VO_20080118
4	<input type="checkbox"/>	Detailed Strategy Result	1171303	onroad_2020cc_nov	Strategy_1482_VO_20080118
5	<input type="checkbox"/>	Detailed Strategy Result	1380356	onroad_2020cc_may	Strategy_1481_VO_20080117
6	<input type="checkbox"/>	Detailed Strategy Result	1171303	onroad_2020cc_mar	Strategy_1480_VO_20080117
7	<input type="checkbox"/>	Detailed Strategy Result	1309364	onroad_2020cc_jun	Strategy_1479_VO_20080117
8	<input type="checkbox"/>	Detailed Strategy Result	1309364	onroad_2020cc_jul	Strategy_1478_VO_20080117

13 rows : 12 columns [Filter: None, Sort: Start Time(-)]

Input Inventory
 Result
 Controlled Inventory

Export Folder:

Reproducing Point and Area Analyses from the Ozone NAAQS RIA

Aside from the extensive mobile analysis, some time was spent trying to reproduce point and area source analyses for the RIA. A source by source comparison between the results output from CoST and AirControlNET was performed. Through this process it was possible to validate that the recently implemented point source cost equations were working properly, and that CoST was properly selecting measures from the database and associating them with the sources. Overall, the CoST results were comparable with the AirControlNET-based results. However, several important discrepancies were identified. In some cases the matches were not exact because CoST had some additional control measures available. In other cases, it was determined that AirControlNET was using information about existing controls on the sources that was not available to CoST. This was because much of the existing control information had not been propagated into the future year 2020 inventory, even though it was available in the base year inventory exported from the National Emissions Inventory (NEI).

A persistent 10% difference in costs was found between CoST and AirControlNET. After some research, it was determined that this difference resulted from a change that occurred in the year 2000 regarding the series of GDP implicit price deflator estimates that are provided by the U.S. Bureau of Economic Analysis (BEA). The calculation of the GDP implicit price deflator was changed in that year to reflect a revised estimate of "chained" GDP estimates (i.e., calculations based on connecting different paths of price estimates over time to a single base year) to improve the accuracy of implicit price deflator estimates. Our control measure database contains individual control measure base year costs dating back to 1990. Hence, estimates of annualized costs in dollars more recent than 2000 will be different than those on or before 2000 based on this difference in price deflator methodology, even if all other parts of the calculation are the same.

In addition, CoST had to be updated to take into consideration the existing control efficiency information on the sources prior to applying replacement control measures. This update was implemented in the spring of 2008. In the current version of CoST, a strategy constraint is available that specifies the minimum difference in the resulting percent reduction that is required before an existing control is replaced with another, more effective control measure. If the control efficiency of a new measure exceeds this threshold, the new measure will replace the old one. One discrepancy between the two systems still remains: AirControlNET has the ability to apply control measures in addition to what is already on the source and uses a different set of cost information when it does this - CoST does not yet have this feature. However, CoST should support this process by the end of the current work assignment.

