Control Measures Database (CMDB) Technical Support Document: Otherwise Undocumented Updates 2020-2023

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Contents

1 Introduction

EPA's Control Strategy Tool (CoST) estimates emissions reductions and costs associated with control measures applied to stationary sources of air pollution. CoST merges the Control Measures Database (CMDB) with EPA emissions inventories to compute source- and pollutant-specific emissions reductions and associated costs at various geographic levels (national, regional, and/or local).[1] The CMDB comprises control measure and cost information for reducing the emissions of criteria pollutants (e.g., NO_x, SO_2, VOC, PM_{10}, $PM_{2.5}$, and NH_3) from point and nonpoint sources.[2] Controls are matched to sources by the Source Classification Code (SCC) of the emissions inventory record.[3]

Cost equations are used to estimate costs of control measures for some point sources but are not used to estimate the costs for nonpoint sources. Cost equations are used to determine engineering costs using relevant data for the source when data is available from the emissions inventory for those variables. When this data is not available, a simple cost factor in terms of dollars per ton of pollutant reduced is used to calculate the annual cost of the control measure.

This technical support document (TSD) provides details about several updates that have been made to the CMDB. The equations and associated default cost per ton values have been updated for numerous control measures, the SCCs for which control measures are applicable have been updated, and some obsolete control measures have been removed from the CMDB. Several control efficiencies for co-pollutant reductions associated with area source $PM_{2.5}$ controls have also been removed pending further review.

2 Updates and Corrections to NO_x and SO_2 Equations from ERG (2019)

In 2019, updates were made to the cost equations for several NO_x and SO_2 controls for industrial, commercial, and institutional (ICI) boilers. These updates are described in *Documentation of Cost Equation Development Procedures for ICI Boilers* (ERG, 2019). This section discusses revisions that have since been made to these equations.

The equations developed in ERG (2019) were based on the 2016 version of the EPA Control Cost Manual spreadsheets for Selective Catalytic Reduction (SCR) and Selective Non-Catalytic Reduction (SNCR). These spreadsheets have since been revised as part of the ongoing updates to the EPA Control Cost Manual (U.S. EPA, 2017). The revised equations that appear in Table 1 below are based on the 2019 versions of the spreadsheets.

The revised equations also correct several errors in ERG (2019). While ERG (2019) indicated that the SCR and SNCR costs were in 2016 dollars, most of the costs were actually in terms of 2014 dollars. In the updated estimates, all values are in terms of 2016 dollars.

[1] More information about the Control Strategy Tool (CoST) and the control measures database (CMDB) can be found at https://www.epa.gov/economic-and-cost-analysis-air-pollution-regulations/cost-analysis-modelstools-air-pollution.

[2] For more information about the types of point and nonpoint sources included in emissions inventories, see https://www.epa.gov/air-emissions-inventories/national-emissions-inventory-nei.

[3] For more about Source Classification Codes, see https://sor-scc-api.epa.gov/sccwebservices/sccsearch/.

Calculation errors were also identified in ERG (2019) that impacted the total capital investment (TCI) and operation and maintenance cost (O&M) estimates for wet scrubbers, and the O&M estimates for dry scrubbers. ERG (2019) also omitted some valid observations in the analysis for wet scrubbers, which affected the results. This update corrects these oversights.

Table 1 presents both the original equations from ERG (2019) as well as the revised equations.

Table 1 Original Equations from ERG (2019) and Revisions (2016$)

Control Technology (Control Measure Abbreviation)	Original Equations		Revised Equations (7/24/2020)	
	TCI	O&M	TCI	O&M
Coal				
SCR (NSCRICBC)	y=37,202x	y=1,323x	y=42,864x	y=1,384x
SNCR (NSNCRICBC)	y=9,723x	y=938x	y=9,867x	y=1,089x
Wet Scrubber (SWSICIBC)	y=7,837x	y=4,826x	y=4,307x	y=1,172x
Dry Scrubber (SDSICIBC)	y=28,185x	y=3,437x	y=27,574x	y=3,037x
Fuel Oil				
SCR (NSCRICBO)	y=12,994x	y=611x	y=14,095x	y=628x
SNCR (NSNCRICBO)	y=5,275x	y=244x	y=5,259x	y=268x
Wet Scrubber (SWSICIBO)	y=7,966x	y=4,574x	y=4,317x	y=1,058x
Dry Scrubber (SDSICIBO)	y=28,577x	y=3,525x	y=27,090x	y=2,998x
Natural Gas				
SCR (NSCRICBG)	y=16,188x	y=557x	y=17,723x	y=579x
SNCR (NSNCRICBG)	y=5,701x	y=218x	y=5,785x	y=244x
Wet Scrubber (SWSICIBG)	y=8,378x	y=4,928x	y=4,161x	y=1,081x
Dry Scrubber (SDSICIBG)	y=30,954x	y=3,923x	y=28,139x	y=3,218x

Note: Independent variable for each equation is the boiler heat input capacity (MMBtu/hr).

The revisions to the equations also led to changes in the default cost per ton estimate for each control measure. These changes are shown in Table 2.

Table 2 Original Default Cost per Ton Values from ERG (2019) and Revisions (2016$)

Control Technology (Control Measure Abbreviation)	Original Equations	Revised Equations (7/24/2020)
	Default Cost per Ton	Default Cost per Ton
Coal		
SCR (NSCRICBC)	$7,004	$7,851
SNCR (NSNCRICBC)	$7,069	$8,058
Wet Scrubber (SWSICIBC)	$1,306	$1,199
Dry Scrubber (SDSICIBC)	$5,680	$4,341
Fuel Oil		
SCR (NSCRICBO)	$7,182	$8,541
SNCR (NSNCRICBO)	$7,454	$9,138
Wet Scrubber (SWSICIBO)	$4,365	$4,009
Dry Scrubber (SDSICIBO)	$9,752	$15,343
Natural Gas		
SCR (NSCRICBG)	$10,161	$10,962
SNCR (NSNCRICBG)	$9,495	$10,608
Wet Scrubber (SWSICIBG)	$5,098	$4,623
Dry Scrubber (SDSICIBG)	$11,238	$18,640

While this section details updates that were made to the equations originally estimated in ERG (2019), the equations for wet and dry scrubbers have been superseded by the estimates in GDIT (2021), described later in this TSD.

