Appendix I:

75 ppb 8-Hour Ozone National Ambient Air Quality Standard Reasonably Available Control Technology (RACT) Determination

USEPA Guidance and OTC Principles Statement

MAY 18, 2006

NOTE

SUBJECT: RACT Qs & As – Reasonably Available Control Technology (RACT): Questions and Answers

FROM: William T. Harnett
Director, Air Quality Policy Division (C539-01)

TO: Regional Air Division Directors

The attached Reasonably Available Control Technology (RACT) Questions and Answers (Q&A) document addresses issues we have received from the Regional Offices and States. The document provides additional clarification that will be helpful for the RACT State implementation plans (SIPs) which are due September 15, 2006. Please distribute this document to your States, local control agencies, and tribal governments. Regional Office staff may contact William Johnson at (919) 541-5246 or Johnson.WilliamL@epa.gov, with any questions.

May 18, 2006

Questions Related to RACT in 8-hour ozone implementation

A. What is RACT?

1. **Q**: Is the facility expected to perform the RACT analysis? Is this similar to a BACT analysis?

A: The State is responsible for the RACT determination but is likely to have considerable interaction with the affected facilities. States may rely on past EPA guidance, such as CTGs, for help and should also review other available information regarding the appropriate controls. BACT requires that new or modified sources adopt the best available controls and, as such, the analysis is a "top-down" analysis that first looks at the most stringent level of control available for a source. Industries applying for a construction permit list in their application what are the currently most stringent levels of control. The State verifies this by checking the application against other data sources including EPA's RACT/BACT Clearinghouse. RACT requires that sources adopt controls that are reasonably available and thus they may not be the most stringent controls that have been adopted for other similar sources.

2. **Q**: If a State in or near the Ozone Transport Region failed to adopt one of the model rules which the Ozone Transport Commission developed to help meet the ozone standard in that region, would this mean that a rule the State may have for that source is no longer considered to be RACT?

A: No, not necessarily. The model rules developed for the Ozone Transport Region were for the purpose of bringing areas in the OTR into attainment with the 1-hour NAAQS and thus may be more stringent than what would be considered RACT. In performing a RACT analysis, States should look at available controls, such as those that were the basis for the model rules developed by the OTR, to conclude whether they are reasonably available for a specific source or source category. However, the fact that another similar source has such controls in place does not mean that such a control is reasonably available for all other similar sources across the country.

3. **Q**: Some moderate 8-hour areas were severe 1-hour nonattainment areas. As such, the "major source" threshold for 1-hour RACT rules was 25 TPY potential emissions. For the purposes of certifying 1-hour RACT determinations, must the State address only down to the applicable 8-hour threshold [which is 100 TPY or in the Ozone Transport Region 50 TPY for VOC non-CTG major sources and the 100 TPY for all NOx sources] or down to the 1-hour threshold of 25 TPY?

A: For purposes of meeting the 8-hour RACT requirement, the State's RACT analysis only needs to include an evaluation of RACT for CTG sources and for non-CTG major sources based on the area's 8-hour classification.

We note however, that under the anti-backsliding requirements, the State may not remove RACT requirements for sources that were subject to RACT for the 1-hour standard (but that would not be subject to RACT based on the area's 8-hour classification). Similarly, if the State has never met the RACT requirement for one or more sources for the 1-hour standard, the anti-backsliding requirements require the State to meet that obligation. The anti-backsliding provisions may be found at 40 CFR 51.905 and apply to all former 1-hour non-attainment areas.

4. **Q**: Where a State determines that sources subject to Federal rules, such as NESHAPs, the municipal waste incinerator rules under CAA section 111(d), and NSR/PSD settlement agreements, meet RACT by compliance with those requirements, how should those requirements be addressed as part of the SIP?

A: To rely on federal rules to meet the RACT requirement, the State must incorporate these requirements into the SIP. For example, a State could incorporate by reference the Federal requirement or could submit a permit that includes this provision as a SIP revision.

5. **Q**: Can a State rely for RACT determinations on control obligations in Federally enforceable permits issues under a State approved nonattainment new source review program (or a PSD program)?

A: Yes, a State may rely on control obligations required by federally enforceable permits. The State would need to submit the relevant portions of these permits (i.e., the portions establishing the VOC and NOx obligations) as SIP revisions along with a demonstration that such controls are RACT.

6. **Q**: For NOx RACT for stationary source categories, other than wall and tangentially fired electric utility boilers, EPA guidelines in 1994 indicate States should consider in their RACT determinations technologies that achieve 30-50 percent reduction within a cost range of $160-1300 per ton of NOx removed. Do EPA VOC guidance documents, CTGs and ACTs, give percentage reductions and cost per ton removed guidelines for VOC?

A. The VOC CTGs and ACTs usually do not give percent reductions. The emission levels are typically expressed as weight of VOC emitted per some unit of production. For example, for coatings the units are often pounds of VOC emitted per gallon of coating. However in calculating the emission limits, EPA made an assumption of 90% capture of emissions and 90% control of these captured emission for an 81% overall control in many cases. Some of the CTGs, such as for degreasers and storage tanks, define RACT as certain types of equipment, rather than an emission limit.

EPA has never issued a general cost of control guideline for VOC, but costs of control in the CTGs generally ranged around $2000/ton in 1980s dollars. However, EPA never published this figure as a cut-point that had should not be exceeded.

7. **Q**: What is the primary difference between an ACT and a CTG?

A: The ACTs give percent reductions that can be achieved with various controls at various levels of stringency and the costs per ton to achieve those levels of control. The ACTs do not recommend a particular level as being RACT. The CTGs do specify a particular level of control as being presumptive RACT.

8. **Q**: Does EPA maintain a website containing all the RACT Control Techniques Guidelines and Alternative Control Techniques documents for both NOx and VOC?

A: The EPA web site http://www.epa.gov/ttn/atw/ctg_act.html contains a list of all published CTGs. This web site also contains a partial list of ACTs, although this ACT list is missing the ACTs for bakeries, organic waste process vents and polyester foam manufacture. The following website includes two updates to NOx ACTs (see items J.3-4): http://www.epa.gov/ttn/naaqs/ozone/ozonetech/#nox . A list of CTGs and ACTs is also attached to this list of Qs & As.

9. **Q:** Does a RACT analysis need to be done for source categories for which an Alternative Control Techniques (ACT) document has been published?

A: Yes. A RACT analysis needs to be done for all CTG sources and all major non-CTG sources. While the CTGs and ACTs provide a starting point for such an analysis, RACT can change over time as new technology becomes available or the cost of existing technology adjusts. States are encouraged to use the latest information available in making RACT determinations, whether that information is in CTGs, ACTs, other guidance that is available or through information submitted during the public review process.

10. **Q**: Would EPA's "Beyond VOC RACT CTG Requirements" guidance (EPA-53/R-010. April 1995) found at http://www.epa.gov/ttn/catc/dir1/byndract.pdf be of help in determining RACT? How about documents such as "Control Techniques for Volatile Organic Emissions from Stationary Sources," EPA-450/2-78-022, May 1978, or "Fugitive Emission Sources of Organic Compounds –Additional information on Emission, Emissions Reductions, and Costs," EPA-450/3-82-010, April 1982?

A: The "Beyond RACT" document could be a source to evaluate in performing a RACT analysis. We note that this document was originally written primarily for States that needed to get reductions beyond RACT in order to attain and maintain the ozone NAAQS. However, in the ten years since that document was issued these controls may have become more economically feasible and thus it is possible that controls considered beyond RACT in that document could be considered RACT for certain sources. The second two documents are somewhat analogous to ACT documents which describe various control techniques that can be applied to various industry sectors but do not identify a presumptive RACT-level of control. Some of the industry sectors addressed in these documents are also covered by a CTG, while others are not.

11. **Q**: For source categories for which an NSPS has been adopted, would a statement that there are no sources that preexisted the NSPS be an acceptable RACT analysis? In other words, does the fact that all existing sources meet the NSPS mean that they also meet RACT?