Least Cost and Least Cost Curve Analyses

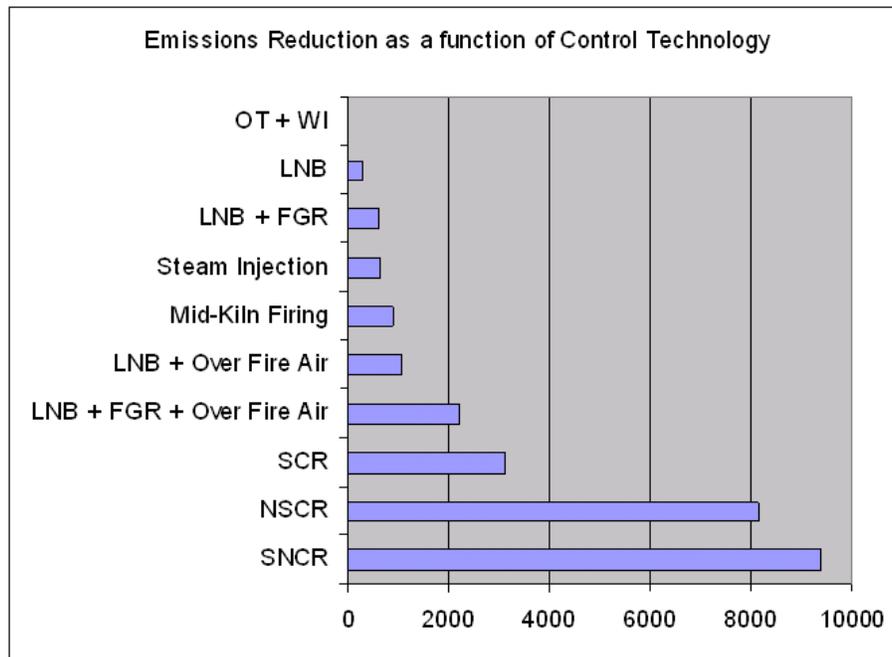
Least cost analysis is a feature that is available in AirControlNET but had not been available in CoST prior to the 2008 project year. During a least cost analysis, the software determines how to achieve a specific percent reduction in a pollutant with the available control measures at the minimum cost. Least cost analysis is an important tool for EPA to determine the most cost efficient way to make the needed reductions. The fact that least cost analysis was missing from CoST was a significant hole in its functionality as compared to that of AirControlNET. An additional requirement was to be able to perform least cost analysis across multiple emissions inventory sectors (e.g. point and area).

In the spring of 2008, as the team prepared to incorporate a least cost analysis algorithm into CoST, an optimization solver embedded in Microsoft Excel was applied to a very small inventory with a small set of control measures. The team studied the results of this solver and compared its results to a least cost algorithm implemented in a similar fashion to that of AirControlNET. It was found that the AirControlNET-style algorithm did not give a true least cost result, but was more of a heuristic that provided an approximation of the least cost solution. The AirControlNET-style algorithm operated by first eliminating control choices for sources if higher cost did not achieve higher control, and then performing an overall ranking of control measure-source combinations based essentially on the estimated cost per ton. The source-measure combinations that used the cheapest cost per ton were included in the result first, and then higher cost per ton measures were incorporated until the targeted reduction was reached. This approach differed from the true optimization algorithm in that the true optimization would often choose to control a smaller number of large sources with a cost effective control without including many of the intervening controls on smaller sources that would be included with the AirControlNET result. It seemed, however, that the AirControlNET-style algorithm would yield results that were reasonable and defensible, and it could be implemented in a timely fashion. So, the team decided to proceed with incorporating that style of algorithm into CoST for the near-term. The possibility of incorporating a true optimization solver that might also support targeted reductions for multiple pollutants was left open for the future.

Once the least cost algorithm was incorporated into CoST, a feature to support the application of the algorithm simultaneously to multiple inventory sectors was added. Through this feature, the user selected all the inventories of interest as inputs to the least cost strategy. When the strategy was run, the essential data from each inventory was extracted into a single 'merged inventory' and the least cost analysis was run on that merged inventory. The appropriate measures were still assigned to all of the sources based on their SCC, regardless of the emissions sector from which the source originated. Once the strategy run was complete, a detailed result was generated that included the measure-source matches from all of the sectors. During this effort, the tool was updated so that it could use the merged result to develop controlled inventories separately that corresponded to each of the individual input inventories. One limitation for this approach is that it will not work properly for source sectors that require multiple

control measures to be applied to each source, as they were for the onroad and nonroad mobile study described above. The inclusion of these sectors in a least cost analysis may be explored in the future. The least cost feature, when combined with all of the existing features of an optional inventory filter, county list, measure selection, and constraints results in CoST being a very powerful strategy analysis tool. A plot created from a summary of a least cost analysis based on the electric generating utility (EGU) sector is shown in Figure 9. Some of the technologies included were Low NOx burners (LNB), Low NOx burners with Flue Gas Recovery (LNB + FGR), Non-Selective Catalytic Reduction (NSCR), and Selective Non-catalytic Reduction (SNCR).