3 Revisions to $PM_{2.5}$ Equations from GDIT (2019)

Also in 2019, updates were made to the cost equations for $PM_{2.5}$ point source control measures. These updates are described in *CoST $PM_{2.5}$ Control Measures Report* (GDIT, 2019). Since the time of that update, EPA has developed an automated process for generating the equations for the $PM_{2.5}$ control measures. While this process relies upon the same logic as employed in GDIT (2019), some improvements to the calculations were also made.

There was some truncation of data values in GDIT (2019) that has now been corrected. Also, the model sources in GDIT (2019) were based on exhaust gas flow rate ranges that were manually identified. The updated estimates use flow rate ranges calculated from the underlying data. That is, the model plant for small sources is derived from sources in the 0-20^{th} percentile of the flow rate variable, the model plant for medium sources is derived from sources in the 20^{th}-40^{th} percentile of the flow rate variable, and so forth.

GDIT (2019) relies upon an updated version of the CO$T-AIR (U.S. EPA, 1999) spreadsheets for calculation of the costs of controls for the model sources. When calculating the cost of venturi scrubbers, the updated process numerically solves for the saturation absolute humidity parameter required by the spreadsheet for calculation of the saturation temperature (t_s) of the waste gas stream. U.S. EPA (1999) noted that:

> The saturation temperature (t_s) is primarily a complex function of the inlet waste gas temperature and absolute humidity and the saturation absolute humidity, all of which are user-supplied parameters. Traditionally, t_s has been determined graphically via a psychometric chart once the inlet temperature and humidity and the saturation humidity are set. To expedite the process, we programmed the (empirical) saturation humidity-temperature curve and the gas-water enthalpy and mass balances into the spreadsheet. (U.S. EPA, 1999)

In CO$T-AIR, it was necessary to enter a value for saturation absolute humidity and manually iterate this value until the following two temperatures converged (e.g., $\pm$ 0.5 °F).

$$T_{SE} = T_{IS} - \left(\frac{970 \cdot (H_s - H_I)}{0.24 + 0.45 \cdot H_I}\right)$$

$$T_S = \left(\frac{H_s}{0.000000009405}\right)^{\frac{1}{3.335}}$$

where

T_{SE} = Saturation enthalpy temperature (°F)
T_S = Saturation temperature (°F)
T_{IS} = Inlet stream temperature (°F)
H_S = Saturation absolute humidity (lb/lb bone dry air)
H_I = Inlet absolute humidity (lb/lb bone dry air)

Because many of the parameters needed to calculate saturation enthalpy temperature and saturation temperature are assumed or are constants in GDIT (2019), there are two equations in one unknown. As a result, the saturation absolute humidity parameter can be calculated numerically.

Finally, for venturi scrubbers the Liquid to Gas Ratio (L/G) was approximated in GDIT (2019) based on Figure 2.7 in the relevant chapter of the EPA Control Cost Manual (U.S. EPA, 2002). For reference this figure is reproduced below in Figure 1.

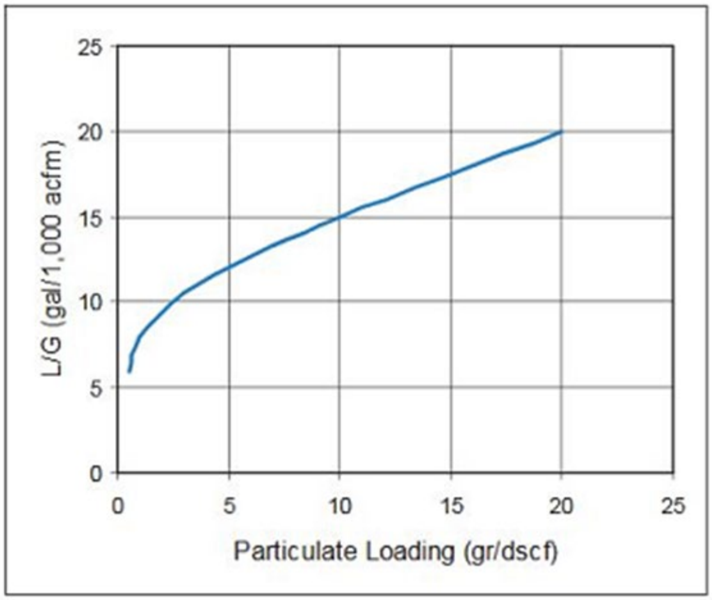

Figure 1 Liquid-to-Gas Ratio versus Particulate Loading Graph from EPA Control Cost Manual (U.S. EPA, 2002)

The figure in the cost manual refers to the 2002 version of the *Air Pollution Control Equipment Selection Guide* (Schifftner, 2002). In the 2013 version of the same guide (Schifftner, 2013), this graph appears as in Figure 2 below.

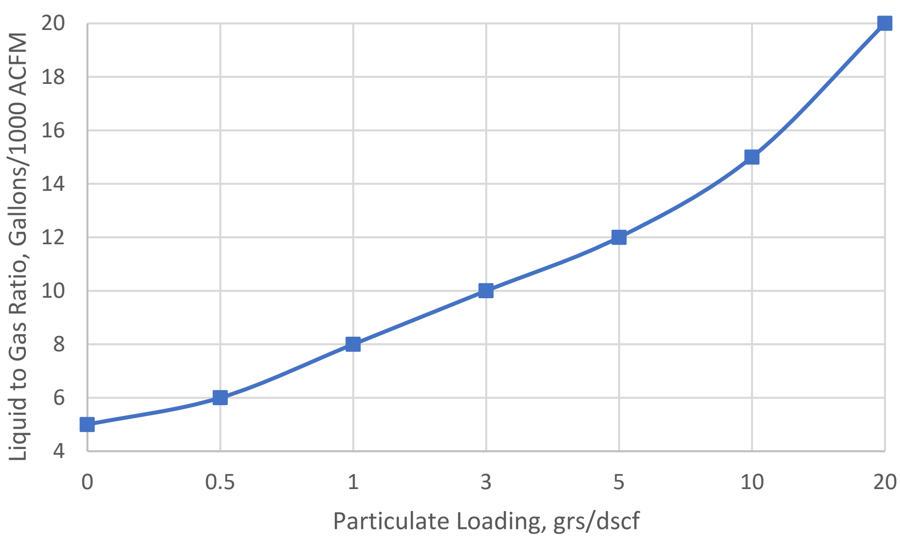

Figure 2 Updated Liquid-to-Gas Ratio versus Particulate Loading Graph
Source: Reproduced from Figure 19.3 in Schifftner (2013)

