

Response to Peer Reviews of EPA's Control Strategy Tool (CoST)

The Air Economics Group (AEG) of the Environmental Protection Agency (EPA) requires an objective peer review of its new cost and control strategy software, the Control Strategy Tool (CoST), by experts in control measure selection and engineering cost estimation.

CoST is a client-server system and is part of EPA's Emissions Modeling Framework (EMF). CoST models the emission reductions and engineering costs associated with control strategies applied to point, area, and mobile sources of air pollutant emissions to support the analyses of air pollution policies and regulations. CoST accomplishes this by matching control measures to emission sources using algorithms such as "maximum emissions reduction", "least cost", and "apply measures in series". Control strategy results can be exported to comma-separated value (CSV) files or viewed in graphical tables which support sorting, filtering, and plotting. The results can also be merged with the original inventory to create controlled emissions inventories. These can be exported to files which can then be input to the Sparse Matrix Operator Kernel Emissions (SMOKE) emissions model.

CoST was developed as a replacement for the AirControlNET software tool. In 2006, it was determined that it was time to replace AirControlNET with a newer software that could provide improved effectiveness, functionality, and transparency to support current and upcoming needs. CoST has the functionality of AirControlNET but with added features. Some of these added features allow users to:

- Insert emissions inventories almost seamlessly from the EMF
- Insert new control measure data
- More easily track their analyses and output
- Identify errors in emissions and control measure data through CoST-provided QA steps
- Apply monthly, seasonal, or annual mobile source control measures

Information on control efficiencies and costs is contained in the Control Measure Database (CMDB). This dataset currently focuses on criteria pollutants, with plans to add coverage for control information and costs for hazardous air pollutants (HAP) and greenhouse gases (GHG).

AEG produced an initial version of CoST, including a detailed user's manual, a development document describing the algorithms supporting the tool, a separate document describing the CMDB, and a document detailing the cost equations employed by the tool.

The purpose of this report is to provide and organize comments on CoST provided by eight peer reviewers and to present EPA's response to those comments. Peer reviewers were solicited from industry, state and regional air pollution agencies, federal agencies, academia, and non-OAQPS EPA offices. Exhibit 1 lists the organizations solicited for peer reviewers.

Exhibit 1: Organizations Solicited for Peer Reviewers

Allegheny County American Petroleum Institute California Air Resources Board Colorado Department of Public Health and Environment (Colorado DPHE) Electric Power Research Institute EPA Office of Research and Development, Air Pollution Prevention and Control Division (EPA/ORD/APPCD) Mid-Atlantic Regional Air Management Association General Motors

Houston Advanced Research Center
Michigan Department of Natural Resources (Michigan DNRE)
New Hampshire Department of Environmental Services (New Hampshire DES)
North Carolina Department of Environment and Natural Resources (North Carolina DENR)
North Carolina State University
State of Pennsylvania
U.S. Department of Transportation
Wisconsin Department of Natural Resources
Western Regional Air Partnership

The individuals who reviewed CoST and submitted comments are acknowledged in Exhibit 2.

Exhibit 2: Peer Reviewers

Andy Bodnarik, New Hampshire DES
Teresa Cooper, Michigan DNRE
Gayle Hagler, EPA/ORD/APPCD
Ozge Kaplan, EPA/ORD/APPCD
Dan Loughlin, EPA/ORD/APPCD
Glenn Sappie, North Carolina DENR
Curtis Taipale, Colorado DPHE
Will Yelverton, EPA/ORD/APPCD

Peer reviewers were provided with the documentation and materials listed in Exhibit 3.

Exhibit 3: Materials Provided to Peer Reviewers

CoST Development Document - Attached
Documentation of CoST Equations in EPA's Control Strategy Tool
CoST Glossary of Terms
EPA Cost Manual
Least Cost Example CoST Run
CoST Run Outputs for an On-Road Mobile Strategy

Peer reviewers were asked to:

- Review the CoST equations documentation listed above, focusing on the description and definitions concerning equations and algorithms.
- Review the example scenarios and the accompanying outputs.
- Use the questions in Exhibit 4 to guide the review.

Exhibit 4: Questions to Guide the Review

1. Are the algorithms used in the Control Strategy Tool (as described and defined in the CoST Development Document) reasonable, current, and consistent with standard operating procedures for calculating emission reductions from control measures, and the associated costs? This question should be considered separately for each type of strategy in CoST:
 - a. Max Emissions Reduction
 - b. Apply Measures in Series
 - c. Least Cost
 - d. Least Cost Curve
 - e. Annotate Inventory
 - f. Project Future Year Emission Inventory
2. Are the equations used in the Control Strategy Tool (as described and defined in the CoST

Equations Document) reasonable, current, and consistent with standard operating procedures for calculating costs of control measures?

3. Are there any source categories or controls that have not been addressed adequately?
4. Are the results plausible for the example scenario(s)?
5. Are there critical omissions in the algorithms or equations that significantly influence the results?

The peer review comments and EPA responses to the comments are provided in Appendix A in the order of responses to each of the five questions in Exhibit 4.

Appendix A: CoST Peer Review Comments and EPA Responses

General Comments

Commenter 2 - Teresa Cooper, Michigan DNRE

From a non-engineer's prospective, I found all the documentation and sample runs very informative and easy to follow.

If the program operates as proposed and predicted it will be a great tool in the state's efforts to come up with control strategies in non-attainment areas. I was happy to see that coal switching was discussed in the review of EGU controls. That is the most common first step that fossil fuel fired sources take to decrease their emissions. It should be included in the industrial boiler scenarios as well.

I did not see any glaring problems or notice any inconsistencies with the equations used.

Response: We agree with the commenter that fuel switching as a control measure for industrial boilers is something that EPA should explore. We will do so as soon as resources become available.

Commenter 1 - Curtis Taipale, Colorado DPHE

The development documentation appears to be thorough and does a good job at explaining the rationale behind various control scenarios. Absent, running the actual software, it is a little difficult ascertain the nuances between running different control scenarios. I looked at most of the formulas and they appear to be consistent with methods I have used. I did not perform an exhaustive and careful evaluation of each formula in the documents.

One area that I had a question on, is the issue of accounting for future growth? In traditional emission inventory work, the future projections are based on growing baseline emission inventories. It appears that CoST does a good job at projecting controls on existing sources but doesn't appear to address future growth of new sources. Is this correct?

Response: CoST relies on the emissions inventories for projected future emissions including changes in emissions resulting from new sources. It should be noted that some new sources actually result in emission reductions by replacing older, higher emitting sources. EPA's Emission Inventory and Analysis Group is working on an approach to better reflect the impact of future growth on emissions. As the emission inventories improve, CoST will take advantage of these improvements.

Commenter 5 - Gayle Hagler, EPA/ORD/APPCD

My background is civil and environmental engineering and daily work is focused on source or near-source measurements, primarily in the mobile sector. I took a big picture approach to the review, but do not have the expertise to comment in detail on many of the control measures for specific sectors. I think it is excellent that the tool considers multipollutant impacts of controls. One future improvement would be to expand the model to include additional pollutant types. For example, ultrafine particles (UFPs) or particle number (PN) are of growing scientific interest. It would be nice to see some aspect of particle size beyond PM2.5/PM10 in the model, for sources that have this type of information in their emissions inventory and control measures. It would also greatly strengthen the model to add in GHGs, which I believe is already in the works.