Figure 9. Control Technologies used during a Least Cost Analysis



An extension to the least cost algorithm was implemented into CoST in the form of an analysis algorithm called “Least Cost Curve”. The purpose of this algorithm is to inform the policy designers regarding the point at which the cost to increase the level of emissions reductions reaches the point of diminishing returns for each additional dollar that is added into the emissions controls. The Least Cost Curve feature requires the user to specify a domain-wide percent reduction increment for the target pollutant, in addition to a starting percent reduction and an ending percent reduction, as shown in Figure 10. When the control strategy is run, it will run for the starting percent reduction (unless that is specified as 0% reduction, which will be skipped), and then for every percent reduction increment until it reaches the ending percent reduction. So, if the starting percent reduction is 0%, the increment is 25%, and the ending percent reduction is 100%, it will perform least cost analyses for 25%, 50%, 75%, and 100%. Note that the percent reductions are specified in terms of the total emissions in the inventory, not in terms of the total controllable emissions. This marks a significant improvement over AirControlNET. A detailed strategy result output is created for each increment that is run. If the percent reduction cannot be achieved (e.g., 100% reduction is often not attainable), the maximum level of reduction that could actually be achieved is specified in the “least cost curve summary” output that is generated from the least cost curve analysis.

Figure 10. Setting Constraints for Least Cost Curve Analysis

Edit Control Strategy: Least cost curve

Summary | Inventories | Measures | **Constraints** | Outputs

All Strategies

Constraints for Target Pollutant:

Minimum Emissions Reduction (tons)	<input type="text"/>
Minimum Control Efficiency (%)	<input type="text"/>
Maximum 2006 Cost per Ton (\$/ton)	<input type="text"/>
Maximum 2006 Annualized Cost (\$/yr)	<input type="text"/>
Minimum Percent Reduction Difference for Replacement Control (%)	<input type="text" value="10.0"/>

Least Cost Curve

Specify an increment, starting and ending percent reduction (%) for the Target Pollutant:

Domain-wide Percent Reduction Increment (%)	<input type="text" value="25.0"/>
Domain-wide Percent Reduction Start (%)	<input type="text" value="0.0"/>
Domain-wide Percent Reduction End (%)	<input type="text" value="100.0"/>

Save | Copy | Close | Run | Refresh | Stop

An example of the Outputs tab of the control strategy editor for the least cost curve analysis is shown in Figure 11. Note that the user may do one set of runs (e.g., with increment set to 25%) and then come back and perform a second more refined set of runs with a smaller increment (e.g., 5%) to get a clearer picture of one section of the curve. The least cost curve summary will contain the results of all the runs that have been performed, and all of the individual strategy run results are retained. An example of this can be seen in the least cost curve summary table shown in Figure 12. An example of a cost curve that can be generated from a least cost curve summary is shown in Figure 13. The results from 25% interval runs are shown as circles and results from 5% interval runs are shown as diamonds. The purple line shows the total available inventory emissions.

Figure 11. Outputs from a Least Cost Curve Analysis

Output Datasets

#	Select	Result Type	Record Count	Result
2	<input type="checkbox"/>	Detailed Strategy Result	13	pct_91_0_least_cost_test_20080505122737605
3	<input type="checkbox"/>	Detailed Strategy Result	13	pct_92_0_least_cost_test_20080505122737948
4	<input type="checkbox"/>	Detailed Strategy Result	13	pct_93_0_least_cost_test_20080505122738230
5	<input type="checkbox"/>	Detailed Strategy Result	13	pct_94_0_least_cost_test_20080505122738495
6	<input type="checkbox"/>	Detailed Strategy Result	13	pct_95_0_least_cost_test_20080505122738698
7	<input type="checkbox"/>	Detailed Strategy Result	8	pct_25_0_least_cost_test_20080505122757152
8	<input type="checkbox"/>	Detailed Strategy Result	9	pct_50_0_least_cost_test_20080505122757573
9	<input type="checkbox"/>	Detailed Strategy Result	13	pct_75_0_least_cost_test_20080505122757902
10	<input type="checkbox"/>	Detailed Strategy Result	13	pct_100_0_least_cost_test_20080505122758277
11	<input type="checkbox"/>	Least Cost Control Measure Worksheet	66	Measure_Worksheet_least_cost_test_200805051227
12	<input checked="" type="checkbox"/>	Least Cost Curve Summary	10	Cost_Curve_Summary_least_cost_test_200805051227