For the purpose of automation, the piecewise linear function implied in Figure 2 was used to determine the L/G ratio in the latest updates. Table 3 presents both the original equations for total capital investment (TCI) and operation and maintenance cost (O&M) from GDIT (2019) as well as the revised equations. All values are in terms of 2017 dollars.

Table 3 Original Equations from GDIT (2019) and Revisions (2017$)

Control Technology (Control Measure Abbreviation)	Original Equations		Revised Equations (1/10/2022)	
	TCI	O&M	TCI	O&M
ICI Boilers and Heaters – Coal and Solid Fuels				
Dry Flat-plate ESP (PESPICICOAL)	y=21.7x+2,400,000	y=3x+792,000	y=23.3x+2,574,000	y=2.8x+1,026,000
Fabric Filter –Pulse Jet (PFFICICOAL)	y=14.1x+791,000	y=3.1x + 891,000	y=13.9x + 827,000	y=2.8x+1,150,000
Venturi Scrubber (PVSICICOAL)	y=9.6x+993,000	y=3.2x+483,000	y=9.3x+1,025,000	y=3.2x+586,000
ICI Boilers and Heaters – Gas and Oil				
Dry Flat-plate ESP (PESPICIGAS)	y=89.7x+4,000,000	y=6.3x+254,000	y=90.3x+3,883,000	y=6.3x+243,000
Fabric Filter –Pulse Jet (PFFICIGAS)	y=20.8x+774,000	y=2.2x+258,000	y=20.9x+830,000	y=2.2x+264,000
Venturi Scrubber (PVSICIGAS)	y=8.7x+983,000	y=7.3x+177,000	y=8.6x+999,000	y=7.3x+179,000
ICI Boilers and Heaters – Wood				
Dry Flat-plate ESP (PESPICIWOOD)	y=73x+2,500,000	y=5.3x+165,000	y=70.2x+2,727,000	y=5.5x+158,000
Fabric Filter –Pulse Jet (PFFICIWOOD)	y=24.4x+697,000	y=2.6x+254,000	y=26x+634,000	y=3.1x+233,000
Venturi Scrubber (PVSICIWOOD)	y=11.4x+783,000	y=7.1x+165,000	y=11.4x+783,000	y=7.3x+157,000
Generic Industrial Processes - MMD of 10.0 microns				
Dry Flat-plate ESP (PESPIPSIZE10)	y=38.8x+1,200,000	y=3.2x+197,000	y=39.5x+1,313,000	y=3.5x+225,000
Fabric Filter –Pulse Jet (PFFIPSIZE10)	y=8.2x+702,000	y=2x+371,000	y=8.4x+697,000	y=2.4x+406,000
Venturi Scrubber (PVSIPSIZE10)	y=12.8x+721,000	y=3.3x+189,000	y=12.8x+721,000	y=3.5x+203,000
Generic Industrial Processes - MMD of 5.0 microns				
Dry Flat-plate ESP (PESPIPSIZE5)	y=44x+1,800,000	y=3.4x+134,000	y=39.8x+1,578,000	y=3x+191,000
Fabric Filter –Pulse Jet (PFFIPSIZE5)	y=12.4x+700,000	y=2x+295,000	y=12.3x+718,000	y=1.9x+345,000
Venturi Scrubber (PVSIPSIZE5)	y=10.5x+790,000	y=3.3x+151,000	y=10.1x+809,000	y=3x+185,000
Generic Industrial Processes - MMD of 1.0 microns				
Dry Flat-plate ESP (PESPIPSIZE1)	y=75x+4,000,000	y=5.5x+251,000	y=76.2x+3,754,000	y=5.6x+251,000
Fabric Filter –Pulse Jet (PFFIPSIZE1)	y=24.2x+756,000	y=2.6x+267,000	y=24.8x+730,000	y=2.7x+269,000
Venturi Scrubber (PVSIPSIZE1)	y=8.7x+969,000	y=7.1x+185,000	y=8.7x+969,000	y=7.2x+185,000

Note: Independent variable for each equation is the boiler heat input capacity (MMBtu/hr).

The revisions to the equations also led to changes in the default cost per ton for each control measure. These changes along with the original values are shown in Table 4.

Table 4 Original Default Cost per Ton Values from GDIT (2019) and Revisions (2017$)