A: The NSPS and RACT requirements are separate obligations under the Act and both must be met. So the fact that a source meets a NSPS does not necessarily mean that it also meets RACT. A State should evaluate the control obligation required through NSPS to determine whether the source is currently meeting the RACT obligation or whether additional control is necessary for RACT.

B. Certifications

12. **Q**: If a source is subject to a rule that is beyond 1-hour RACT, can a State give a certification that this source meets RACT?

A: Even though a source may have been subject to control that was beyond RACT for the 1-hour standard, the State needs to evaluate whether that requirement is, at a minimum, RACT based on the current information that is available.

13. **Q**: Would a certification need to include a commitment to upgrade rules in the future if/when we determine that RACT levels of control have become more stringent?

A: No. The RACT analysis needs to be performed at the time the RACT SIP is being developed and once the RACT SIP is approved there is no additional duty to reconsider this control obligation for a source.

14. **Q**: By what date does a facility need to have a federally enforceable permit to meet requirements for RACT?

A: A RACT SIP is due by September 15, 2006 for subpart 2 areas and with submission of an attainment demonstration request for subpart 1 areas seeking an attainment date more than 5 years after designation. RACT must be implemented no later than the beginning of the first ozone season or portion thereof that occurs 30 months after the required submission date. States should have enforceable measures in place by that date. If a source has or is required to have a Title V operating permit, the provisions of Title V program would govern when the RACT requirement must be incorporated into the SIP and a facility should consult with the permitting authority regarding that issue.

15. **Q**: Must RACT based emission limits, and associated monitoring, record keeping and reporting be included in a Federally enforceable permit (Title V operating permit)?

A: For purposes of meeting the requirements of Title I of the Act (i.e., the nonattainment area provisions), RACT needs to be adopted and approved into the SIP. This can be accomplished in a variety of ways. Typically, States have adopted regulations.

However, the State could first specify the obligation in an enforceable permit and submit the permit (or portions of the permit) for inclusion into the SIP. In some cases, States have also submitted enforceable consent orders as SIP revisions. In general, the RACT requirement for a specific source or source category would include a requirement for a specific control measure or for a specific level of reduction and, as appropriate, monitoring, recordkeeping and reporting requirements.

16. **Q**: Does EPA intend to issue guidance on how States should reassess their rules in light of currently available technologies to determine if their rules incorporate RACT?

A: At this time, EPA is not working on further RACT guidance. States should consult with the appropriate EPA Regional office if they have questions regarding how the analysis for a specific source or source category should be performed.

17. **Q**: What should a State do if it concludes that for a specific source or source category no additional controls are necessary beyond what was required by the RACT analysis under the 1-hour standard?

A: Where a State concludes that the no control is required beyond what was required for purposes of the 1-hour NAAQS, the State should submit its analysis justifying such a conclusion as part of its RACT SIP.

18. **Q**: What is required in a RACT analysis in order for a State to give a certification that previously required RACT controls or newly applied controls represent RACT for 8-hour implementation purposes?

A: A State should evaluate RACT for a source or source category by examining existing EPA guidance as well as other available information such as that identified in the responses above. To conclude that the existing level of control is RACT for a source or source category, the State's analysis should demonstrate that more effective controls are not economically or technically feasible.

C. Relationship between RACT and the Clean Air Interstate Rule (CAIR) and the NOx SIP Call

19. **Q**: Can a State rely on its participation in the CAIR trading programs to demonstrate that certain source categories meet RACT?

A: EPA has received a petition for reconsideration asking it to reconsider and reopen for public comment its determination that certain sources in States participating in the EPA-administered CAIR NOx trading program meet ozone NOx RACT requirements. EPA intends to grant the petition for reconsideration on this issue. If necessary, EPA will provide further guidance on this subject after the reconsideration process is complete.

20. **Q**: Do all sources subject to a State's NOx SIP call trading program presumptively meet RACT even if the trading program covers non-EGU sources?

A: Yes, EPA believes that the NOx SIP Call constitutes RACT for those sources covered by the NOx SIP Call. However, whether our judgment that non-EGU sources subject to the NO_x SIP Call trading system meet RACT will continue to apply in the future depends upon how the State chooses to make the transition from the NO_x SIP Call trading system to the CAIR trading system. This issue is discussed in greater detail in the preamble to the November 29, 2005 8-hour implementation rule at 70 Fed. Reg. 71657.

21. **Q:** If electrical generating units (EGU) in a State are covered by the NOx SIP Call trading program, would any EGU be presumed to have met the requirements of NOx 8-hour ozone RACT even though the source just buys additional needed allocations to comply? Or does the State need to look to see if combustion modifications (e.g. adding low NOx burners or over fire air) are RACT?

A: As stated in the preamble to the November 29, 2005 8-hour implementation rule, the NOx SIP Call is estimated to achieve a beyond-RACT degree of control regionally, and sources were required to install any controls needed for compliance no later than May 2004. Under these circumstances, EPA believes that the NOx SIP call constitutes RACT for those sources covered by the NOx SIP Call, regardless of the manner of compliance of individual sources (e.g., control equipment installation or purchase of allowances from other sources).

22. **Q**: Does a source that came into existence after the State's NOx SIP call rule was adopted meet RACT if it is subject to the State's SIP call rule?

A: Yes, if that source is covered by the NOx SIP Call trading program. A large EGU will automatically become part of the NOx SIP Call trading program and thus will be considered to meet ozone NOx RACT requirements. If the source is a cement kiln or stationary internal combustion engine, a control level of at least a 30 percent or 82 percent reduction respectively from uncontrolled levels would be considered RACT.

23. **Q**: May a State rely on its compliance with the NOx SIP Call to show that cement kilns and stationary internal combustion engines are meeting the RACT requirements?

A: Yes, if the cement kilns and stationary internal combustion engines are subject to a SIP approved as meeting the NOx SIP Call obligation to install and operate controls that are expected to achieve at least a 30 percent and 82 percent reduction, respectively, from uncontrolled levels.

24. **Q**: The November 29, 2005 preamble to the 8-hour ozone implementation rule says, at page 71656, that: "….a State need not perform a NOx RACT analysis for non-EGU sources that after 2008 continue to be subject to a SIP that regulates those non-EGU sources equally or more stringently than the State's current rules meeting the NOx SIP call." Does this apply to the whole facility or just to the unit that is subject to the NOx SIP call?

A: The State need not perform such an analysis (and may instead rely on the analysis performed by EPA) only for the unit covered by the NOx SIP call.

D. Negative Declarations

25. **Q**: Are negative declarations required? That is, must a State certify that it has no sources in a particular CTG category if the State does not adopt a RACT rule for this category?

A: A negative declaration that there are no sources in a specific CTG category or no major non-CTG sources would need to be included as part of the RACT SIP submittal. As part of the RACT submission, the negative declaration and the information supporting the declaration would be subject to the SIP public hearing at the State level.

26. **Q**: If the State area believes that there are no major non-CTG sources located in the nonattainment area, would the area need to submit a negative declaration?

A: Yes, the negative declaration would need to assert that there are no major non-CTG sources in the area, and the accompanying analysis would need to support that conclusion.

E. Other Issues

27. **Q**: Can the State calculate the potential to emit (PTE) for an emission unit based on emissions after a control device if the operation and installation of the control device are federally enforceable, e.g., a NSPS or MACT standard requires the control device to be installed and operated?

A: Yes. Where a source has a federally enforceable limit on emissions or a federally enforceable restriction on the hours of operation, then the analysis of whether the source is subject to RACT would be based on emissions considering those restrictions.

28. **Q**: What must a State do for sources in a subpart 2 area not subject to 1-hour RACT SIP regulation?

A: The State must perform a RACT analysis for all CTG and major non-CTG sources in the nonattainment area. Where a source is currently not regulated, the State could start its analysis by considering EPA guidance documents (e.g., CTGs and ACTs). After considering these documents as well other available information, the State would need to submit a SIP revision providing for RACT for all CTG and major non-CTG sources in the area, and a negative declaration where no sources within a category are located in the area. Additionally, section §182(f) provides for an exemption from NOx RACT if certain criteria are met.