12 rows : 12 columns [Filter: None, Sort: Start Time(-)]

Input Inventory
 Result
 Controlled Inventory

View Edit Export Analyze Create

Export Folder: D:/ Browse

Save Copy Close Run Refresh Stop

Figure 12. Contents of Least Cost Curve Summary

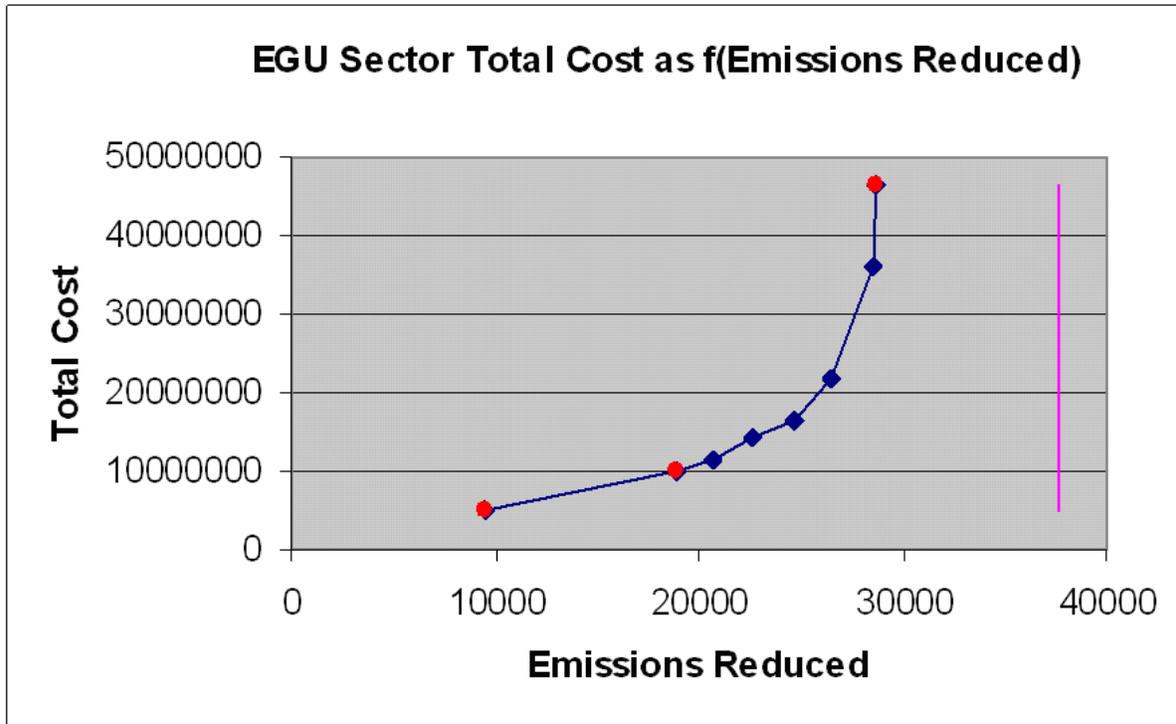
File Name: D:\Cost_Curve_Summary_least_cost_test_20080505122736417_05may2008_v0