One final improvement I'd suggest would be to provide outputs that show a timeline of change for a given scenario, for situations that may have multiple steps occur over the time window. It would be informative for the user to see the impact of a regulation that would be applied at a certain year and then causing change over time as the rule penetrates the market.

Response: The primary purpose of CoST is to support analysis of the National Ambient Air Quality Standards so the focus is on controls that reduce criteria pollutants. However, we recognize that it is also beneficial to assess the co-impacts of control strategies on other pollutants such as GHGs and to identify control strategies that are beneficial across multiple pollutant goals. Because of this, we will seek to incorporate into the CMDB additional control measure and cost information for GHGs, HAPs, and other pollutants, as this information becomes available and as resources allow.

Concerning outputs of changes in emissions over time, this can currently be accomplished by adding additional time-related control measure impacts to the Control Measures Database (CMDB) and by running CoST for multiple years. For example, you can input into the CMDB the impact of a measure or measures for years 2017, 2020, 2025, etc (varying the percent reduction, rule effectiveness, and/or rule penetration from year to year) and then run CoST for any or all of those years to see the change in emissions and costs. We will examine algorithms and outputs that make this task easier in the future.

Commenter 6 – Will Yelverton, EPA/ORD/APPCD

I have reviewed the CoST development documentation provided and, from what I have been able to glean from the documentation and demonstration, it appears to be a potentially useful tool. I must admit that I am not an economist so the majority of my attention was focused on the engineering assumptions located in the Equations Documentation, although I have made some broader contextual comments where they were noticed and I felt they were relevant

It appears that the general logic behind each type of control strategy is reasonable. I did not spend time analyzing the *Apply Measures in Series* strategy, as it is stated that this strategy is mainly applied for mobile sources and my background is predominately with stationary – particularly utility (IPM) – point sources. The other measures however are reasonable estimations, given the goal of each strategy (e.g. least cost, max reduction with a single measure applied), to determine how control measures may be applied without incurring the level of detail of more sector-specific models such as IPM that can take into account specific details of how a particular market operates.

No response needed.

Commenter 6 – Dan Loughlin, EPA/ORD/APPCD

In general, I am very impressed with CoST. The design is powerful and flexible. Nearly seamless integration into the Emissions Modeling Framework (EMF) means that the EMF's powerful data storage and querying, versioning, summary and QA capabilities can be brought to bear in control strategy development activities. Further, integration into the EMF facilitates the use of CoST in policy analysis by helping maintain consistency in emission inventories among the various steps of a regulatory impact assessment, including base-year modeling, baseline projections, control strategy development and application, and air quality modeling. With only minor exceptions, CoST appears to be well documented and user friendly. All-in-all, the product greatly enhances the Agency's ability to conduct air quality policy analyses in a manner that is efficient, transparent, achievable and repeatable.

I believe that the tool should support several additional features that will be helpful in sensitivity and scenario analyses. One of these features is the addition of optional capital cost escalation multipliers. Recent years have seen capital costs for large equipment escalate considerably. For example, cost estimates for nuclear plants are now four or five times what they were only a decade ago. A capital cost escalation parameter would allow different assumptions about how capital costs may change in the future to be explored. This feature may be useful in comparing control option alternatives that differ with respect to their cost structure, with some more vulnerable to capital cost escalation than others.

As a side note (since it falls outside of the charge of the review), it appears that the CoST tools would be very useful to states and regional groups in efforts such as SIP planning. Currently, CoST, the EMF, and the relevant databases are available to the EPA only. Technology transfer, including training, to parties outside of the EPA should be a high priority if these tools are to have their greatest societal benefit.

Response: We agree with the commenter that the addition of capital cost escalation multipliers would be an improvement to CoST. We will explore this further as additional resources become available.

Concerning sharing CoST with state air quality management agencies for SIP planning, we agree

that CoST could provide benefits to states in this area. In 2012, we obtained a modest amount of funding to explore packaging a version of CoST for sharing with states and we held a one day hands-on training course for a small number of state personnel. As a result, we learned that additional resources would be necessary to support this on a broader scale. We will pursue this further as resources become available.

Question 1: Are the algorithms used in the Control Strategy Tool (as described and defined in the CoST Development Document) reasonable, current, and consistent with standard operating procedures for calculating emission reductions from control measures, and the associated costs? This question should be considered separately for each type of strategy in CoST?

Commenter 4 - Andy Bodnarik, New Hampshire DES

It is difficult to determine if the algorithms are reasonable since several components used in the algorithms are not adequately explained in the Cost Equations Documentation. See questions below related to the need for additional information on the origin of, and basis for the Capital Cost Multiplier and the Capital Cost Exponent.

We will respond to the specific comments from Mr. Bodnarik below.

Commenter 5 – Gayle Hagler, EPA/ORD/APPCD

The algorithms seem reasonable for the sources described. One future improvement I would suggest would be to allow the model to output a range of possible reductions and costs, rather than only one outcome for one set of inputs. It is a nice thing that the model currently allows the user to override the rule penetration and rule effectiveness, which is beneficial in allowing the user to test what may be the realistic range of success for a specific measure. It would be helpful if the user could input a range of rule penetration or rule effectiveness percentages and have model output results covering the range. It would also be an improvement if the control measure reduction would have some estimated uncertainty associated with it, which would translate through to an uncertainty in the final reduction and associated cost.

Response - We agree that a range of possible reductions and costs would be beneficial, although it is also helpful to output a single reduction and cost representing an average or most likely value. As resources allow, we will explore adding this to CoST, as well as the ability to input a range of rule penetration and rule effectiveness percentages. Uncertainty values for control measure percent emission reductions are not generally available.

Commenter 8 – Ozge Kaplan, EPA/ORD/APPCD

I have thoroughly looked at strategies a, c, and d, and analyzed their corresponding algorithms. In terms of finding a least cost strategy the database employs a more heuristic approach than a formal optimization approach. I would suggest given the availability of funds inclusion of formal optimization algorithms should be considered for future improvements and updates. One example that a formal optimization algorithm might be useful is consideration of following scenario: to generate least cost strategy that reduces emissions by 30%. The current algorithm will sort through the sources and controls and match them based on locality, max emission reduction and cost, then starting from the minimum cost to benefit ratio algorithm assigns the controls. In this scenario all the sources are open to the controls, so what if the user only wants to apply controls to a certain sector, but reduce emissions globally. As I understand from the current structure this could not be achieved with the current set up. A formal optimization technique could provide this type of analysis.

Response - We agree that optimization algorithms would be beneficial to the tool and we will pursue incorporation of such algorithms as resources become available.

Commenter 3 - Glenn Sappie, North Carolina DENR

The cost equation documentation was pretty well organized and logical, except that I don't understand why you placed "Equation Type 2" before "Equation Type 1"... The numbering of types

of all the rest of the equations may be more logical by following your table of contents as a more logical order.

I don't find the "code" to be of much use (especially without some introduction and further explanation on how a user can either access the code or substitute values or do whatever a user might do.

I liked the approach of applying default \$/ton... in cases where more specific variables are not available.