29. **Q**: What must a State do for sources which were subject solely to 1-hour RACT rules in their SIP (excluding sources covered by certain NOx SIP call/CAIR trading programs)?

A: For sources subject to 1-hour RACT, the State should review available EPA guidance and other available information to determine whether additional control is needed to meet 8-hour RACT. If no additional control is needed, the State may submit a certification with an accompanying analysis demonstrating that the current level of control is RACT. The State need not resubmit the existing SIP-approved 1-hour RACT rules. If additional control is needed, the State would need to make that obligation federally enforceable through a SIP revision.

30. **Q**: What must a State do for sources (excluding sources covered by certain NOx SIP call/CAIR trading programs) subject to 1-hour RACT rule in the SIP, but subsequently subject to a more stringent regulation ("beyond 1-hour RACT rule") in State rule which is already in the approved SIP where such rule was adopted as necessary for ROP/attainment?

A: See previous answer to question 29.

31. **Q**: Would the units covered by EPA's January 1, 1995 memorandum "De Minimis Values for NOx RACT" also fall into the category where the State used this guidance/policy to set cut-offs for small emissions units?

A: The purpose of the January 1, 1995 memorandum is to provide technical data that may be used to evaluate de minimis NOx for various categories of sources. EPA does not recommend specific de minimis values, but presents factors as a guide in the development and review of State de minimis rules. Similar to other RACT guidance issued for the 1-hour ozone standard, a State may continue to use this guidance--along with any other relevant infomation--for purposes of the 8-hour ozone RACT SIP.

32. **Q**: Subpart 1 areas must demonstrate they will attain the 8-hour standard within 5 years of designation, or submit RACT rules with their attainment date extension request. A State/Air District in a subpart 1 nonattainment area plans to submit an extension request and will need to adopt RACT rules for EGUs. In the meantime, a facility has shutdown an old EGU. They submitted a package to bank the shutdown emissions as emission reduction credits (ERCs). Do the calculated ERCs in the facility's submittal need to be reduced to account for the future RACT rule the State/Air District needs to adopt?

A: If the State plans to ask for an attainment date extension for a subpart 1 area beyond 5 years, RACT rules must be submitted. The ERCs must be discounted to the extent that emissions must be reduced to meet the new RACT rule. That is, the ERCs only continue to exist to the extent that the emissions reductions in the ERC represent lower emissions than those which would have been allowed under the new RACT rule if the rule had existed when the ERCs were generated.

Additional guidance on the issue of ERCs and RACT may be found in the 1994 memo, "Response to Request for Guidance on Use of Pre-1990 ERC's and Adjusting for RACT at Time of Use," dated August 26, 1994 from John S. Seitz, Director Office of Air Quality Planning and Standards to David Howekamp, Director Region IX Air and Toxics Division. This memo may be found at this web site: http://www.epa.gov/Region7/programs/artd/air/nsr/nsrmemos/pre-1990.pdf

33. **Q**: Is there any option for using Title V permits as the means of complying with the non-CTG major stationary source obligation – either submitting the permits for SIP approval or pulling the salient pieces from them and submitting these components, rather than going to the trouble of adopting a prohibitory rule for the source category?

A: Because Title V permits must be renewed every 5 years, the permits themselves should not be submitted as RACT rules because they are not permanent. However, if State law allows, the State may submit components of the permit as requirements that would remain enforceable until such time as the SIP is revised.

34. **Q**: May a State's RACT submission include commitments to adopt one or more RACT rules in the future?

A: A RACT submission that does not address RACT for all CTG and non-CTG sources would not be a complete official submission as required by the RACT provisions of the CAA. The State may address RACT through adoption of rules or submission of permits or consent orders; through one or more negative declarations; or through a request for a NOx RACT exemption. In addition, for non-CTG sources, some states have taken the approach of submitting a RACT rule that provides a process for the source-specific adoption of RACT through a future process. However, such a rule must also provide a backstop control obligation that would apply no later than the RACT compliance date if a source-specific rule had not been adopted, approved and implemented by that date.

35. **Q**: If a state includes its RACT SIP with its 8-hr ozone attainment demonstration as a submittal sometime after September 15, 2006, would that State's compliance date remain the same, or be adjusted to correspond with the actual submittal date?

A: The RACT compliance date would not change where a State chooses to delay submission of its RACT SIP beyond the required submission date.

36. **Q**: When are RACT SIPs due?

A: Subpart 2 moderate and above areas must submit RACT SIPs no later than September 15, 2006. Subpart 1 areas that seek an attainment date later than five years following designation are required to submit their RACT SIP at the time they request the attainment date extension, which can be no later than the time required for submission of the attainment demonstration – i.e., June 15, 2007. Subpart 1 areas that do not request an extension of the attainment date would meet RACT through submission of an attainment demonstration that demonstrates attainment as expeditiously as practicable. Thus, the area's attainment demonstration, which is due June 15, 2007, would also be the RACT submission for such area.

37. **Q**: For an area with a year-long ozone season, such as California, when does the implementation date for RACT begin?

A: Areas are required to implement RACT no later than the first ozone season or part thereof that occurs 30 months after the RACT SIP is due. Thus areas with a year-long ozone season would be required to implement RACT 30 months after the SIP submission is required – i.e., March 15, 2009.

38. **Q**: The maximum attainment date for a moderate 8-hour nonattainment area is June 15, 2010. All reductions needed for attainment are supposed to be achieved by the beginning of the ozone season prior to the attainment date. For areas with full year ozone seasons (such as California), the final full ozone season prior to the required attainment date would be the ozone season beginning January 1, 2009. RACT requirements must be implemented by 30 months after SIP submittal, which would be March 15, 2009. When must the RACT requirements be implemented – by January 1, 2009 or by March 15, 2009?

A: Where a State is relying on RACT reductions as part of its attainment demonstration, then those reductions would need to be achieved by the beginning of the final full ozone season prior to the area's attainment date. For some areas, that may mean that RACT requirements will need to be implemented earlier than required under the RACT provisions of the Act and our regulations.

39. **Q**: What is the reference size cut-offs for major non-CTG source categories?

A: RACT applies to CTG sources and to major non-CTG stationary sources of VOC and/or NOx. The major-source threshold is based on the classification of the nonattainment area and are specified in Clean Air Act section 182(d) for VOC and 182(f)(1) for NOx. For example, for a severe 8-hour ozone non-attainment area, such as South Coast, ''major source'' means 25 tpy or more of VOCs or NOx.

40. **Q**: Does a VOC or NOx stationary source cut-off (e.g. 25 tpy for NOx or 25 tpy for VOC in any severe nonattainment area) represent an uncontrolled or controlled level?

A: In general, RACT applicability is based on the source's potential to emit – i.e., uncontrolled emissions. However, if the source has a federally enforceable restriction on the emission level or on the hours of operation, those restrictions would be considered in determining whether the source is a major source (see, e.g., Blue Book pages 2-3 at http://www.epa.gov/ttn/naaqs/ozone/ozonetech/voc_bluebook.pdf). The emissions restriction cannot be solely on the emissions, but must be on the operation of the source so that the potential to emit is below the applicability threshold.

41. **Q**: Does "major source" in the context of a RACT determination represent "equipment" or "facility."

A: EPA guidance provides that when assessing whether a source is “major” for purposes of non-CTG RACT, the State should consider the building, structure, facility or installation. See the Blue Book at: (http://www.epa.gov/ttn/naaqs/ozone/ozonetech/voc_bluebook.pdf). As provided in the guidance, the State should consider the emissions from all sources that were not required to install RACT (e.g., the source emissions are below those that would be subject to RACT under the applicable CTG) as well as any other sources at the facility. For purposes of determining whether a facility is subject to RACT pursuant to a CTG, the State should examine the aggregate of all emissions from sources in that particular CTG category at the facility.