Header: strategy least cost curve summary #Implements control strategy: least cost test ##EXPORT Full Description

target_perc...	actual_percent_reduction	total_annual_cost	average_ann_cost_per_ton	total_emis_reduction
25	41.214	30212.37	725.08	41.66771
50	50.174	37336.62	736.04	50.72667
75	75.917	91133.98	1187.37	76.75257
90	90.031	230429.62	2531.57	91.0224
91	91.568	248348.26	2682.62	92.576625
92	92.321	257116.91	2754.71	93.3372
93	94.474	282214.06	2954.69	95.514075
94	94.474	282214.06	2954.69	95.514075
95	94.474	282214.06	2954.69	95.514075
100	94.474	282214.06	2954.69	95.514075

10 rows : 11 columns [Filter: None, Sort: actual_percent_reduction(+)]

Figure 13. Example of a Least Cost Curve



Specifying Existing Control Measures in Inventories

One of the goals for CoST that has not yet been met is for the tool to be able to intelligently make use of control measures that can be applied in addition to other controls (also known as ‘add-on’ controls). In order for the software to be able to meet this goal, it is important for it to be able to determine whether there are any existing control measures on the emissions source and the type of control device(s) used by the existing measures. Currently, a data gap exists in this area for both the base year emissions inventories and the future year emissions inventories which may be used as inputs to a control strategy run. The NEI contains data fields to store this information, and there is a limited amount of existing control efficiency and control device code data in the base year NEI. However, these fields are not very well populated in the base year inventory for sectors other than the EGU point sources, and the fields are even less well populated in the future year modeling inventories. Generally, the control efficiency field is much better populated than the control device fields. In addition, the control device codes that are stored in the NEI are a lot less specific than the control measure abbreviations that CoST uses. Therefore, even if the control device codes were well populated, these codes would need to be translated into the CoST control measure abbreviations for CoST to really have the information it needs to properly apply add-on controls.

To address the issue of unspecified control measures in inventories that can be input to CoST, several steps have been taken. First, when CoST creates a controlled inventory, in addition to filling in the information in the CEFF, REFF, and RPEN columns, CoST populates several additional columns in the ORL inventory that specify information about measures that it has applied. These columns are:

- Control Measures: An ampersand (&) separated list of control measure abbreviations that correspond to the control measures that have been applied to this source.

- Pct Reduction: An ampersand separated list of percent reductions that have been applied to this source, where percent reduction = control efficiency (CEFF) * rule effectiveness (REFF) * rule penetration (RPEN).
- Current Cost: The annualized cost for that source in the most recent control strategy that was applied.
- Total Cost: The total cost for the source across all strategies that have been applied to it.

In this way, the controlled inventories created by CoST will always specify the relevant information about the measures that have been applied as a result of a CoST control strategy.

A second step that has been taken to provide more information about existing control measures was the addition of a new control strategy analysis algorithm called “Annotate Inventory”. When a strategy is run using this algorithm, CoST will look at the percent reduction specified by the CEFF, REFF, and RPEN columns and will use the available control measures to try to determine what control measure has the closest percent reduction to the one specified in the inventory. It will then fill in the control measures column described above with the measure that was found. If no measure was found, it will leave the entry blank. A separate report can be generated that shows the sources with non-zero CEFF values and the difference between the inventory specified percent reduction and the percent reduction that the control measure that CoST “guessed” had been applied to the source. It is important for the user to then examine the results of this report to find cases where the matches were not even close and those for which no match was found. Both of these situations can indicate that there is missing or incorrect data in the control measures database, or that the information in the inventory was erroneous. When an Annotate Inventory strategy was run on existing EPA point source inventories, a number of records fell into these situations. Over the course of this summer, the CoST team plans to try to track down the reason(s) for the missing or incomplete control measure data so that a base year inventory with more complete existing control measure information will be available for future analyses – especially those involving add-on controls.