This question relates to each type of strategy. I followed the logic of maximum emission reduction, least cost and least cost curve approach. I missed an adequate explanation of how 'apply measures in series' is used in mobile source sector. I didn't fully understand what the annotate inventory" strategy meant. The usefulness of projecting a future year emission inventory or how it is used was not clear or I missed finding it. Having relied entirely on the CoST Development documentation, instead of having the actual tool to 'test and try out functions' is sometime a needed step for me in learning something like the CoST tool. Sometimes I need to work through the interface between the documentation and the program. The program was not available to us for review, so you have to imagine the program interface.

Response - We agree that the improvements recommended by the commenter would be beneficial to the CoST documentation and will make these improvements as resources and time allow.

Commenter 7 – Dan Loughlin, EPA/ORD/APPCD

In the algorithmic area, most of my comments are on the topic of the Least Cost feature. This feature implements a heuristic that essentially sorts the available control options by cost effectiveness and works down the list until target reduction levels are met. The heuristic itself is effective (I believe I understand its implementation, although this part of the documentation could use some additional descriptive detail and a more informative example). I believe the design and implementation of the least cost algorithm could be improved, however, to provide results that would be more similar to those produced by a formal mathematical programming optimization algorithm. I suggest some potential improvements later in Part 3 of this review.

A second comment related to optimization is that I would strongly suggest that OAQPS consider using a formal optimization algorithm to implement the optimization feature. Formal optimization algorithms are very computationally efficient and may greatly reduce the time necessary to construct least cost control strategies. More importantly, formal optimization algorithms could provide the ability to conduct multi-pollutant assessments, optimizing over many pollutants simultaneously. There are several free open-source optimization solvers that could be applicable.

Response - We agree that optimization algorithms would be beneficial to the tool and we will pursue incorporation of such algorithms as resources become available.

a. Max Emissions Reduction

I am not aware of any standard operating procedures for calculating emission reductions from control measures. The methodology, as I understand it, appears to be sound. From the documentation, it was noted that costs for technologies would go to zero if a cost equation is specified but not all of the values are supplied. This is a dangerous outcome if there are not QA measures in place to identify these situations and notify the user. It wasn't clear from the documentation whether such measures exist.

Response - We agree that it would be beneficial to notify the user when an output includes emission reductions where some or all of the costs could not be calculated. We will explore methods for including such a notification as resources become available.

b. Apply Measures in Series

I believe the approach that has been implemented is reasonable and effective. In some instances, I

suspect that the use of controls in series may be better represented with multiplicative factors instead of additive factors. For example, under some circumstances, two devices with 80% removal efficiencies, used in series, could have an overall efficiencies of $[1 - (1-.8)*(1-.8)]*100 = 94\%$. Is this a feature that should be supported?

Response - The "Apply Measures in Series" algorithm does currently apply multiple controls in a multiplicative, not additive, manner. The example equation listed in the comment above correctly reflects how CoST currently works (although the result in the example should be 96%). We will try to make this clearer in the CoST documentation.

c. Least Cost

I believe that the current implementation, as I understand it, will produce reasonable results. It may be possible to improve the performance given the alternative method that I propose below. There is one portion of the methodology where the example shows NO_x and VOC costs being added together. I think more information is needed here. Perhaps more description, a footnote, or an appendix, would allow this step to be described and justified more fully. In addition, I think that OAQPS should very strongly consider implementing a formal optimization algorithm that would utilize mathematical programming. Such an algorithm would facilitate multi-pollutant optimization in a manner that the current heuristic does not.

Response - We will improve the documentation describing the basis for cases where costs are based on multiple pollutant reductions. There are only a few such cases in CoST. As mentioned previously, we agree that the addition of optimization algorithms would be beneficial and will incorporate this as resources become available.

d. Least Cost Curve

I think that this is a very useful feature, and I suspect that these curves would be of value in other applications as well. This general approach seems reasonable, although the iterative process may be more complicated than necessary. For example, do you actually need points at 5% increments, or would it also make sense to generate all the points on the curve? I looked over the example cost curve that was generated (Least Cost Curve Control Measure Worksheet.xls) using the algorithm.

Response - As resources allow, we will explore the option of generating all points on the curve.

e. Annotate Inventory

I did not review this function.

f. Project Future Year Emission Inventory

This is a very useful feature. There is some overlapping functionality with some of the EMF's other tools. Also, it appears that some features that have been implemented in SMOKE's projection packet interface (e.g., SCC wildcards) have not been implemented in CoST.

Response - As resources allow, we will explore the implementation of other useful features from the SMOKE projection packet interface.

Question 2: Are the cost equations used in CoST (as described and defined in the Cost Equations Documentation) reasonable, current, and consistent with standard operating procedures for calculating costs of control measures?

Commenter 5 – Gayle Hagler, EPA/ORD/APPCD

In general, the cost equations seem reasonable. It would be nice if the cost to remove any older systems would be included in the future.

Response - We agree that removal costs for old control equipment in a replacement scenario would be an improvement to CoST. We will pursue adding this information as resources allow.

Commenter 3 - Glenn Sappie, North Carolina DENR

The cost algorithms seem to be consistent with previous accounting approaches that I am familiar with and were similar to those used in AirControlNet, so the results were pretty much as I expected although I didn't have an opportunity to try to reproduce any specific cost at any plant, by plugging value into the equation and checking the result. The "Capital to Annual" ratio was an accounting practice that is somewhat new to me and I think it could use some better explanation.

Response - As resources and time allow, we will improve the explanation of the "Capital to Annual" ratio in the documentation.

Commenter 4 - Andy Bodnarik, New Hampshire DES

The control efficiencies estimated for the various types of NO_x controls appear to be within the range of current estimates. The Capital Recovery Factors used for the Non-IPM Sector NO_x control costs, as shown on page 13, Table 1 of the Cost Equations Documentation, appear to be somewhat lower than more current estimates for Non-IPM sectors sources (see specific comment 4 below).

Response - We are currently updating the CMDDB control and cost information for NO_x control measures. In 2012 we will complete an update of the NO_x control and cost information for ICI Boilers and will continue this effort for other sectors as resources become available.

Commenter 8 - Ozge Kaplan, EPA/ORD/APPCD

Most of the equations that is used to assess cost of a technology looks like it represents some type of a cost curve of individual equipment. If this is the case, a brief remark could be made for each equation type. In addition, the rationale behind using different types of equation could be useful. It is rather confusing to me that the equations are called Type 1, 2, ...

What is the reasoning behind naming the equations type 1, 2, ...? Is there a physical meaning behind them?

There is no guidance on how to use the equations? At the beginning of the documentation, a list that provides a brief description of each equation type could be useful. It looked like some of them actually cost curves for very specific equipment. Maybe that equipment could also be mentioned. It was not clear whether the user has flexibility to select different equation types for different equipment. How does the user select appropriate type of equation for a certain technology application? How flexible the user is to add new control technology to the database? If there is flexibility, any guidance on which equation type to use could be useful.

The equations could be formatted to differentiate which parameter could be changed by the user and/or which are read from the database/ hardcoded into the code, etc.

Response - We agree with many of these ideas for improving the Cost Equations Documentation. We will improve the documentation, addressing as many of these comments as possible, as resources and time allow.

Commenter 7 - Dan Loughlin, EPA/ORD/APPCD

I am not aware of SOPs for cost calculation. The equations appear to be well-formed and useful. I would need to see the original data to determine whether alternative analytical or empirical forms would be better. I suspect that a quick review by a statistician would be useful in validating the approach. I see that some equations include an additional 4%-of-capital expense for taxes and other fees. Are these expenses and fees incorporated to some degree for all controls? If not, should they be?