42. **Q.** May States adopt generic RACT provisions in their 8-hour RACT SIP rules for VOC and/or NOx?

A. On November 7, 1996, EPA issued a policy memorandum providing additional guidance for approving regulations that contains these generic provisions (Sally Shaver, Director, Air Quality Strategies and Standards Division, memorandum to EPA Division Directors, “Approval Options for Generic RACT Rules Submitted to Meet the non-CTG VOC RACT Requirement and Certain NOx RACT Requirements”). A State may adopt generic RACT rules as part of its SIP. EPA encourages States to follow the provisions of the November 7, 1996 memorandum.

43. **Q**: Can you provide a complete list of CTGs and ACTs?

A: Here is as complete a listing as we have been able to compile. The CTG list is complete. We believe the ACT list is complete:

Pre 1990 CTGs

1. Design Criteria for Stage I Vapor Control Systems - Gasoline Service Stations, November 1975. [Note – this document is regarded as a CTG although it was never published with an EPA document number.]

2. Control of Volatile Organic Emissions from Existing Stationary Sources, Volume I: Control Methods for Surface Coating Operations, EPA-450/2-76-028, November 1976 [Note – although often listed with the CTGs for historical reasons, this document does not define RACT for any source. It is a compilation of control techniques.]

3. Control of Volatile Organic Emissions from Existing Stationary Sources, Volume II: Surface Coating of Cans, Coils, Paper, Fabrics, Automobiles, and Light-Duty Trucks, EPA-450/2-77-008, May 1977.

4. Control of Volatile Organic Emissions from Solvent Metal Cleaning, EPA-450/2-77-022, November 1977.

5. Control of Refinery Vacuum Producing Systems, Wastewater Separators, and Process Unit Turnarounds, EPA-450/2-77-025, October 1977.

6. Control of Hydrocarbons from Tank Truck Gasoline Loading Terminals, EPA-450/2-77-026, December 1977.

7. Control of Volatile Organic Emissions from Existing Stationary Sources, Volume III: Surface Coating of Metal Furniture, EPA-450/2-77-032, December 1977

8. Control of Volatile Organic Emissions from Existing Stationary Sources, Volume IV: Surface Coating for Insulation of Magnet Wire, EPA-450/2-77-033, December 1977

9. Control of Volatile Organic Emissions from Existing Stationary Sources, Volume V: Surface Coating of Large Appliances, EPA-450/2-77-034, December 1977.

10. Control of Volatile Organic Emissions from Bulk Gasoline Plants, EPA-450/2-77-035, December 1977

11. Control of Volatile Organic Emissions from Storage of Petroleum Liquids in Fixed Roof Tanks, EPA-450/2-77-036, December 1977.

12. Control of Volatile Organic Compounds from Use of Cutback Asphalt, EPA-450/2-77-037, December 1977

13. Control Techniques for Volatile Organic Emissions from Stationary Sources, EPA-450/2-78-022, May 1978. [Note – This document is often listed with CTGs, but it does not define RACT for any particular source.]

14. Control of Volatile Organic Emissions from Existing Stationary Sources, Volume VI: Surface Coating of Miscellaneous Metal Parts and Products, EPA-450/2-78-015, June 1978

15. Control of Volatile Organic Emissions from Existing Stationary Sources, Volume VII: Factory Surface Coating of Flat Wood Paneling, EPA-450/2-78-032, June 1978.

16. Control of Volatile Organic Compound Leaks from Petroleum Refinery Equipment, EPA-450/2-78-036, June 1978.

17. Control of Volatile Organic Emissions from Manufacture of Synthesized Pharmaceutical Products, 450/2-78-029, December 1978.

18. Control of Volatile Organic Emissions from Manufacture of Pneumatic Rubber Tires, EPA-450/2-78-030, December 1978.

19. Control of Volatile Organic Emissions from Existing Stationary Sources, Volume VIII: Graphic Arts - Rotogravure and Flexography, EPA-450/2-78-033, December 1978.

20. Control of Volatile Organic Emissions from Petroleum Liquid Storage in External Floating Roof Tanks, EPA-450/2-78-047, December 1978.

21. Control of Volatile Organic Emissions from Perchloroethylene Dry Cleaning Systems, EPA-450/2-78-050, December 1978. [Note – Perchloroethylene has been exempted as a VOC, so this CTG is no longer relevant. However, there is a MACT standard for perchloroethylene dry cleaners.]

22. Control of Volatile Organic Compound Leaks from Gasoline Tank Trucks and Vapor Collection Systems, EPA-450/2-78-051, December 1978.

23. Fugitive Emission Sources of Organic Compounds – Additional Information on Emissions, Emission Reductions, and Costs, EPA-450/3-82-010, April 1982. [Note – This document does not define RACT for any particular source.]

24. Control of Volatile Organic Compound Emissions from Large Petroleum Dry Cleaners, EPA-450/3-82-009, September 1982

25. Control of Volatile Organic Compound Emissions from Manufacture of High-Density Polyethylene, Polypropylene, and Polystyrene Resins, EPA-450/3-83-008, November 1983

26. Control of Volatile Organic Compound Equipment Leaks from Natural Gas/Gasoline Processing Plants, EPA-450/2-83-007, December 1983.

27. Control of Volatile Organic Compound Fugitive Emissions from Synthetic Organic Chemical Polymer and Resin Manufacturing Equipment, EPA-450/3-83-006, March 1984

28. Control of Volatile Organic Compound Emissions from Air Oxidation Processes in Synthetic Organic Chemical Manufacturing Industry, EPA-450/3-84-015, December 1984.

Post 1990 CTGs

1. SOCMI Distillation and Reactor Processes CTG (EPA 450/4-91-031, August 1993).

2. Wood Furniture (CTG-MACT) - draft MACT out 5-94; Final CTG, EPA-453/R-96-007, April 1996; see also 61 FR 25223, and, 61 FR 50823, September 27, 1996.

3. Shipbuilding/repair ACT (EPA 453/R-94-032, April 1994) and CTG, see 61 FR 44050, August 27, 1996.

4. Aerospace (CTG & MACT) (see 59 FR 29216, June 6, 1994); CTG (Final), EPA-453/R-97-004, December 1997.

The VOC Available Control Technology (ACTs) Documents

1. Control Techniques for Organic Emissions from Plywood Veneer Dryers, EPA-450/3-83-012. May 1983. [This document is labeled as a control technique document (CTD) rather than an ACT. However, the information is similar to that in an ACT.]

2. Reduction of Volatile Organic Compound Emissions from Application of Traffic Markings – EPA-450/3-88-007, August 1988. [Note – the Architectural and Industrial Maintenance coatings (AIM) national rule issued in 1998 includes limits for traffic coatings and superseded the ACT.]

3. Ethylene Oxide Sterilization ACT (EPA 450/3-89-007) March 1989.

4. Alternative Control Technology Document – Halogenated Solvent Cleaners – EPA-450/3-89-030. August 1989.

5. Alternative Control Technology Document – Organic Waste Process Vents – EPA-450/3-91-007, December 1990.

6. Polystyrene Foam Manufacturing – EPA-450/3-90-020, 1990.

7. Bakery Ovens ACT (EPA 453/R-92-017, December 1992)

8. Control Techniques for Volatile Organic Compound Emissions from Stationary Sources, EPA-453/R-92-018, December 1992

9. Industrial Wastewater CTG (draft) (EPA-453/D-93-056, September 1992); ACT: April 94 ACT consists of cover memo with option tables + CTG (draft).

10. Control of VOC Emissions from the Application of Agricultural Pesticides, EPA-450/R-92-011, March 1993.

11. Alternative Control Techniques Document: Volatile Organic Liquid Storage In Floating and Fixed Roof Tanks, EPA 453/R-94-001, January 1994.