Control Technology (Control Measure Abbreviation)	Original Equations	Revised Equations (1/10/2022)
	Default Cost per Ton	Default Cost per Ton
ICI Boilers and Heaters – Coal and Solid Fuels		
Dry Flat-plate ESP (PESPICICOAL)	$1,983	$1,778
Fabric Filter –Pulse Jet (PFFICICOAL)	$1,686	$1,533
Venturi Scrubber (PVSICICOAL)	$1,302	$1,205
ICI Boilers and Heaters – Gas and Oil		
Dry Flat-plate ESP (PESPICIGAS)	$28,793	$17,107
Fabric Filter –Pulse Jet (PFFICIGAS)	$8,686	$5,238
Venturi Scrubber (PVSICIGAS)	$15,056	$9,454
ICI Boilers and Heaters – Wood		
Dry Flat-plate ESP (PESPICIWOOD)	$4,306	$1,831
Fabric Filter –Pulse Jet (PFFICIWOOD)	$2,000	$883
Venturi Scrubber (PVSICIWOOD)	$2,762	$1,249
Generic Industrial Processes - MMD of 10.0 microns		
Dry Flat-plate ESP (PESPIPSIZE10)	$1,916	$1,467
Fabric Filter –Pulse Jet (PFFIPSIZE10)	$1,437	$1,140
Venturi Scrubber (PVSIPSIZE10)	$1,346	$1,076
Generic Industrial Processes - MMD of 5.0 microns		
Dry Flat-plate ESP (PESPIPSIZE5)	$2,661	$1,688
Fabric Filter –Pulse Jet (PFFIPSIZE5)	$1,662	$1,112
Venturi Scrubber (PVSIPSIZE5)	$1,673	$1,133
Generic Industrial Processes - MMD of 1.0 microns		
Dry Flat-plate ESP (PESPIPSIZE1)	$3,688	$2,690
Fabric Filter –Pulse Jet (PFFIPSIZE1)	$1,446	$1,065
Venturi Scrubber (PVSIPSIZE1)	$2,167	$1,653

4 Revisions to SO_2 Equations from GDIT (2021)

In 2021, updates to the cost equations and default cost per ton estimates were prepared for wet scrubbers and spray dryer absorbers (SDA) applied to ICI boilers burning bituminous and subbituminous coal, and the cost equation and default cost per ton of a packed bed scrubber control applicable to all non-EGU sources was estimated. These estimates are documented in *CoST SO_2 Control Measures - September 2021* (GDIT, 2021). The wet scrubber and spray dryer absorber controls estimated in GDIT (2021) replaced the wet and dry scrubber controls for coal-fired boilers estimated in ERG (2019).

Improvements and corrections have since been made to the estimates. The original estimates were based on a 2018 emissions inventory that was later determined to have duplicate entries and data issues. As a result, the equations have been re-estimated using the 2016 emissions inventory that had been previously used to estimate the $PM_{2.5}$ equations in GDIT (2019).

Additionally, in GDIT (2021) the parameters for the model sources for the wet scrubber and SDA estimates were based on the value of the parameters at the percentiles (10^{th}, 30^{th}, 50^{th}, 70^{th}, and 90^{th}) rather than the average over the ranges represented by the percentiles ($0\text{-}20^{th}$, $20^{th}\text{-}40^{th}$, etc.). To be consistent with the procedure used for packed bed scrubbers and in GDIT (2019), this was changed so that the parameter values are the averages over the ranges. Calculation errors in the packed bed scrubber averages and the SDA capital cost equation were also corrected.

While it was not documented in GDIT (2021), the model sources for the packed bed scrubber estimates were based on records from the National Emissions Inventory (NEI) excluding electricity generating units (SCCs 101xxxxx or 201xxxxx) and airports (SCCs 2265xxxxxx or 2275xxxxxx) with annual emissions of SO_2 greater than or equal to 10 tons and exhaust gas stream flow rate greater than or equal to 100 cubic feet per minute. The current estimates maintain this convention.

For several control measures, the control measure abbreviations were slightly modified from what appears in GDIT (2021) to better align with current naming conventions in the CMDB. Specifically, SWSICIBC was changed to SWSICIBBC, SDSICIBC was changed to SDSICIBBC, SWSICISBC was changed to SWSICIBSBC, and SDSICISBC was changed to SDSICIBSBC. These changes are reflected in Table 5 and Table 6 below and should be kept in mind when comparing these tables to GDIT (2021).

Table 5 presents both the original equations for total capital investment (TCI) and operation and maintenance cost (O&M) from GDIT (2021) as well as the revised equations. All values are in terms of 2016 dollars.

Table 5 Original Equations from GDIT (2021) and Revisions (2016$)

Control Technology (Control Measure Abbreviation)	Original Equations		Revised Equations (1/10/2022)	
	TCI	O&M	TCI	O&M
ICI Boilers – Bituminous Coal				
Wet Scrubber (SWSICIBBC)	y=681,136x+23,715,341	y=36,784x + 2,340,227	y=644,299.3x+24,792,000	y=36,225.2x+2,357,000
Spray Dryer Absorber (SDSICIBBC)	y=158,603x+2,489,235	y=53,720x+1,178,148	y=594,740.4x+10,861,000	y=53,203.6x+1,193,000
ICI Boilers – Subbituminous Coal				
Wet Scrubber (SWSICIBSBC)	y=741,463x+20,579,158	y=22,565x+2,292,620	y=546,197.8x+24,711,000	y=19,601.1x+2,355,000
Spray Dryer Absorber (SDSICIBSBC)	y=187,446x+1,909,692	y=26,169x+1,127,849	y=521,556.8x+11,159,000	y=23,338.3x+1,198,000
All non-EGU and non-airplanes				
Packed Bed Scrubber (SPBSNONEGU)	y=12.0x+251,149	y=1.94x+448,423	y=11.5x+294,000	y=1.7x+721,000

Note: The independent variable for the wet scrubber and spray dryer absorber equations is the boiler capacity (MW). The independent variable for the packed bed scrubber is exhaust gas flow rate (ACFM).

The revisions to the equations also led to changes in the default cost per ton for each control measure. These changes along with the original values are shown in Table 6.

Table 6 Original Default Cost per Ton Values from GDIT (2021) and Revisions (2016$)

Control Technology (Control Measure Abbreviation)	Original Equations	Revised Equations (1/10/2022)
	Default Cost per Ton	Default Cost per Ton
ICI Boilers – Bituminous Coal		
Wet Scrubber (SWSICIBBC)	$1,718	$1,214
Spray Dryer Absorber (SDSICIBBC)	$1,232	$997
ICI Boilers – Subbituminous Coal		
Wet Scrubber (SWSICIBSBC)	$7,312	$3,626
Spray Dryer Absorber (SDSICIBSBC)	$4,387	$2,610
All non-EGU and non-airplanes		
Packed Bed Scrubber (SPBSNONEGU)	$433	$330

5 Revisions to Glass Manufacturing and Engine Controls from RTI (2014)

During the review of results for the Revised Cross-State Air Pollution Rule (CSAPR) Update for the 2008 Ozone NAAQS (U.S. EPA, 2021), some mistakes were identified in control measures in the CMDB. These control measures are originally documented in *Update of NOx Control Measure Data in the CoST Control Measure Database for Four Industrial Source Categories: Ammonia Reformers, NonEGU Combustion Turbines, Glass Manufacturing, and Lean Burn Reciprocating Internal Combustion Engines* (RTI, 2014). This section discusses corrections that have been made to these control measures.