I reviewed the cost equations very quickly. The forms of the equations appeared to be reasonable to me. I note that there are exponential factors on many to represent economies of scale, which I think is very important. Evaluating the degree to which these equations fit the available control data is beyond the scope of my review. It is apparent that the quality of the characterizations of the control

measures that are currently in place and those that comprise the Control Measures Database, both new *and* incremental, is critically important in being able to develop plausible and credible cost projections. If one has not been developed already, a long-term plan for periodically updating these characterizations should be developed. Further, it seems that the activity of keeping the database up-to-date should be prioritized highly in the budgeting process.

Another additional useful feature would be the ability to easily toggle between using cost-per-ton values and the cost equations. Cost equations can capture additional source-level features (e.g., stack height, flow rate). However, when different sources, even within the same sector, use different equations, the results can be more difficult to interpret. This toggle would provide a user with additional information for judging the results and examining the impact of cost assumptions. It would also provide an important QA step. The importance of the choice of which cost equation to use is evident in the example calculations provided in Table 4 and elsewhere. For example, the annual cost-per-ton developed using the default approach is \$126. Using the Type 8 equation, it is \$9,689. The fact that these values are nearly two orders of magnitude different is troublesome.

Response - As resources and time allow, we will examine all cost factors and equations to see if they account for taxes and fees and we will add the ability to toggle between cost-per-ton values and cost equations and their resulting costs. We recently began developing a long-term plan for updates to the control measure characterizations, including cost projections and we will attempt to build this into the budgeting process.

Commenter 6 – Will Yelverton, EPA/ORD/APPCD

Incorporating feedback mechanisms or having more dynamic representations of control costs into the optimization would theoretically produce more representative results. One example of this would be accounting for the increased cost of coal switching if it were implemented across the entire population of coal boilers, thus stressing supplies and perhaps inflating the prices of low sulfur coal (an option presented in Section 3.2). This may or may not be the case in this example or others, but the utilization of fixed factors to estimate implementation costs does incur such limitations. If the purpose for this tool is to get a very general sense of how particular systems might react, the methods used in CoST should produce useful results, given an understanding of its limitations.

With regards to the equations used in CoST: most appear to be reasonable for calculating the cost of control measures, however I have to restate my lack of expertise in cost equation development. I do find some concern with the utilization of varying calculation methods for different control measures within the same analysis (e.g. utilizing multiplicative, scaling factors and exponents, gas and stack flow rate factors, etc. for some versus standard \$/ton factors for others). This is understandable when calculating costs of a particular control method for a small source, where standard equation methods might not be applicable at such scale, as opposed to a more commonly sized one. However, employing varying calculation methods between competing measures would seem to introduce (or at least create increased opportunity for) bias for one control over the other. Granted, if a single equation were used for all methods there could still be bias subject to the accuracy of available input values for each method.

Response - As resources and time allow, we will explore incorporating feedback mechanisms for the impact of control measures. One approach for this would be to create a link with an economic impact model to reflect the impact of control decisions on the economy, and in turn to reflect the changes to the economy on the emission inventory and control costs.

Concerning the potential for bias resulting from using a mix of calculation methods, the cost equations we employ in the tool are generally significantly more accurate than the simpler cost-per-ton factors and therefore the tool by default uses the cost equations whenever possible (i.e., whenever a cost equations exists for a control measure and when the inputs to the cost equation are available in the emission inventory) unless the CoST user overrides this default.

Question 3: Are there any source categories or controls that have not been addressed adequately?

Commenter 7 – Dan Loughlin, EPA/ORD/APPCD

I am not aware of any.

Commenter 8 – Ozge Kaplan, EPA/ORD/APPCD

Not that I noticed.

Commenter 4 - Andy Bodnarik, New Hampshire DES

As noted in comments 5, 6, and 7 below, the algorithms used for estimating the costs of SNCR and SCR need to account for factors related to: the capacity of the boiler (boiler size), gas flow rate, stack flow rate, and the amounts of chemical reagent needed to achieve a specific percent NO_x reduction. Simply put, the NO_x Control Cost algorithms for SNCR and SCR should account for the same factors as the algorithms used for the SO₂ scrubber control costs. I have attached a Power Point presentation that demonstrates the impact of these factors on NO_x control costs for ICI boilers and also documents the impact of boiler size on the default cost per ton NO_x values shown in Table 2 on pages 14 through 20 of the Cost Equations Documentation.

Response – We are currently in the process of updating our NO_x control measure information and we will incorporate these recommendations as resources allow.

Commenter 3 - Glenn Sappie, North Carolina DENR

I really didn't notice anything missing (when compared to earlier tool) and in general I look forward to using the tool. It may be of some value to develop and include a larger regional example, (like the strategy behind the transport rule for instance and include the summary outputs as part of the documentation... You may be able to use that regional strategy output and 'walk' users through the logical steps in determining the reasonableness of the results and just how these example runs interface with EMF, and finally some guidelines for interpretation of the results. I would be helpful, in relation to the transport rule see how the different control cost assumptions of \$/ton control (\$500, \$1000, \$2000) compare to the baseline. So bottom line recommendation: load program with a real world current example to help teach the process of evaluating different alternatives or optimization strategy. In that way a user might learn something useful from a real life example by going through a tutorial or lesson format.

Response - We agree that presenting a recent “real world” example would be useful as part of a training tool or user’s guide for CoST. We will incorporate this into the CoST documentation as resources and time allow.

Commenter 5 – Gayle Hagler, EPA/ORD/APPCD

The coverage of source categories and controls is very impressive, so my suggestions here are primarily possible future improvements. As the CoST document describes, the mobile source category is a quite a different beast than other types of sources. With this model forecasting out several decades in the future, the vehicle fleet the in USA may change considerably over the time horizon of the model and some of the measures applied may alter the fleet as well (e.g., “Plug In Hybrids”). For measures or consumer actions that may significantly alter the fleet, some measures applied to that altered fleet may have different results than if they had been applied to the original fleet. It would be nice to see somewhat of a feedback loop applied to the mobile source category for measures that would alter the fleet or allow the user to have an opportunity to specify a range of realistic future fleet conditions.

Another suggestion for the “Apply Measures in Series” would be to allow more of a portfolio approach, rather than a sequential approach where realistic. There should not be any logical reason why one could not apply “Plug In Hybrids” simultaneously with “Best Workplaces for Commuters”. Allowing the measures to compete and perhaps have an optimization on the degree of rule application may provide a lower cost emissions reduction.

Response – We agree that it would be helpful to include the ability to change the emission inventory

as part of a control strategy, such as altering the vehicle fleet or for stationary sources altering the fuel type. We also agree that the ability to optimize across mobile source control options would be beneficial. We will incorporate these abilities as resources allow.

Question 4: Are the results plausible for the example scenarios? If not, what would you have expected them to be?

Commenter 5 – Gayle Hagler, EPA/ORD/APPCD

Yes.

Commenter 8 – Ozge Kaplan, EPA/ORD/APPCD

Yes.