12. Control of Volatile Organic Compound Emissions from Batch Processes ACT (EPA 453/R-93-017 or EPA 453/R-93-020, February 1994)

13. Alternative Control Techniques Document – Industrial Cleaning Solvents, EPA-453/R-94-015, February 1994

14. Business Machine Plastic Parts coating/Automobile Plastic Parts coating ACT (EPA 453/R-94-017, February 1994)

15. Automobile Body refinishing ACT (EPA 453/R-94-031, April 1994) [Note – a national rule for autobody refinishing was issued in 1998 after the ACT.]

16. Ship building coatings ACT, EPA 453/R-94-032, April 1994. [This was superseded by the Ship building CTG which was issued in August 1996.]

17. Offset Lithography ACT (EPA 453/R-94-054, June 1994)

The NOx ACT documents:

1. NOx Emissions from Nitric and Adipic Acid Manufacturing Plants (EPA-453/3-91-026- December 1991.

2. NOx Emissions from Stationary Combustion Turbines (EPA-453/R-93-007) - January 1993.

3. NOx Emissions from Process Heaters (EPA-453/R-93-034) - revised September 1993.

4. NOx Emissions from Stationary Internal Combustion Engines (EPA-453/R-93-032), July 1993 – [Updated September 2000.]

5. NOx Emissions from Utility Boilers - (EPA 453/R-94-023) March 1994.

6. NOx Emissions from Cement Manufacturing - (EPA 453/R-94-004) March 1994 – [Updated September 2000.]

7. NOx Emissions from Industrial, Commercial & Institutional Boilers - (EPA 453/R-94-022) March 1994.

8. NOx Emissions from Glass Manufacturing - (EPA 453/R-94-037), June 1994.

9. NOx Emissions from Iron and Steel - (EPA 453/R-94-065) September 1994.

Important Information Concerning the Menu of Control Measures

The Menu of Control Measures (MCM), complied by the State and Local Programs Group within U.S. EPA's Office of Air Quality Planning and Standards, was developed to provide information useful in the development of local emission reduction and NAAQS SIP scenarios, and identifying and evaluating potential control measures. This informational document is intended to provide a broad, though not comprehensive, listing of potential emissions reduction measures for direct $PM_{2.5}$ and precursors of ozone and $PM_{2.5}$. Concerning mobile sources, we encourage State air planning agencies to consider these control measures when they do an initial screening step to identify the sectors that warrant more detailed analysis as part of their control strategy preparation for nonattainment ozone or PM SIPs. It is critical that this information be used only as a screening step and that final SIPs should be based on mobile source model runs for States' specific geographic areas following guidance from EPA's Office of Transportation and Air Quality (OTAQ).

We regard this as a “living documents” and as we use these documents, we expect to make ongoing revisions as we receive additional information. We invite users to provide suggestions for additional measures, or additional sources of information on measures, that they believe should be included.

Before examining control measures, an important step is to identify the nature of the $PM_{2.5}$ and ozone problem in their areas and the sources contributing to that problem. The severity, nature and sources of the problem vary in each area, so the measures that are effective and cost-effective will also vary by area. Similarly, the geographic area in which measures are effectively applied will vary depending on the extent to which pollution sources outside the area contribute to the area’s problem. Similarly, the costs of applying a given control measure will have case-specific considerations. While the tables here provide overall control costs and control efficiency estimates derived from the references, there is inherent uncertainty in any estimates of this nature. We do not attempt in these tables to provide any rigorous treatment of these uncertainties, but rather provide the control efficiency and cost estimates as a rough “ballpark” starting point. These documents also do not provide specific emissions monitoring and testing information, such as costs. We encourage the use of source-specific assessments which will be more reliable.

This document contains several tabular lists of point source and non-point source (previously known as 'area' sources) control measures, organized by pollutant, i.e., NOx, VOC, PM, and SO_2. The tables also identify reference sources that the user may wish to consult for more information. Note that this technical document is focused on identification of measures and does not address mechanisms for implementation, such as whether a measure would be implemented on a mandatory or voluntary basis.

Below are additional important aspects of the MCM:

- The MCM is based on data in reports from the U.S. EPA and other organizations (e.g., LADCO, OTC, NACAA, SCAQMD, WRAP, and other Federal agencies).

- The MCM cost and control efficiency information are best characterized as national-level averages so care should be used to consider local cost factors for more refined analysis.

- In many cases the accuracy of the MCM cost and control efficiency information is limited by the information in the emission inventory to which it is applied. For example, it is important to know what control measures currently exist at a source before quantifying the cost and increased control efficiency of a more effective control measure. Information on existing controls is often very limited in emission inventories and sometimes when it is available, it is unreliable.

- VOC Control Measures - This list of measures includes updates for VOC Control Measures based in part on the results of a literature review of the current and proposed measures of various air quality agencies, including the California Air Resources Board, individual California Air Management Districts, the Ozone Transport Commission, and the Lake Michigan Air Directors Consortium. In addition, 40 CFR Part 59 addresses Federal rules for non-point VOC source categories. We considered these Federal rules as the baseline from which additional reductions were measured. The reported control efficiencies are the percent reduction from the Federal baseline. Note that control efficiencies involving product reformulations are highly uncertain and depend on the geographic region. National average reductions are included when possible, but some control efficiencies are based on area specific analyses.

- ICI Boiler Control Measures - Control and cost information in the CMC for Industrial, Commercial, and Institutional Boilers is outdated and may underestimate the costs of control. EPA’s Air Economics Group is initiating a project to update control and cost information for ICI Boiler NOx control measures. We will follow this up with an update of PM and SO2 Boiler control measures if resources are available.

- Four Onroad mobile source control measures are included with reduction and cost ranges based on recent MOVES runs. Reductions associated with these control measures should NOT be applied to MOBILE6-based outputs as these reductions and costs are all based on MOVES data. These are:

- Eliminate Long Duration Idling for Long-Haul Heavy Duty Trucks
- Onroad Heavy Duty Diesel Retrofits
- Continuous Inspection and Maintenance
- Onroad use of Low RVP Fuels

Feedback is welcome and encouraged - please send comments to Tom Coda, US EPA (email address: coda.tom@epa.gov)