The cost per ton and equation parameters for SNCR for Container Glass Manufacturing (NSNCRGMCN), SCR for Container and Float Glass Manufacturing (NSCRGMCN and NSCRGMFT, respectively), and low NO_x burners (LNB) for Container and Float Glass Manufacturing (NLNBUGMCN and NLNBUGMFT, respectively) were corrected. In RTI (2014), the equations were in terms of glass production per day. The parameters of these equations were directly carried over to the CMDB, but the independent variable was redefined as NO_x emissions reductions per day. As a result, the resulting estimates are incorrect. The equation parameters have now been corrected to be in terms of NO_x reductions per day.

Table 7 presents both the original equations for total capital investment (TCI) and total annual cost (TAC) from RTI (2014) as well as the revised equations. All values are in terms of 2008 dollars.

Table 7 Original Equations for Glass Manufacturing Controls from RTI (2014) and Revisions (2008$)

Control Technology (Control Measure Abbreviation)	Original Equations		Revised Equations (7/24/2020)	
	TCI	TAC	TCI	TAC
Container Glass Manufacturing				
SNCR (NSNCRGMCN)	y=2,025x+556,962	y=489x+136,873	y=2,764,155.75x+409,043.48	y=667,364.45x+101,134.3
SCR (NSCRGMCN)	$y=79{,}415x^{0.51}$	y=643x+135,302	y=1,302,274.55x+768,134.21	y=350,282.27x+149,380.49
LNB (NLNBUGMCN)	$y=30{,}930x^{0.45}$	$y=9{,}377x^{0.40}$	y=1,105,967.39x+156,855.74	y=249,796.08x+37,953.7
Float Glass Manufacturing				
SCR (NSCRGMFT)	y=3,681x+1,000,000	y=842x+424,930	y=1,047,586.83x+354,787.87	y=255,944.6x+202,319.88
LNB (NLNBUGMFT)	y=527x+664,557	y=132x+150,105	y=316,990.34x+595,644.2	y=79,247.58x+133,050.18

Note: Independent variable for each equation was tons per day of production in the original report but was entered as NO_x emissions reductions per day in the CMDB. The revised equations correct the coefficients so they are appropriate for NO_x emissions reductions per day.

The updated default cost per ton value for each control measure is presented in Table 8. The original values are shown as a range because there was an estimate for small and large sources. However, these size categories were based on glass production per day in EC (2013) and implemented in the CMDB in terms of annual emissions (0-365 annual tons of NO_x emissions for small sources and greater than 365 annual tons of NO_x emissions for large sources). Because there is not sufficient information in EC (2013) to determine if the previous CMDB categories were appropriate, the default cost per ton is now estimated as a weighted average of the sources.

Table 8 Original Default Cost per Ton Values for Glass Manufacturing Controls from RTI (2014) and Revisions (2008$)

Control Technology (Control Measure Abbreviation)	Original Equations	Revised Equations (7/24/2020)
	Default Cost per Ton	Default Cost per Ton
Container Glass Manufacturing		
SNCR (NSNCRGMCN)	$2,756-$3,266	$2,924
SCR (NSCRGMCN)	$1,684-$2,169	$1,823
LNB (NLNBUGMCN)	$1,072-$1,365	$1,226
Float Glass Manufacturing		
SCR (NSCRGMFT)	$855-$957	$901
LNB (NLNBUGMFT)	$447-$574	$489

While equations and a default cost per ton value were estimated for the application of SNCR to container glass manufacturing, this control was not added to the CMDB because RTI (2014) notes that "[b]ased on conversations between EPA and OECA staff, SNCR entries for glass manufacturing should be removed based on recent NSR settlements that indicate SNCR is not a technically feasible control technology for the removal of NO_x" (RTI, 2014, p. 4-5). Updated estimates are provided here both for completeness and in case the decision to exclude SNCR for these sources is revisited.

In addition to revisions to the controls for glass manufacturing, corrections were made to some controls for internal combustion engines. The equation parameters for the air-to-fuel ratio control (AFRC) measure applied to internal combustion engines (NAFRCICENG) were corrected. Due to a data transcription error when creating the equation based upon the information in CARB (2001), the 1,501 to 2,000 horsepower (hp) range was omitted from the calculations and the cost for that range was entered as the cost for the 1,001 to 1,500 horsepower range. This error has been corrected, and the revised equations are shown in Table 9. As in RTI (2014), these values are in terms of 2001 dollars.

Table 9 Original Equations for Air-to-Fuel Ratio Control from RTI (2014) and Revisions (2001$)

Control Technology (Control Measure Abbreviation)	Original Equations		Revised Equations (7/24/2020)	
	TCI	TAC	TCI	TAC
AFRC (NAFRCICENG)	1.3007x+4354.5	0.1852x+619.99	0.8724x+4453.3	0.1242x+634.05

Note: Independent variable for each equation is engine horsepower.

The associated default cost per ton for the revised measure is shown in Table 10.