Commenter 4 - Andy Bodnarik, New Hampshire DES

Even if the results of the example scenarios are plausible it is difficult to evaluate the accuracy of the methodology used to derive these results without additional information on some of the specific components used in the algorithms.

Commenter 7 – Dan Loughlin, EPA/ORD/APPCD

I looked over the least cost strategy and the least cost curve results. I sorted each by annual cost-per-ton measure, which helped in interpreting the results. Perhaps the queries that generate these files could include sorting of this kind.

Response – We will explore the level of effort necessary to add such a sorting capability versus the value that it adds. Currently, the user can easily export the CoST results to several standard data management software packages such as Excel or Access and perform many functions such as sorting, filtering, and summarizing.

Commenter 3 - Glenn Sappie, North Carolina DENR

I was able to review the results summary, detailed and county excel output and as near as I could determine the different constraint criteria for the filtering results seemed to produce expected results when I closely examined the output. The output for the 3 states examples used: PA, OH and LA, and it seemed to have been correctly placed geographically, based on some of my crude Q&A steps by plotting their location. I think the close links to the emission modeling framework that were included in this software package will be extremely useful as an evaluation tool for comparing several alternatives in a consistent manner. The ability to add get output that is formatted into shape files and Google map coordinates is a nice Q&A procedure to see if there are unusual data anomalies.

Question 5: Are there critical omissions in the algorithms or equations that significantly influence the results?

Commenter 7 – Dan Loughlin, EPA/ORD/APPCD

I am not aware of any.

Commenter 5 – Gayle Hagler, EPA/ORD/APPCD

Not “critical” – the model is useful as is. However, future improvements may enhance the model’s capabilities – please see responses to #1 and #3.

Commenter 8 – Ozge Kaplan, EPA/ORD/APPCD

See my comments on the adding formal optimization procedures to capture various real life scenarios. In addition, some of the cost equations are quite precise in terms of numbers. For example equation Type 4, do those equipment falls under this equation always follow this cost path? Some of the uncertainties in the costs should be pointed out, and also flexibility to update the equation types should be introduced.

Response - As resources and time allow, we will review the documentation for opportunities to better describe the cost uncertainties. Concerning flexibility to update the equation types, the tool was created in a way that allows users to modify or update the cost equations through modifications to the Control Measures Database. This capability is available to users with administrative privileges.

Comments on Control Strategy Tool (CoST) Documentation

Commenter 8 – Ozge Kaplan, EPA/ORD/APPCD

Page 5: Discount rate: does this include investment hurdles? Provide brief explanation.

Response - The discount rate does not include investment hurdles. It only covers the estimated cost of capital. We will add this explanation to the documentation.

Page 6: 2.2.3: measure classes to include: I was not sure in what context the “obsolete” category was utilized in the runs. I understood these control technologies were not used in the new runs. More concise and clear example can be included.

Response - Control measures classified as "Obsolete" are included for historic purposes, to indicate controls that are in place due to previous requirements but are not generally applied as part of future control scenarios because they are assumed to be inferior to other currently available control options. We will add this explanation to the documentation.

Page 8: 2.2.5: fields automatically set by CoST: The “total annualized cost” parameter is calculated and presented in the equations document, and if I understand correctly, some of the annualized cost of equipment is based on magnitude of the emissions reductions. So it was not clear to me how the “total annualized cost” could be set before running the model.

Response - Re total annualized cost of equipment, some are calculated based on magnitude of emissions reductions (simple cost per ton of reduction factors) and others are based on equations that take into account operating parameters such as stack flowrate and boiler design capacity. No total annualized costs are calculated before running CoST. We will review the referenced documentation for ways to clarify this point.

Page 31: step 7 of maximum emissions reduction algorithm: It was not very clear how each criterion is applied to assign a control technology to a source. Does the list impose a hierarchical order? It seems in the example, first elimination criteria is the location, then highest percentage reduction, then cost. If this is true, then maybe this could be clarified in the algorithm as well. Similar comment applies to the following algorithms that utilize this hierarchy.

Response - Concerning hierarchy for determining maximum emissions reduction, we will clarify in the documentation how this works.

Commenter 7 – Dan Loughlin, EPA/ORD/APPCD

Page 3, Figure 1:

- Do 2020 and 2030 represent the only projection years supported, or are these just examples? I believe the latter is true, so perhaps the parenthetical text should read (e.g., 2020 or 2030)

Response - The algorithms in the software support all years. The years are limited only by the year of the emission inventory that the user selects and the year of the available information in the Control Measures Database (CMDDB). The user can provide an emission inventory for a new year, as long as the inventory is in the required format, and the user can add control measure information for any year of interest. We will clarify this in the documentation.

Page 6, paragraph beginning with “Inventory Filter:”

- The filtering feature allows specification of SCCs by a select number of digits, followed by a wildcard (%). Since both point and area sources can start with 2's, it seems that a filter intended for one type of source could potentially be applied to the other. If this is an issue, perhaps there is alternative approach for specifying wildcards that would be better.

Response - We agree that it would be valuable to have a filter that distinguishes between point and

area source SCCs. We will explore this capability as time and resources allow.

Page 7, Section 2.2.4, Input Constraints

- Several options are available for specifying constraints on the control selection process. Controls to be considered must meet all of the constraints. Is there any advantage to also allowing the option that a control be considered if it meets any one of the constraints?

Response - One of the filter functions currently available in CoST allows the option to select controls that match one or all of the constraints.

Page 12, last paragraph

- This paragraph mentions that use of a capital cost ratio to calculate capital costs from O&M costs. It would seem this ratio could differ greatly from one technology to another. The text should clarify whether a common assumption is made and applied to all technologies, if this ratio is technology specific, and whether it is only applied if other sources of capital cost information do not exist.

Response - We will add this explanation as time and resources allow.

Page 13, 1st paragraph

- Since time value of money methods are being used to shift costs related to equipment, is GDP growth really the best metric, or are there other values that would be better (e.g., is there an equipment cost index)?

Response - We will explore whether there are better metrics than GDP growth as time and resources allow.

Page 14, Table 4

- It is disconcerting how different the annual and cost-per-ton values are between the default and cost equation approaches (e.g., almost two orders of magnitude difference). Can this be explained? Can it be demonstrated that the cost equation is capturing important aspects not reflected in the default approach?
- Calculations on this table would benefit from inclusion of units. I see that there are units in the cost equation document. Still, they should be here as well.

Response - We will add a discussion about the uncertainty of the cost equation and cost per ton factor results, especially when applied to a single source or small number of sources rather than the originally intended purpose of doing regional or national analyses.

Page 21, SQL code

- I did not review the SQL code on this or later pages (not familiar enough with SQL to add value)

Page 24

- In the description of TOTAL_COST, the text seems to allude to this value representing all controls that have been applied at the source. Is there an attempt to match up controls listed in the inventory to controls within the CoST Control Measures Database, and to calculate a cost from the result? Additional text here or elsewhere would be useful to clarify whether this is the case.

Response - The value of such a function is limited by the amount of missing control information in the emission inventories.

Page 25, Table 7

- I am not familiar with Segment being applicable to point sources. Is this accurate or an error?

Response - "Segment" is one of the units used to describe point sources in the emissions inventory. The hierarchy is Plant, Point, Segment, etc. For example, Segment could be used to distinguish the different types of fuel used in a boiler during the course of a year.