Point & NonPoint NOx
Menu of Control Measures
Updated 4/12/2012

Sector	Source Category	Emission Reduction Measure Name	Control Efficiency (%)*	Cost Effectiveness (2006$/ton reduced)	Other pollutants controlled	Description/Notes/Caveats	References
NonPoint	Commercial/ Institutional - Natural Gas	Water heater replacement	45	$0		This control would replace existing water heaters with new water heaters. New water heaters would be required to emit less than or equal to 40 ng NOx per Joule heat output. This control applies to all commercial/institutional natural gas burning water heaters.	EPA 2006b, EPA 1986, EPA 1995f, EPA 1996f, EPA 2007b
NonPoint	Industrial Coal Combustion	RACT to 25 tpy (Low NOx Burner)	21	$2,167		The RACT control technology used is the addition of a low NOx burner to reduce NOx emissions. This standard applies to sources with boilers fueled by coal that emit over 25 tpy NOx.	EPA 2006b, EPA 1986, EPA 1998d, EPA 1996f
NonPoint	Industrial Coal Combustion	RACT to 50 tpy (Low NOx Burner)	21	$2,167		The RACT control technology used is the addition of a low NOx burner to reduce NOx emissions. This standard applies to sources with boilers fueled by coal that emit over 50 tpy NOx.	EPA 2006b, EPA 1986, EPA 1998d, EPA 1996f
NonPoint	Industrial Natural Gas Combustion	RACT to 25 tpy (Low NOx Burner)	31	1NJDEP 2003		The RACT control technology used is the addition of a low NOx burner to reduce NOx emissions. This standard applies to sources with boilers fueled by natural gas that emit over 50 tpy NOx.	EPA 2006b, EPA 1986, EPA 1998d, EPA 1996f
NonPoint	Industrial Natural Gas Combustion	RACT to 50 tpy (Low NOx Burner)	31	1NJDEP 2003		The RACT control technology used is the addition of a low NOx burner to reduce NOx emissions. This standard applies to sources with boilers fueled by natural gas that emit over 50 tpy NOx.	EPA 2006b, EPA 1986, EPA 1998d, EPA 1996f
NonPoint	Industrial Oil Combustion	RACT to 25 tpy (Low NOx Burner)	36	$1,894		The RACT control technology used is the addition of a low NOx burner to reduce NOx emissions. This standard applies to sources with boilers fueled by oil that emit over 25 tpy NOx.	EPA 2006b, EPA 1986, EPA 1998d, EPA 1996f
NonPoint	Industrial Oil Combustion	RACT to 50 tpy (Low NOx Burner)	36	$1,894		The RACT control technology used is the addition of a low NOx burner to reduce NOx emissions. This standard applies to sources with boilers fueled by oil that emit over 50 tpy NOx.	EPA 2006b, EPA 1986, EPA 1998d, EPA 1996f
NonPoint	Open Burning	Episodic Ban (Daily Only)	100	$0		This is a generic control measure that would ban open burning on days where ozone exceedances were predicted, reducing NOx emissions on those days. This measure would not reduce the annual emissions.	EPA 2006b, EPA 1986, EPA 2007b, EPA 1996f
NonPoint	Process Heaters - Distillate Oil, Residual Oil, or Other Fuel	Low NOx Burner and Selective Noncatalytic Reduction	75	$3,691 for NOx<1 tpd and $1,990 for NOx>1 tpd		This control is the use of low NOx burner (LNB) technology and selective non-catalytic reduction (SNCR) to reduce NOx emissions. LNBs reduce the amount of NOx created from reaction between fuel nitrogen and oxygen by lowering the temperature of one combustion zone and reducing the amount of oxygen available in another. SNCR controls are post-combustion control technologies based on the chemical reduction of nitrogen oxides (NOx) into molecular nitrogen (N2) and water vapor (H2O). This control is applicable to process heaters fired with distillate, residual oil, and other unclassified fuels.	EPA 2006b, Pechan 2001, EPA 1998e, EPA 2002a, EPA 1993c
NonPoint	Residential/Commercial/ Institutional Water Heaters and/or Space Heaters	Low NOx Water Heaters and Low NOx Burner Space Heaters	7-75	$928-$1,974		This control is the use of low NOx burner (LNB) technology to reduce NOx emissions. LNBs reduce the amount of NOx created from reaction between fuel nitrogen and oxygen by lowering the temperature of one combustion zone and reducing the amount of oxygen available in another. The South Coast and Bay Area AQMDs set emission limits for water heaters and space heaters. This control is based on the installation of low-NOx space heaters and water heaters in residential, commercial and institutional sources for the reduction of NOx emissions.	EPA 2006b, EPA 1986, EPA 2007b, SCAQMD 1996a, Pechan 2006, EPA 1996f
NonEGU Point	Adipic Acid Manufacturing	Extended Absorption	86	$144		This control is the use of extended absorption technologies to reduce NOx emissions. This control applies to adipic acid manufacturing operations.	EPA 2006b, EPA 1998e, EPA 1991
NonEGU Point	Adipic Acid Manufacturing	Thermal Reduction	81	$674		This control is the application of Thermal Reduction controls to Adipic Acid Manufacturing sources to reduce NOx emissions. Thermal reduction reduces NOx by reaction with excess fuel in a reducing environment. NOx laden stream and excess fuel mixture passes through a burner where the mixture is heated above its ignition temperature. The hot gases then pass through one or more chambers to provide sufficient residence time to ensure complete combustion.	EPA 2006b
NonEGU Point	Ammonia Production - Natural Gas-Fired Reformers	Low NOx Burner	50	$1,316 for NOx<1 tpd and $1,043 for NOx>1 tpd		This control is the use of low NOx burner (LNB) technology to reduce NOx emissions. LNBs reduce the amount of NOx created from reaction between fuel nitrogen and oxygen by lowering the temperature of one combustion zone and reducing the amount of oxygen available in another. This control is applicable to natural-gas fired reformers involved in the production of ammonia with uncontrolled NOx emissions greater than 10 tons per year.	EPA 2006b, Pechan 2001, EPA 1998e, EPA 2002a, EPA 1994g
NonEGU Point	Ammonia Production - Natural Gas-Fired Reformers	Low NOx Burner and Flue Gas Recirculation	60	$4,109 for NOx<1 tpd and $947 for NOx>1 tpd		This control is the use of low NOx burner (LNB) technology and flue gas recirculation (FGR) to reduce NOx emissions. LNBs reduce the amount of NOx created from reaction between fuel nitrogen and oxygen by lowering the temperature of one combustion zone and reducing the amount of oxygen available in another. This control is applicable to natural-gas fired reformers involved in the production of ammonia with uncontrolled NOx emissions greater than 10 tons per year.	EPA 2006b, Pechan 2001, EPA 1998e, EPA 2002a, EPA 1993c
NonEGU Point	Ammonia Production - Natural Gas-Fired Reformers	Oxygen Trim and Water Injection	65	$1,091 for NOx<1 tpd and $514 for NOx>1 tpd		This control is the use of oxygen trim and water injection to reduce NOx emissions.Water is injected into the gas turbine, reducing the temperatures in the NOx-forming regions. The water can be injected into the fuel, the combustion air or directly into the combustion chamber. This control is applicable to natural-gas fired reformers involved in the production of ammonia with uncontrolled NOx emissions greater than 10 tons per year.	EPA 2006b, Pechan 2001, EPA 1998e, EPA 2002a, ERG 2000, EPA 1994g