Table 10 Original Default Cost per Ton for Air-to-Fuel Ratio Control from RTI (2014) and Revision (2001$)

Control Technology (Control Measure Abbreviation)	Original Equations	Revised Equations (7/24/2020)
	Default Cost per Ton	Default Cost per Ton
AFRC (NAFRCICENG)	$810	$691

A corresponding change was made to CoST due to the review of this control measure. Two of the controls that used Equation Type 2 (NAFRCICENG and NSCRICE4SNG) were originally specified in terms of horsepower, but the coefficients were converted to be in terms of million British Thermal Units per hour (MMBtu/hr) so the existing equation type 2 could be used. While there is a constraint on the application of equation type 2, this constraint is in terms of MMBtu/hr. Specifically, it can be applied to units of less than 2,000 MMBtu/hr. As a result, this constraint is non-binding for any engines because 2,000 MMBtu/hr translates to approximately 786,000 horsepower. To remedy this problem, a new equation type was created to allow the equation to be specified in terms of horsepower, and the equation type is constrained to engines of less than or equal to 1,500 horsepower. Any engines outside of this constraint but for which the control may be applicable calculate their cost using the default cost per ton value.

Finally, when the layered combustion control for 2-stroke natural gas engines (NLCICE2SNG) was originally added to the CMDB, its application was inadvertently limited to sources with NO_x emissions of less than 365 tons per year. This constraint has now been removed. This control was also allowed to be applied to 4-stroke engine SCCs (20200254 and 20200256), which has now been corrected. Similarly, the control for SCR for 4-stroke natural gas engines (NSCRICE4SNG) was allowed to be applied to 2-stroke engine SCCs (20200252 and 20200255), which has also now been corrected.

6 Updates to Relevant Source Classification Codes

As mentioned in the introduction, CoST matches controls to sources by the SCC of the emissions inventory record. EPA uses SCCs to classify different types of activities that generate emissions. Each SCC represents a unique source category-specific process or function that emits air pollutants.[4] These SCCs are periodically updated.

For each control in the CMDB, a set of SCCs to which the control is applicable is specified. Because updates to controls occur less frequently than updates to SCCs, a mismatch between the SCCs specified for controls and the SCCs used in emissions inventories can occur over time. To support EPA rulemakings, the old SCCs associated with relevant NO_x controls were remapped to their current equivalents, and these changes were reviewed to confirm that they were appropriate. We anticipate initiating a comprehensive update of the SCCs associated with CMDB controls in the near future.

7 Removal of Obsolete Control Measures

A review of the control measures in the CMDB revealed that many of the measures were obsolete. While CoST allows for marking controls as obsolete without removing them from the database of potential controls, doing so over time makes the resulting CMDB cluttered and inefficient because CoST is nearly 20 years old and the original CMDB drew upon the controls in AirControlNET that it replaced. AirControlNET itself drew upon control measure research and evaluations as far back as 1994 (Pechan, 2006). As part of ongoing updates and improvements to the CMDB, obsolete controls have been identified and removed as part of a recent update. Table 11 provides a list of the control measures removed in this review, along with indicators if there is an alternative control available in the CMDB or if the control was replaced in the CMDB. Some control measures in this table also indicate that additional review is needed. In these cases, the control technology may still be applicable to the source group, but the CMDB entry is so dated that it can no longer be considered reliable. These measures may be updated as part of ongoing control measure reviews and could be added back to the CMDB.

There are several reasons a control measure may be considered obsolete. Some older control measures were intended to represent rules that had been implemented by certain states. Some of these rules were scheduled to phase in over time. If these rules have now been completely implemented, they were considered obsolete for the purpose of this review. While other areas wishing to implement similar rules could draw upon the experiences of states that first implemented such rules, at a minimum the cost would need to be re-estimated. Further complicating the application of such control measures is the fact that some are applied to SCCs that typically appear in area source inventories. Because the area source inventories typically lack information about the current level of control, it is often unclear if an area has already implemented a similar measure. In general, when using CoST, considerable care must be taken when applying control measures intended to represent rules or policies, as opposed to end-of-pipe controls.

[4] For more about Source Classification Codes, see https://sor-scc-api.epa.gov/sccwebservices/sccsearch/.

Control measures may also be obsolete if the control technologies they represent are no longer typically used to control emissions. This may be due to technological advances in pollution control technology leading to less expensive, more efficient controls. It could also be due to the inability of a particular control technology to achieve the emissions reductions required by more recent regulations.

Finally, some control measures in the CMDB were deemed obsolete because they have been superseded by other more recent control measures, or because the information used to develop their cost and control efficiency values is too dated to be plausible. For example, in Table 11 there are two NOx controls for internal combustion engines that have been replaced in more recent versions of the CMDB. That is, the CMDB also contains a more recent control that applies to the same types of sources as the control being removed. In the case of control measures removed due to the age of their underlying information, if the control is still in use in the industry and it proves possible to update its cost and control efficiency values, it may be added back to the CMDB at a later date.

Table 11 Obsolete Control Measures Removed from CMDB

Control Measure Abbreviation	Control Technology	Source Group	Alternative Control	Control Replaced	Additional Review Needed
NO_X					
NNSCRINGNS	Non-Selective Catalytic Reduction	Industrial NG ICE, 4cycle (rich) - SCCs w/ technology not specified	x	x	
NLECICEGAS	Low Emission Combustion	Lean Burn IC Engine – Gas	x	x	
SO_2					
SAMSCSRP95	Amine Scrubbing - Additional Tail Gas Step	Sulfur Recovery Plants - Elemental Sulfur (Claus: 2 Stage w/o control (92-95% removal))	x		
SAMSCSRP96	Amine Scrubbing - Additional Tail Gas Step	Sulfur Recovery Plants - Elemental Sulfur (Claus: 3 Stage w/o control (95-96% removal))	x		
SAMSCSRP97	Amine Scrubbing - Additional Tail Gas Step	Sulfur Recovery Plants - Elemental Sulfur (Claus: 3 Stage w/o control (96-97% removal))	x		
SCOGDCOP	Coke Oven Gas Desulfurization	By-product Coke Manufacturing (Coke Oven Plants)	x		
SDLABPLSS	Dual absorption	Primary Lead Smelters – Sintering			
SDLABPZSS	Dual absorption	Primary Zinc Smelters – Sintering			
SDSICIBC	Dry Scrubber	ICI Boilers – Coal	x	x	
SFGDSCMOP	Flue Gas Desulfurization	By-Product Coke Manufacturing (Other Processes)	x		
SFGDSIPFBC	Flue Gas Desulfurization	In-process Fuel Use - Bituminous/Subbituminous Coal			
SFGDSMIPR	Flue Gas Desulfurization	Mineral Products Industry	x		