Page 34, Table 12

- The column name "Effective Date" is not intuitive. Perhaps something like "First Available Yr" would be more descriptive. Or, "Available in Yr".

Response - We will explore more intuitive terms for this field as time and resources allow.

Page 37, equations

- These equations require units to be able to evaluate. For example, I would assume a metric like "Typical Capital Cost" is in \$s and that minimum stack flow rate is in cubic meters per second (or some equivalent volumetric flow rate). The produce of these would have units of \$/cms, which would not be consistent with "Total Capital Cost". Maybe "Typical Capital Cost" should read "Typical Capital Cost per Stack Flow Rate"?
- In the "Annual Cost" calculation, it is not clear to me what the (0.04 x capital cost) term is for, since the first term annualizes the capital cost. Perhaps these are described in the cost equation documentation. A page or section reference to that documentation would be helpful.

Response - We will add information on units where it is missing in the documentation.

Page 38, Paragraph 1

- The text: "Note that if there is no default cost per ton and the information needed to compute the cost is not available... the cost will currently be computed as zero dollars." This is obviously an important note. Are there warning messages that alert the user that this use of zero has occurred?

Response - Yes, notes are included in the output detailed summary reports.

Page 43, Table 16

- A value of 30 days-per-month is assumed. Including leap years, I believe the average number of days per year, divided by the number of months per year is 30.44. Is 30 a reasonably accurate assumption?

Response - The default of 30 days is used only when the month is not specified. However, the month is generally specified so it is expected that the default would rarely be used. As resources and time allow, we will investigate the value added of revising the default to 30.44.

Page 44, Table 17

- Some controls that would be used in series could have multiplicative impacts (instead of additive). E.g., two controls in series that each reduced 80% could have the following combined impact: $[1 - (1-.8)*(1-.8)]*100 = 96\%$ reduction.

Response – CoST currently uses multiplicative impacts in several of the algorithms. In the "Apply Measures in Series" algorithm, the user can choose multiple controls and CoST will apply them in a multiplicative calculation in the order selected by the user. The order does not affect the percent

reduction but does affect the estimated costs. In the “Max Emissions Reduction”, “Multipollutant Max Emissions Reduction”, “Least Cost”, and “Least Cost Curve” algorithms, we have a small number of combined controls (e.g., SCR + LNB) identified as such with multiplicative percent reductions and costs already calculated. In a control strategy run using one of these algorithms, CoST will select a combined control or individual control depending on which best fits the constraints of the run. If a combined control is chosen, then the multiplicative impacts are reflected in the results. Alternatively, if the user is selecting the specific controls to be applied then they can choose the combined or individual controls depending on which best fits the needs of their control strategy.

Page 46, bottom of page

- The italicized warning indicates that a tonnage removal target will be overwritten by a percent reduction target. Is the user warned in some way?

Response – The overwrite is indicated to the user at the time the user is specifying the constraints.

Page 47, marginal cost discussion

- This metric is called “marginal cost,” but is actually the “average per-ton cost” for a particular control technology. I suppose that this term is used because the value also would represent the marginal cost to the system for the application of a unit of control at this particular source. Still, I thought that I would point out that this use of the term “marginal” might not be intuitive to all.
- I don’t understand the marginal cost equation in which NO_x and VOC annual costs are added together in the numerator. This does not seem like it would produce the desired result. I think this discussion would benefit from an example that demonstrates how and why this calculation is made.

Response – For a small number of control measures, limited to the mobile source sector, costs are calculated in terms of NO_x and VOC reductions, additive. This was for a few measures where NO_x and VOC are the shared primary targets of the measures. We will add a discussion as suggested.

Page 49, steps 11, and 12

- I found these steps difficult to follow. Perhaps they could be re-worded to clarify?
- Based on how these are currently written, the approach taken appears to be different than the one that I would have implemented. There may be reasons why the your steps are better than mine, but here is a quick summary of how I would implement:
 - Cycle through each source and each control option for each source
 - Remove control options at each source that are dominated (e.g., for which you can achieve a higher level of control at that source for an equal or lower cost)
 - Then, I would make a master list of the available controls and sort first by tons removed, then by cost-per-ton (e.g., the list would be ordered by cost-per-ton, but when multiple controls share the same cost-per-ton, the option that removes more tonnage would appear first).
 - Next, I would walk down the list, from low cost-per-ton to higher, turning on each control. When a control is turned on for a source that already has a control indicated the previously turned-on control would be turned off so that there is no more than one selected control from the list for each source.
 - This process would terminate when the targeted amount of emissions reduction is met. Alternatively, if the goal were to generate a tradeoff curve, the process would continue up to the end of the list.
- With both the implementation that you describe and mine, there is the potential to overshoot the target control amount substantially. If this overshoot is great, a true, optimized least cost solution might opt to drop some controls with lower marginal costs for some with higher

marginal costs, such that the overall cost target is met at least cost without as great an overshoot. It isn't clear whether this functionality is important, but it could be achieved using an optimization algorithm (e.g., to solve the classic 'napsack problem'). A formal optimization algorithm may also facilitate additional functionality, such as the simultaneous consideration of multiple objectives and the consideration of much more complicated constraints (e.g., multi-pollutant, least cost control strategies). I suggest exploring this functionality in the future.

Response – We will examine the described alternative approach for selecting controls and we will explore optimization algorithms as resources allow.

Page 76, Table 27/28

- SMOKE used to allow SCCs wildcards to be specified by using trailing 0s. CoST appears to have dropped that ability. It seems having some ability to specify SCC groups using wildcards would be useful. If 0s are problematic, perhaps? s would work?

Comment on Control Strategy Tool (CoST) Cost Equations Document

Commenter 7 – Dan Loughlin, EPA/ORD/APPCD

Response – We agree that the use of SCC wildcards would be useful, in part to reduce the size of the Control Measures Database in cases where a control measure applies to a whole series of SCCs. We will add this capability as time and resources allow.

Page 1, Introduction

- The writing in these documents is very good. It could be advantageous to have a technical writer review before a release to the public. For example, "... in 2 ways; cost equations..." would more conventionally read "... in two ways: cost equations..."

Response – We agree that the Equations Document would benefit from a thorough review by a technical editor. We will conduct a technical edit of the document as time and resources allow.

Page 5, Incrementally applying controls

- It is good that you are accounting for economies of scale with the annual cost exponent. I'm intrigued that there is a different annual cost exponent for incrementally applied controls. Will these factors be derived via regression? Is there a logical reason why this factor would be different for additional controls... or is this just a placeholder in case there is a need for the factor to be different?

Page 9, Capital to annual cost ratios

- How are these values derived?

Page 11, Incremental controls

- Should the equations be changed to signify that incremental cost values are used?

Page 13, Tables

- When were these data generated? How often are they updated?

Response – We greatly appreciate the time and attention given in preparing these comments and identifying areas in the documentation that need additional or improved explanations. As time and resources allow, we will revise the Equations Document to add or clarify discussions and explanations that are missing or unclear, addressing the comments listed above.

Commenter 6 – Will Yelverton, EPA/ORD/APPCD

Page 13: More explanation of the sources for the data in Tables 1&2 would be beneficial. I assume

they are from the control measures database? Either way an example of or reference to how they are developed might be helpful in this document.