Sector	Source Category	Emission Reduction Measure Name	Control Efficiency (%)*	Cost Effectiveness (2006$/ton reduced)	Other pollutants controlled	Description/Notes/Caveats	References
NonEGU Point	Ammonia Production - Natural Gas-Fired Reformers	Selective Catalytic Reduction	90	$2,852		This control is the selective catalytic reduction of NOx through add-on controls. SCR controls are post-combustion control technologies based on the chemical reduction of nitrogen oxides (NOx) into molecular nitrogen (N2) and water vapor (H2O). The SCR utilizes a catalyst to increase the NOx removal efficiency, which allows the process to occur at lower temperatures. This control is applicable to natural-gas fired reformers involved in the production of ammonia with uncontrolled NOx emissions greater than 10 tons per year.	EPA 2006b, EPA 2007b, EPA 1998e, EPA 2002a, EPA 2007d, Sorrels 2007
NonEGU Point	Ammonia Production - Natural Gas-Fired Reformers	Selective Non-Catalytic Reduction	50	$6,211 for NOx<1 tpd and $2,520 for NOx>1 tpd		This control is the reduction of NOx emission through selective non-catalytic reduction add-on controls. SNCR controls are post-combustion control technologies based on the chemical reduction of nitrogen oxides (NOx) into molecular nitrogen (N2) and water vapor (H2O). This control is applicable to natural-gas fired reformers involved in the production of ammonia with uncontrolled NOx emissions greater than 10 tons per year.	EPA 2006b, Pechan 2001, EPA 1998e, EPA 2002a, EPA 1994g
NonEGU Point	Ammonia Production - Oil-Fired Reformers	Low NOx Burner	50	$642 for NOx<1 tpd and $690 for NOx>1 tpd		This control is the use of low NOx burner (LNB) technology to reduce NOx emissions. LNBs reduce the amount of NOx created from reaction between fuel nitrogen and oxygen by lowering the temperature of one combustion zone and reducing the amount of oxygen available in another. This control is applicable to oil-gas fired reformers involved in the production of ammonia with uncontrolled NOx emissions greater than 10 tons per year.	EPA 2006b
NonEGU Point	Ammonia Production - Oil-Fired Reformers	Low NOx Burner and Flue Gas Recirculation	60	$1,798 for NOx<1 tpd and $626 for NOx>1 tpd		This control is the use of low NOx burner (LNB) technology and flue gas recirculation (FGR) to reduce NOx emissions. LNBs reduce the amount of NOx created from reaction between fuel nitrogen and oxygen by lowering the temperature of one combustion zone and reducing the amount of oxygen available in another. This control is applicable to oil-gas fired reformers involved in the production of ammonia with uncontrolled NOx emissions greater than 10 tons per year.	EPA 2006b
NonEGU Point	Ammonia Production - Oil-Fired Reformers	Selective Catalytic Reduction	80	$2,375 for NOx<1 tpd and $1,300 for NOx>1 tpd		This control is the selective catalytic reduction of NOx through add-on controls. SCR controls are post-combustion control technologies based on the chemical reduction of nitrogen oxides (NOx) into molecular nitrogen (N2) and water vapor (H2O). The SCR utilizes a catalyst to increase the NOx removal efficiency, which allows the process to occur at lower temperatures. This control is applicable to oil-gas fired reformers involved in the production of ammonia with uncontrolled NOx emissions greater than 10 tons per year.	EPA 2006b
NonEGU Point	Ammonia Production - Oil-Fired Reformers	Selective Non-Catalytic Reduction	50	$4,141 for NOx<1 tpd and $1,685 for NOx>1 tpd		This control is the reduction of NOx emission through selective non-catalytic reduction add-on controls. SNCR controls are post-combustion control technologies based on the chemical reduction of nitrogen oxides (NOx) into molecular nitrogen (N2) and water vapor (H2O). This control is applicable to oil-gas fired reformers involved in the production of ammonia with uncontrolled NOx emissions greater than 10 tons per year.	EPA 2006b
NonEGU Point	Asphalt Plant Manufacture	Low NOx Burner and Flue Gas Recirculation	30-50	N/A		This control is the use of low NOx burner (LNB) technology and flue gas recirculation (FGR) to reduce NOx emissions. LNBs reduce the amount of NOx created from reaction between fuel nitrogen and oxygen by lowering the temperature of one combustion zone and reducing the amount of oxygen available in another. This control is applicable to asphalt plant manufacturing sources.	STAPPA/ALAPCO 2006
NonEGU Point	Asphaltic Concrete - Rotary Dryer - Conventional Plant	Low NOx Burner	50	$3,531 for NOx<1 tpd and $2,889 for NOx>1 tpd		This control is the use of low NOx burner (LNB) technology to reduce NOx emissions. LNBs reduce the amount of NOx created from reaction between fuel nitrogen and oxygen by lowering the temperature of one combustion zone and reducing the amount of oxygen available in another. This control is applicable to construction operations with rotary driers and uncontrolled NOx emissions greater than 10 tons per year.	EPA 2006b, EPA 1998e, EPA 2002a, EPA 1993c
NonEGU Point	By-Product Coke Manufacturing - Oven Underfiring	Selective Non-Catalytic Reduction	60	$2,632		This control is the reduction of NOx emission through selective non-catalytic reduction add-on controls. SNCR controls are post-combustion control technologies based on the chemical reduction of nitrogen oxides (NOx) into molecular nitrogen (N2) and water vapor (H2O). This control applies to all by-product coke manufacturing operations with oven underfiring and uncontrolled NOx emissions greater than 10 tons per year.	EPA 2006b, Pechan 2001, EPA 1998e, EPA 2002a, EPA 1994e
NonEGU Point	Cement Kilns	Biosolid Injection Technology	23	$407		This control is the use of biosolid injection to reduce NOx emissions. This control applies to cement kilns.	EPA 2006b, EPA 2007c
NonEGU Point	Cement Kilns	Changing feed composition	25-40	$587		This control is changing the cement formulation by adding steel slag to lower the clinkering temperatures and supress NOx. The patented feed modification technique known as the CemStar Process is a raw feed modification process that can reduce NOx emissions by about 30 percent and increase production by approximately 15 percent. It involves the addition of a small amount of steel slag to the raw kiln feed. Steel slag has a chemical composition similar to clinker and many of the chemical reactions required to convert steel slag to clinker take place in the steel furnace. By substituting steel slag for a portion of the raw materials, facilities can increase thermal efficiency and thereby reduce NOx emissions. This control is applicable to wet- and dry-process kilns, as well as those with preheaters or precalciners.	STAPPA/ALAPCO 2006

Sector	Source Category	Emission Reduction Measure Name	Control Efficiency (%)*	Cost Effectiveness (2006$/ton reduced)	Other pollutants controlled	Description/Notes/Caveats	References
NonEGU Point	Cement Kilns	Process Control Systems	<25	N/A		This control is the modification of the cement production process to improve fuel efficiency, increase capacity and kiln operational stability. NOx reductions result from the increase in productivity and reduced energy use. One process control that specifically targets NOx emissions is continuousemissions monitoring systems (CEMS). CEMS allow operators to continuously monitor oxygen andcarbon monoxide (CO) emissions in cement kiln exhaust gases. The levels of these gases indicate the amount of excess air in the combustion zone. At a given excess air level, NOx emissions increase as the temperature increases. Knowing the excess air level allows operators to maintain a lower temperature and thereby minimize NOx creation. Studies indicate that reducing excess air by half can reduce NOx emissions by about 15 percent This control is applicable to wet- and dry-process kilns, as well as those with preheaters or precalciners.	STAPPA/ALAPCO 2006
NonEGU Point	Cement Manufacturing - Dry Process	Selective Non-Catalytic Reduction - Ammonia	50	$1,364		This control is the reduction of NOx emission through ammonia based selective non-catalytic reduction add-on controls. SNCR controls are post-combustion control technologies based on the chemical reduction of nitrogen oxides (NOx) into molecular nitrogen (N2) and water vapor (H2O). This control applies to dry-process cement manufacturing operations with uncontrolled NOx emissions greater than 10 tons per year.	EPA 2006b, Pechan 2001, EPA 1998e, EPA 2002a, EPA 1994h
NonEGU Point	Cement Manufacturing - Dry Process	Selective Non-Catalytic Reduction - Urea	50	1NJDEP 2003		This control is the reduction of NOx emission through urea based selective non-catalytic reduction add-on controls. SNCR controls are post-combustion control technologies based on the chemical reduction of nitrogen oxides (NOx) into molecular nitrogen (N2) and water vapor (H2O). This control applies to dry-process cement manufacturing with uncontrolled NOx emissions greater than 10 tons per year.	EPA 2006b, EPA 1998e, EPA 2002a, EPA 1994h
NonEGU Point	Cement Manufacturing - Dry Process or Wet Process	Low NOx Burner	25	$577		This control is the use of low NOx burner (LNB) technology to reduce NOx emissions. LNBs reduce the amount of NOx created from reaction between fuel nitrogen and oxygen by lowering the temperature of one combustion zone and reducing the amount of oxygen available in another. This control applies to dry-process or wet-process cement manufacturing operations with indirect-fired kilns with uncontrolled NOx emissions greater than 10 tons per year.	EPA 2006b, EPA 1998e, EPA 2002a, EPA 1994h, EC/R 2000
NonEGU Point	Cement Manufacturing - Dry Process or Wet Process	Mid-Kiln Firing	30	$72		This control is the use of mid- kiln firing to reduce NOx emissions. Mid-kiln firing is the injection of solid fuel into the calcining zone of a long kiln. This allows for part of the fuel to be burned at a lower temperature, reducing NOx formation. This control applies to wet-process and dry-process cement manufacturing operations with uncontrolled NOx emissions greater than 10 tons per year.	EPA 2006b, EPA 1998e, EPA 2002a, EPA 1994h, EC/R 2000
NonEGU Point	Cement Manufacturing - Wet Process	Selective Catalytic Reduction	90	$4,776		This control is the selective catalytic reduction of NOx through add-on controls. SCR controls are post-combustion control technologies based on the chemical reduction of nitrogen oxides (NOx) into molecular nitrogen (N2) and water vapor (H2O). The SCR utilizes a catalyst to increase the NOx removal efficiency, which allows the process to occur at lower temperatures.This control applies to wet-process cement manufacturing with uncontrolled NOx emissions greater than 10 tons per year.	EPA 2007b
NonEGU Point	Ceramic Clay Manufacturing - Drying	Low NOx Burner	50	$2,889-$3,531		This control is the use of low NOx burner (LNB) technology to reduce NOx emissions. LNBs reduce the amount of NOx created from reaction between fuel nitrogen and oxygen by lowering the temperature of one combustion zone and reducing the amount of oxygen available in another. This control is applicable to drying processes at ceramic clay manufacturing operations with uncontrolled NOx emissions greater than 10 tons per year.	EPA 2006b, EPA 1998e, EPA 2002a, EPA 1994h
NonEGU Point	Coal Cleaning-Thermal Dryer - Fluidized Bed	Low NOx Burner	50	$222-$1,108		This control is the use of low NOx burner (LNB) technology to reduce NOx emissions. LNBs reduce the amount of NOx created from reaction between fuel nitrogen and oxygen by lowering the temperature of one combustion zone and reducing the amount of oxygen available in another. This control is applicable to thermal drying processes at coal cleaning operations with uncontrolled NOx emissions greater than 10 tons per year.	EPA 2006b, EPA 1998e, EPA 2002a, EPA 1994g
NonEGU Point	Combustion Turbine - Aeroderivative Gas Turbines	Water Injection	74	$2,206		This control is the use of water injection to reduce NOx emissions. Water is injected into the gas turbine, reducing the temperatures in the NOx-forming regions. The water can be injected into the fuel, the combustion air or directly into the combustion chamber. This control applies to aeroderivative gas-fired turbines.	EPA 1993d
NonEGU Point	Combustion Turbines - Natural Gas	Low NOx Burner	68% for small sources, 84% for large sources	$490 for NOx<1 tpd and $100 for NOx>1 tpd		This control is the use of low NOx burner (LNB) technology to reduce NOx emissions. LNBs reduce the amount of NOx created from reaction between fuel nitrogen and oxygen by lowering the temperature of one combustion zone and reducing the amount of oxygen available in another. This control applies to natural gas fired turbines with uncontrolled NOx emissions greater than 10 tons per year.	EPA 2006b, Pechan 2001, EPA 1998e, EPA 2002a, EPA 1993d
NonEGU Point	Combustion Turbines - Natural Gas	Selective Catalytic Reduction and Low NOx Burner	94	$4,125 for NOx<1 tpd and $963 for NOx>1 tpd		This control is the selective catalytic reduction of NOx through add-on controls. SCR controls are post-combustion control technologies based on the chemical reduction of nitrogen oxides (NOx) into molecular nitrogen (N2) and water vapor (H2O). The SCR utilizes a catalyst to increase the NOx removal efficiency, which allows the process to occur at lower temperatures.This control applies to natural gas fired turbines with NOx emissions greater than 10 tons per year.	EPA 2006b, Pechan 2001, EPA 1998e, EPA 2002a, EPA 1993d
NonEGU Point	Combustion Turbines - Natural Gas	Selective Catalytic Reduction and Steam Injection	95	$3,226 for NOx<1 tpd and $1,348 for NOx>1 tpd		This control is the selective catalytic reduction of NOx through add-on controls. SCR controls are post-combustion control technologies based on the chemical reduction of nitrogen oxides (NOx) into molecular nitrogen (N2) and water vapor (H2O). The SCR utilizes a catalyst to increase the NOx removal efficiency, which allows the process to occur at lower temperatures.This control applies to natural gas fired turbines with NOx emissions greater than 10 tons per year.	EPA 2006b, Pechan 2001, EPA 1998e, EPA 2002a, EPA 1993d