In order for the future year base inventories to have information on existing control measures, it will be helpful if the inventory projection process (that takes the base year inventory and projects it to a future year inventory) can specify what control measures have been applied to the sources. This can be accomplished in a similar way to how the annotate inventory strategy analysis works. It can also be accomplished by incorporating the concept of control programs into CoST and the EMF. The process of projecting inventories is currently done using a series of SAS programs that take as input data tables collected from various sources. For several years, EPA has wanted to make the process of applying the control programs more explicit and documentable. By incorporating the control programs into CoST and having CoST apply the projection and control factors to create the projected inventory, it will be possible to annotate the inventories as the projection takes place.

To accomplish the application of control programs and projection factors to an inventory, the control programs concept is being incorporated into CoST. For each control program it will be possible to specify the type of program, the start date, and one or more accompanying datasets that identify the sources that will be affected by the program (e.g., a list of plants that will close). The types of control programs are expected to include the following:

- Plant closures
- Planned reductions at specific plants
- Planned growth at specific plants
- Caps on emissions at existing plants

- SCC-based reduction programs
- Commuter programs
- Estimated growth for specific sectors

In situations where the desired control measures or technologies for the control program are known, these can be specified as part of the control program. If the control measures are not known, CoST can search for a measure with the desired control efficiency and provide that as the best guess for the applied measure. To implement the process of inventory projection, a new strategy analysis algorithm is being added called "Project Inventory". The detailed result for this strategy will show the control efficiency or growth factor that was applied and a probable control measure for each projected source. This strategy will also be able to generate a complete inventory for use as input to SMOKE. It is important to note that there is another important data need to collect planned control program data (e.g. from SIPs) from states so that future EPA control strategy modeling can incorporate these programs and thereby produce more realistic results than if the planned state-specific programs are ignored.

Greenhouse Gas Pilot Application

A preliminary test of the applicability of CoST to greenhouse gas (GHG) analyses was performed in 2007. The goal was to assess the affect of traditional control strategies on greenhouse gas pollutants. Due to the limited availability of source level emissions inventory data for greenhouse gases, the 2007 effort focused on black carbon, emissions of which can be derived from the PM 2.5 inventory combined with speciation profiles. Existing control measures were used and the EC control efficiencies were assumed to be equal to the PM 2.5 control efficiencies. The study in 2007 showed that CoST could effectively produce results for strategies that affect multiple pollutants, including EC, PM 2.5 and PM 10. In 2008, the focus of the study shifted to an analysis of carbon dioxide emissions from cement plants. The cement industry is a substantial contributor to CO₂ emissions in the United States [Hanle, 2004]. GHG analyses would be simplified for other emission source sectors if more plant level GHG inventory information were available. Unfortunately, the majority of available inventory data is at a much more aggregate level, such as state or country level.

A source of plant level GHG emissions data from cement plants has been identified, along with accompanying materials that discuss control measures for cement plants and their impact on criteria and GHG pollutants. This will allow the team to explore potential applications of CoST to GHG emissions, including cobenefits for criteria pollutants. A challenge for this study is to apportion the plant level emissions to the individual SCCs, points, and segments used at those plants. This study is in an early stage, but the goal for the end of the year is to examine some policy alternatives for managing GHG and other emissions from cement plants. Aside from the ongoing greenhouse gas pilot application, another challenge to be addressed in 2008 is to determine the best way to achieve least cost optimization for multiple pollutants simultaneously, and to determine ways in which uncertainty and sensitivity analysis can be better supported by CoST.

CONCLUSIONS

From this study, we have shown that CoST is a powerful and flexible tool that can be used to analyze control strategies for point, area, and mobile sources. A number of different strategy analysis algorithms are available, including: maximum emissions reduction, apply measures in series, least cost, least cost curve, and annotate inventory. An additional algorithm to project inventories is currently being developed. The client-server framework that CoST resides within provides for a powerful platform that can facilitate high throughput analyses on inventories in excess of two million records along with control measures with collective efficiency records in excess of one million records. Multiple average day or annual inventories can be processed in a single strategy run. The archival of CoST strategy run

configuration settings and results supports comparative analyses and the ability to reproduce results when needed. Information about control measures is readily visible within the tool and new control measure data can be added easily.

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KEY WORDS

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SMOKE