Page 23: The fourth paragraph discusses use of a scaling factor for source sizes below 500MW. What is the reasoning behind the selection of the 500MW threshold, and how are the scaling factors determined to that point? 500MW is a relatively large size for a single utility boiler, and most likely beyond the point at which incremental changes in control costs begin to vary linearly with capacity. A number of different control options for NO_x and other pollutants were recently analyzed using EPA's Coal Utility Environmental Cost (CUECost) workbook (similar to the CoST Least Cost Curve methodology) for purposes of determining proper bin sizes of existing US coal generation capacity resources. The results showed that investment costs varied essentially linearly with capacity for sources larger than 100MW. Also, It seems to me that the last sentence just restates the same logic as the previous two.

Page 23: The sixth paragraph appears to be mixing use of the term *capacity factor* with the definition for efficiency; specifically the second and third sentences. Typically the term *capacity factor* refers to the unit's availability. E.g. a value of 1.00 would mean that the unit is available 100% of the time with no necessary down time for pump maintenance (e.g. wet FGD), catalyst replacement/regeneration (i.e. SCR), etc. The definition used in the text seems to refer to thermodynamic or mechanical efficiency, a term typically used to describe the operational limitation of boilers, engines, etc. A third term, which is probably more appropriate here when discussing pollution control methods, is control or capture efficiency. This refers to the ability of a measure to capture the targeted pollutant, and appears to be what's referred to in the fourth column of Table 3, under the heading "CE". E.g. a value of 1.00 would indicate that the control measure captures or mitigates 100% of the targeted pollutant on average.

It seems like the control efficiency (CE) is utilized in the strategy algorithms to determine which measure, and thus equation type, to use for calculating costs. In this case the capacity factor (CF) term appears to be used correctly in the equations. The verbiage in this paragraph was confusing however, so I thought it worth noting. The issue is righted in the fourth and final sentences, discussing pre-calculated *capacity utilization factor*, although I'm not sure why those aren't just combined into one as the same statement is repeated for a different list of control measures.

Page 27: A better explanation of, or reference to, data sources in Table 3 would be useful to answer questions such as why capacity factors and equipment life differ among the various control options. This is the case for other similar tables in the equation document.

Page 28: What is the reference for the *Gas Flow rate Factor*? Is this net power per acfm? Many variables could skew this among different sources. Most notably, different fuel heating values and source stoichiometry. Also the use of actual cubic feet per minute (acfm) rather than standard cubic feet per minute (scfm) could skew these values among sources that operate at varying temperatures, pressures, etc. I would assume that this factor comes from a source where these variables are accounted for, but a reference would be helpful.

Page 50: The last paragraph on this page has the same issues with CF terminology as mentioned earlier regarding the sixth paragraph on page 23. Page 54: It is good to see that fuel sulfur content for wet FGD controls is accounted for, as it's critical to the amount of sorbent required. I would think the use of a CF=1.0 is optimistic for LSD and LSFO controls. While they are reliable methods, it's hard to estimate that any control would be available 100% of the time. Of course if you assume that it is available 100% of the time when the source (e.g. boiler, etc.) is available (usually 60-85%, depending on source type), and the source availability does factor in somewhere in the analysis, then this may alright. This is another example of where better reference to table data would be helpful.

Commenter 8 – Ozge Kaplan, EPA/ORD/APPCD

2.1.1.1: what are the units of "Capital Cost Multiplier"?

2.1.1.2: what are the units of "Annual Cost Multiplier"? Does this cost include capital and O&M? Where do you get this multiplier? It seems an awkward type of data to attain.

2.1.2.2.3: What does O&M cost include? Does it include cost of fuel, material (e.g. some scrubbers may need lime), electricity and labor?

2.1.2.3: this equation has being updated or added in CoST. So while update has been conducted for incremental application of controls to a source, which equation has been utilized?

2.1.3: Type 2 equation code: what are the variable_coefficient1, 2,..?

2.1.4: “emission reduction is calculated by CoST”, elaborate on this. I can infer that this is a variable that model calculates for? Maybe refer to Development Documentation for cross-referencing to some of the scenarios. So if a control has 90% control efficiency, and the source has 100 units of emissions, then model calculates the emission reduction as 90?

2.2.1.2: last sentence”...8760 is the number of hours of operation assumed per year”. This sounds misleading. 8760 is the total number of hours in a year, and capacity factor in the equation should cover the fraction of the year that the equipment is operational. Also define capacity factor in the documentation explicitly.

3.1.1.1: what is “retrofit factor”?

Are gas flow rate factor and capital cost factor fixed and hardcoded in the database? If so then Type 3 equation is applicable to only that certain SO₂ control technology applied in non-IPM sector? If this is the case maybe it could be noted.

3.1.1.2: The “flow rate” parameter in the Capital Cost. Is it equivalent to STKFLOW?

3.1.1.4: Correct spelling of “Capital” in the equation.

3.1.2.2: see comment for 3.1.1.2.

3.1.1.3: Variable O&M equation: “hours per year = 8736” is it meant to be for hours that equipment is running per year or number of hours in a year. Clarify. Keep consistency throughout the model. As far as in equation type 1 (see 2.2.1.2, the number of hours that the equipment is in operation was covered by capacity factor.

Page 32: equation type 3 code: capital cost calculation in both cases (i.e. STKFLOW < or >= 1028000), the equation is missing the “60” conversion factor (sec/min) that is mentioned in the 3.1.1.2 and 3.1.2.2.

Page 32: equation type 3 code: operation_maintenance_cost equation: some things are not adding up when you look at the 3.1.1.3. I can see the code is again missing the “60 sec per min” conversion factor, and in the 3.1.1.3, fixed O&M equation is missing the STKFLOW multiplier.

Page 36: equation type 4 code: capital cost and O&M cost calculation are missing the “60 sec/min” conversion factor that is mentioned in the 3.1.4.1 and 3.1.4.2.

Page 40: similar issue as in page 36. Missing the 60 sec/min conversion in capital and O&M cost calculations.

Page 43: similar issue as in page 36 and 40.

3.1.13.1: add brief explanation for the emissions reduction parameter.

3.1.13.2: “Capital Cost” and “Annualized Capital Cost” equations look little bit cyclic.

Page 46: equation type 11 code: what does “Variable_coefficient1,2,..5” entail?

Page 47: equation type 11 code: I can gather from the code that the cost per ton value is computed based on design capacity, then included in the annual cost. However in the 3.1.13.1, this reasoning is not explained. It might be good to spell this out in the main text. In addition, the total annualized cost includes Default Cost per Ton, not computed cost per ton. This is confusing.

3.2.1.2: The quote “8760 is the number of hours the equipment is assumed to operate a year” is misleading. Capacity factor supposed to cover the fraction of the year that the equipment is operational. Please clarify in the document.

4.1.1.3: none of the other equations (except Type 10) included explicitly a fee for taxes, insurance, and administrative costs. Why does only equation type 8 include these?

Page 59: what are the “Variable_Coefficient1, 2, ..”?

Page 60: similar issue as in page 36, 40, and 43.

4.2.1: text refers us back to 2.3.1.1. there is no such section. Clarify.

4.2.4.1: there is no unit conversion factor (60 sec/min) for STKFLOW in this equation type. Clarify.

4.2.4.2: correct spelling of “electricity”.

4.2.7.3: similar comment as in 4.1.1.3.