Control Measure Abbreviation	Control Technology	Source Group	Alternative Control	Control Replaced	Additional Review Needed
SFGDSPETR	Flue Gas Desulfurization	Petroleum Industry	x		
SFGDSPHOG	Flue Gas Desulfurization	Process Heaters (Oil and Gas Production Industry)			
SFGDSPPSP	Flue Gas Desulfurization	Pulp and Paper Industry (Sulfate Pulping)	x		
SFGDSSGCO	Flue Gas Desulfurization	Steam Generating Unit - Coal/Oil	x		
SNS93SACA	Increase % Conversion to Meet NSPS (99.7)	Sulfuric Acid Plants - Contact Absorber (93% Conversion)	x		
SNS97SACA	Increase % Conversion to Meet NSPS (99.7)	Sulfuric Acid Plants - Contact Absorber (97% Conversion)	x		
SNS98SACA	Increase % Conversion to Meet NSPS (99.7)	Sulfuric Acid Plants - Contact Absorber (98% Conversion)	x		
SNS99SACA	Increase % Conversion to Meet NSPS (99.7)	Sulfuric Acid Plants - Contact Absorber (99% Conversion)	x		
SSADPPRMTL	Sulfuric Acid Plant	Primary Metals Industry	x		
SSPRADRKL	Spray Dry Absorber	Cement Kilns	x		x
SSPRAPRKL	Spray Dry Absorber	Cement Kilns	x		x
SSPRAPRPR	Spray Dry Absorber	Cement Kilns	x		x
SWFGDCEMKL	Wet Flue Gas Desulfurization	Cement Kilns	x		x
SWFGDDRKL	Wet Flue Gas Desulfurization	Cement Kilns	x		x
SWFGDPETCK	Wet Flue Gas Desulfurization	Petroleum Refinery Catalytic and Thermal Cracking Units	x		x
SWFGDPETPH	Wet Flue Gas Desulfurization	Petroleum Refinery Process Heaters	x	x	
SWFGDPRKL	Wet Flue Gas Desulfurization	Cement Kilns	x		x
SWFGDPRPR	Wet Flue Gas Desulfurization	Cement Kilns	x		x
SWSICIBC	Wet Scrubber	ICI Boilers – Coal	x	x	
VOC					
V1148ONGPF	SCAQMD Proposed Rule 1148.1	Oil and Natural Gas Production - Fugitive Emissions	x		
VAIRCOTC	Reformulation-Process Modification	Aircraft Surface Coating			
VAITCSCPH1	Reformulation (Phase I)	Architectural, Industrial Maintenance, and Traffic Coatings			
VAITCSCPH2	Reformulation (Phase II)	Architectural, Industrial Maintenance, and Traffic Coatings			

Control Measure Abbreviation	Control Technology	Source Group	Alternative Control	Control Replaced	Additional Review Needed
VAITCSCPH3	Reformulation (Phase III)	Architectural, Industrial Maintenance, and Traffic Coatings			
VAOCLPLP	Add-on controls, work practices, and material reformulation/substitution	Lithographic Printing & Letterpress Printing	x		
VARCTAIMOT	Reformulation (OTC Rule)	Architectural Coatings			
VARPTTIER2	Reformulation	Aerosol Paints			
VASPHREFRM	Reformulation-Process Modification	Cutback Asphalt			
VATRFBARCT	BARCT	Automobile Refinishing			
VATRFFR1	Reformulation	Automobile Refinishing			
VATRFFR2	Reformulation-Process Modification (Fed Rule)	Automobile Refinishing			
VATRFOTC	Reformulation-Process Modification (OTC Rule)	Automobile Refinishing			
VBAKEINC	Incineration	Bakery Products			
VCLDMACT	MACT	Cold Cleaning			
VCLDOTC	Reformulation-Process Modification (OTC Rule)	Cold Cleaning			
VCLDS1122A	Reformulation-Process Modification	Cold Cleaning			
VCLDS1122B	Process Modification	Cold Cleaning			
VCSADARB1	Reformulation (ARB Phase I)	Consumer Adhesives			
VCSADARB2	Reformulation (ARB Phase II)	Consumer Adhesives			
VCSADFR	Reformulation (Fed Rule)	Consumer Adhesives			
VCSADOTC	Reformulation (OTC Rule)	Consumer Adhesives			
VCSOLVARB1	Reformulation (ARB Phase I)	Consumer Solvents			
VCSOLVARB2	Reformulation (ARB Phase II)	Consumer Solvents			
VCSOLVOTC	Reformulation (OTC Rule)	Consumer Solvents			
VDCPERMACT	MACT	Dry Cleaning – Perchloroethylene			
VDEGS1122A	Reformulation-Process Modification	Open Top Degreasing			
VDEGS1122B	Process Modification	Open Top Degreasing			