Page 78: in the code for equation type 10: the annual cost does not include the term “0.04 x Capital

Cost” for the taxes, insurance, etc. clarify.

Response – We greatly appreciate the time and attention given in preparing these comments and identifying areas in the documentation that need additional or improved explanations. As time and resources allow, we will revise the Equations Document and other CoST documentation to add or clarify discussions and explanations that are missing or unclear, addressing the comments listed above.

Specific comments on NO_x Control Cost Equations for Non-IPM (ptnonipm) NO_x Control Cost Equations

Commenter 4 - Andy Bodnarik, New Hampshire DES

1. There is a large difference in the boiler design and in the types of air pollution control equipment applied to boilers based on the boiler capacity (size of a boiler). The choice of a 2,000 million Btu/hr size as the upper bound for non-IPM boilers seems too high since a 2,000 million Btu/yr boiler can be a 200 MW unit, which is more similar in design to a small utility boiler than a large industrial boiler. I suggest that the upper bound for non-IPM (ptnonipm) cost analysis be 250 million Btu/hr (\approx 25 MW) as EPA is already using 250 million Btu/hr as the minimum size threshold for applying controls to EGUs (e.g., CAIR Phase 1, the proposed CATR).

Response – EPA is currently in the process of updating the control and cost information for ICI (Industrial, Commercial, and Institutional) boilers. As part of the update, we will review the upper bounds for application of ICI boiler controls and revise it if appropriate.

2. The origin of, and basis for the Capital Cost Multiplier needs to be clarified in the CoST Equations Documentation. For example, an equation could be added to Section 2.1.2.2.1, Capital Cost Equations on page 4 of the document to show how the Capital Cost Multiplier is calculated. Simply referring the reader to Table 1, on page 13 does not sufficiently explain why different types of controls applied to different types of devices have different Capital Cost Multipliers, or how the different the Capital Cost Multipliers were calculated. I realize that capital costs for different types of NO_x control equipment will increase with boiler size, but an explanation needs to be added on how this factor, in conjunction with the Capital Cost Exponent, will estimate this variation. Note that if a low NO_x burner is the NO_x control and the capital cost for a single burner is fixed, then if four burners of a given size are required instead of two burners; the raw, bare bones, off the shelf burner cost for four burners is twice the cost for two burners and the installation costs, while not directly proportional to the number of burners, could be proportional to the sum of the installation costs for a single burner. I’m not sure how/if factors that affect capital costs like sales taxes, freight costs, installation costs (e.g., foundations, piping, electrical, insulation, buildings, etc.) are covered by the Capital Cost Multiplier. I am also not sure how/if the indirect capital costs are factored into the Capital Cost Multiplier. Please note that the same comments apply to the equations used for when no control is in place for a source and when a control is applied incrementally to a source.

Response – As time and resources allow, we will add an explanation as to how the Capital Cost Multipliers and Exponents are derived and why they vary from control device to control device.

3. The origin of and basis for the Capital Cost Exponent needs to be clarified in the CoST Equations Documentation. For example, an equation could be added to Section 2.1.2.2.1, Capital Cost Equations on page 4 of the document to show how the Capital Cost Exponent is

calculated. Simply referring the reader to Table 1 on page 13 does not sufficiently explain why different types of controls applied to different types of devices have different Capital Cost Exponents, or how the different the Capital Cost Exponents were calculated. I realize that capital costs for different types of NO_x control equipment will increase with boiler size, but an explanation needs to be given on how this factor, in conjunction with the Capital Cost Multiplier, will estimate this variation. I'm not sure how/if factors that affect capital costs like sales taxes, freight costs, installation costs (e.g., foundations, piping, electrical, insulation, buildings, etc.) are covered by the Capital Cost Exponent. I am also not sure how/if the indirect capital costs are factored into the Capital Cost Exponent. Please note that the same comments apply to the equations used when no control is in place for a source and when a control is applied incrementally to a source.

Response – See response to previous comment.

4. Capital recovery factors (CRFs) are dependent on interest rates, equipment life, and the rate at which an individual company decides to amortize its costs. Interest rates can range from 7% -10% and equipment life can range from 10-20 years. Industrial sources generally pay higher interest rates than utility sources and equipment life can also be lower. These factors can result in capital recovery factors that range from a low of 0.0994 to a high of 0.1627. Since the annualized capital cost is determined by multiplying the capital cost times the CRF, I suggest that bounding runs be performed using a low and high CRF to test the sensitivity of the CoST model to change in the CRF and if possible, the results be compared to the actual costs for specific control installations. Note that in Table 1, page 13 of the CoST Equation Documentation, the highest CRF used is 0.1098 and the original EPA NO_x ACT EPAQ 453/R-94-022, March 1994 used a CRF of 0.1627 based on a 10 year equipment life and a 10% interest rate.

Response – As time and resources allow, we will explore the basis for CRFs and perform sensitivity analyses to determine the response of the tool to variations in the CRF and to determine if changes are needed in CRFs or in the way the tool applies CRFs.

5. Since the total Annualized Cost is calculated by multiplying the emission reduction by the Default Cost per ton for a specific control measure, it is critical that the Default Cost per ton be accurate. I suggest that that bounding runs be performed using a low and high Cost per ton estimate to test the sensitivity of the CoST model to changes in the cost per ton, and if possible, the results be compared to the actual costs for specific control installations.

Response – Annualized costs are directly related to the default Cost per Ton values so the sensitivity of the tool is 1 to 1. These values are generally based on an average of costs for a small number of control installations and vary considerably from unit to unit. The uncertainty is lowest when applied to a large number of sources while the uncertainty is highest when applied to a single source. It is not clear what would be gained from a comparison of CoST results to actual costs at a few specific installations other than to confirm what we already know – that costs vary considerably from one unit to another.

6. Annualized costs are also dependent on the capacity factor for the unit. The total annual costs will be different for units used only during the heating season for building heat when compared to boilers used for process steam, especially for NO_x controls and SO₂ controls that require the use of chemical reagents (e.g., ammonia or urea for SNCR and SCR systems and alkaline sorbents for FGD systems). The dollar/ton costs are different for NO_x controls used only during the ozone season than for NO_x controls used on an annual basis. I'm not sure how/if these differences are factored into the CoST model for calculating NO_x control

costs. It appears that the hours of operation are factored into the O&M costs for SO₂ controls (e.g., the equation for Variable O&M on page 29), but similar equations were not used for NO_x controls like SNCR and SCR.

Response – As we update the control information for ICI Boilers we will expand the explanation of how these equations are derived and what dependencies are included.

7. Why aren't retrofit factors, gas flow rate factors, and stack flow rates (STKFLOW) used for SNCR and SCR? If retrofit factors are used to describe the degree of difficulty for installing an SO₂ scrubber, shouldn't retrofit factors also be used to describe the degree of difficulty for installing an SCR system? Gas flow rates are critical for determining the amount of ammonia or urea used in these types of NO_x controls just as gas flow rate factors are critical for determining the amount of limestone needed for SO₂ scrubbers. Stack flow rates are also important for both SCRs and SO₂ scrubbers. I suggest an equation be developed for SCRs similar to the equations that have been developed for SO₂ controls on pages 28-31 of the CoST Equations documentation.

Response – We will consider these comments and attempt to address them as we update the control and cost information for ICI Boilers.