Control Measure Abbreviation	Control Technology	Source Group	Alternative Control	Control Replaced	Additional Review Needed
VEECTS1164	Reformulation-Process Modification	Electrical/Electronic Coating			
VFLAFLA	Flare	Petroleum Flare	x		x
VFUGEQMAN1	Process Modification	SOCMI Fugitives			
VFUGEQMAN2	Process Modification	Petroleum Refinery Fugitives			
VGARTRACT	RACT	Graphic Arts			
VINADS1168	Reformulation	Adhesives – Industrial			
VMARCINC	Incineration	Marine Surface Coating			x
VMCLCBAQMD	Process Modification	Metal Coil Coating			
VMCLCINC	Incineration	Metal Coil Coating			x
VMCNCBAQMD	Process Modification	Metal Can Coating			
VMCNCINC	Incineration	Metal Can Coating			x
VMERCMACT	MACT	Machine, Electric, and Railroad Coating			
VMERCOTC	Reformulation-Process Modification (OTC Rule)	Machine, Electric, and Railroad Coating			
VMERCS1107	Reformulation-Process Modification	Metal Part and Products Coating			
VMTFNS1107	Reformulation-Process Modification	Metal Furniture, Appliances, and Parts Coating			
VMVCTMACT	MACT	Motor Vehicle Coating			
VOGSEQMAN	Process Modification	Oil and Natural Gas Production			
VPESTFR	Reformulation	Pesticide Application			
VPTENFLPR	Permanent Total Enclosure (PTE)	Flexographic Printing	x		x
VPTENPRPG	Permanent Total Enclosure (PTE)	Publication Rotogravure Printing	x		x
VRBPLS1145	Reformulation-Process Modification	Rubber/Plastics Coating			
VREEVPRPU	Solvent Recovery System	Printing/Publishing	x		
VREEVSCOL	Petroleum and Solvent Evaporation	Surface Coating Operations	x		
VREEVSCOM	Petroleum and Solvent Evaporation	Surface Coating Operations	x		
VSOLUTIL1	Solvent Utilization	Coating; Arts; Miscellaneous			
VSOLUTIL2	Solvent Utilization	Coating; Arts			
VSTGIILPV1	LPV Relief Valve	Stage II Service Stations			
VSTGIILPV2	LPV Relief Valve	Stage II Service Stations - Underground Tanks			
VSWASRECOV	Gas Recovery	Municipal Solid Waste Landfill			x
VWDCTADDON	Add-On Controls	Wood Furniture Surface Coating			

Control Measure Abbreviation	Control Technology	Source Group	Alternative Control	Control Replaced	Additional Review Needed
VWDCTCTG	Control Technology Guidelines	Wood Furniture Surface Coating			
VWDCTINC	Incineration	Wood Product Surface Coating			x
VWDCTS1104	Reformulation	Wood Product Surface Coating			
VWPSSAICS	Work practice standards, solvent substitution, and add-on controls	Industrial Cleaning Solvents	x		
VWWPWW	Wastewater	Petroleum Wastewater	x		

8 Updates to Area Source PM controls

In 2020, the area source $PM_{2.5}$ controls were updated in the CMDB. These changes are documented in *CoST $PM_{2.5}$ Nonpoint Control Measures Report* (GDIT, 2020). The updated controls, $PM_{2.5}$ control efficiencies, and cost per ton estimates are entirely drawn from a 2015 Houston Advanced Research Center and Texas Environmental Research Consortium report titled *Fine Particulate Matter in Harris County* (HARC, 2015).

As noted in GDIT (2020), the goal of the Harris County project was to prepare a list of potential options to reduce the $PM_{2.5}$ inventory by 10% and 25%. A similar approach was adopted in developing control measures for the CMDB, with two measures being developed for each option: the first having a 10% rule penetration rate and the second having a 25% rule penetration rate. The penetration rate is the percentage of the relevant emissions inventory to which a control can be applied. This approach has since been amended to provide more flexibility in the creation of control strategies, by allowing for addition rule penetration rates of 5%, 15%, 20%, 30%, and 35%.

Control efficiencies for associated co-reductions in pollutants from residential wood smoke controls were derived from the EPA report *Strategies for Reducing Residential Wood Smoke* (EPA, 2013). However, these control efficiencies for co-reductions have been removed from the current version of the CMDB because it is unclear if they are accurate. Specifically, while EPA (2013) states that the pollutants listed in Table 12 may be controlled, the exact level of control is not indicated in the report or the associated spreadsheet. The control efficiencies for co-reductions will be updated in the future when appropriate values have been confirmed.

Table 12 Control Measures and Associated Control Efficiencies for Co-reductions Removed from CMDB

Control Measure Abbreviations	Pollutant	Control Efficiency
PBBFPHHWDS5, PBBFPHHWDS10, PBBFPHHWDS15, PBBFPHHWDS20, PBBFPHHWDS25, PBBFPHHWDS30, PBBFPHHWDS35	CO	75
	CO_2	75
	VOC	75
PCTGLGFPL5, PCTGLGFPL10, PCTGLGFPL15, PCTGLGFPL20, PCTGLGFPL25, PCTGLGFPL30, PCTGLGFPL35	CO	100
	CO_2	100
	VOC	100
PECWSWDSTV5, PECWSWDSTV10, PECWSWDSTV15, PECWSWDSTV20, PECWSWDSTV25, PECWSWDSTV30, PECWSWDSTV35	CO	60
	CO_2	60
	VOC	60
PEP2QUFPL5, PEP2QUFPL10, PEP2QUFPL15, PEP2QUFPL20, PEP2QUFPL25, PEP2QUFPL30, PEP2QUFPL35	CO	70
	CO_2	70
	VOC	70
PICHHHHTR5, PICHHHHTR10, PICHHHHTR15, PICHHHHTR20, PICHHHHTR25, PICHHHHTR30, PICHHHHTR35	CO	90
	CO_2	90
	VOC	90
PIRDSHHTR5, PIRDSHHTR10, PIRDSHHTR15, PIRDSHHTR20, PIRDSHHTR25, PIRDSHHTR30, PIRDSHHTR35	CO	60
	CO_2	60
	VOC	60
PIRDVCFPL5, PIRDVCFPL10, PIRDVCFPL15, PIRDVCFPL20, PIRDVCFPL25, PIRDVCFPL30, PIRDVCFPL35	CO	70
	CO_2	70
	VOC	70
PNGSTWDSTV5, PNGSTWDSTV10, PNGSTWDSTV15, PNGSTWDSTV20, PNGSTWDSTV25, PNGSTWDSTV30, PNGSTWDSTV35	CO	99
	CO_2	99
	VOC	99
PROWSWDSTV5, PROWSWDSTV10, PROWSWDSTV15, PROWSWDSTV20, PROWSWDSTV25, PROWSWDSTV30, PROWSWDSTV35	CO	70
	CO_2	70
	VOC	70

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