Sector	Source Category	Emission Reduction Measure Name	Control Efficiency (%)*	Cost Effectiveness (2006$/ton reduced)	Other pollutants controlled	Description/Notes/Caveats	References
NonEGU Point	Combustion Turbines - Natural Gas	Selective Catalytic Reduction and Water Injection	95	$4,382 for NOx<1 tpd and $1,814 for NOx>1 tpd		This control is the selective catalytic reduction of NOx through add-on controls in combination with water injection. SCR controls are post-combustion control technologies based on the chemical reduction of nitrogen oxides (NOx) into molecular nitrogen (N2) and water vapor (H2O). The SCR utilizes a catalyst to increase the NOx removal efficiency, which allows the process to occur at lower temperatures. This control applies to natural gas-fired gas turbines with uncontrolled NOx emissions greater than 10 tons per year.	EPA 2006b, Pechan 2001, EPA 1998e, EPA 2002a, EPA 1993d
NonEGU Point	Combustion Turbines - Natural Gas	Steam Injection	80	$1,669 for NOx<1 tpd and $802 for NOx>1 tpd		This control is the use of steam injection to reduce NOx emissions. Steam is injected into the gas turbine, reducing the temperatures in the NOx-forming regions. The steam can be injected into the fuel, the combustion air or directly into the combustion chamber. This control applies to natural gas-fired gas turbines with uncontrolled NOx emissions greater than 10 tons per year.	EPA 2006b, Pechan 2001, EPA 1998e, ERG 2000, EPA 1993d
NonEGU Point	Combustion Turbines - Natural Gas	Water Injection	76	$2,423 for NOx<1 tpd and $1,172 for NOx>1 tpd		This control is the use of water injection to reduce NOx emissions. Water is injected into the gas turbine, reducing the temperatures in the NOx-forming regions. The water can be injected into the fuel, the combustion air or directly into the combustion chamber. This control applies to natural gas-fired gas turbines with uncontrolled NOx emissions greater than 10 tons per year.	EPA 2006b, Pechan 2001, EPA 1998e, ERG 2000, EPA 1993d
NonEGU Point	Combustion Turbines - Oil or Jet Fuel	Selective Catalytic Reduction and Water Injection	90	$3,691 for NOx<1 tpd and $1,621 for NOx>1 tpd		This control is the selective catalytic reduction of NOx through add-on controls in combination with water injection. SCR controls are post-combustion control technologies based on the chemical reduction of nitrogen oxides (NOx) into molecular nitrogen (N2) and water vapor (H2O). The SCR utilizes a catalyst to increase the NOx removal efficiency, which allows the process to occur at lower temperatures. This control applies to oil-fired and jet fuel-fired turbines with uncontrolled NOx emissions greater than 10 tons per year.	EPA 2006b, Pechan 2001, EPA 1998e, EPA 2002a, EPA 1993d
NonEGU Point	Combustion Turbines - Oil or Jet Fuel	Water Injection	68	$2,070 for NOx<1 tpd and $1,043 for NOx>1 tpd		This control is the use of water injection to reduce NOx emissions. Water is injected into the gas turbine, reducing the temperatures in the NOx-forming regions. The water can be injected into the fuel, the combustion air or directly into the combustion chamber. This control applies to oil turbines and jet fuel-fired turbines with uncontrolled NOx emissions greater than 10 tons per year.	EPA 2006b, Pechan 2001, EPA 1998e, ERG 2000, EPA 1993d
NonEGU Point	Commercial/ Institutional or Industrial Incinerators	Selective Non-Catalytic Reduction	45	$1,814		This control is the reduction of NOx emission through selective non-catalytic reduction add-on controls. SNCR controls are post-combustion control technologies based on the chemical reduction of nitrogen oxides (NOx) into molecular nitrogen (N2) and water vapor (H2O). This control applies to commercial/institutional incinerators and industrial incinerators with uncontrolled NOx emissions greater than 10 tons per year.	EPA 2006b, Pechan 2001, EPA 1998e, EPA 2002a, EPA 1994i
NonEGU Point	Fluid Catalytic Cracking Units - Cracking Unit	Low NOx Burner and Flue Gas Recirculation	55	$5,120 for NOx<1 tpd and $3,964 for NOx>1 tpd		This control is the use of low NOx burner (LNB) technology and flue gas recirculation (FGR) to reduce NOx emissions. LNBs reduce the amount of NOx created from reaction between fuel nitrogen and oxygen by lowering the temperature of one combustion zone and reducing the amount of oxygen available in another. This control is applicable to fluid catalytic cracking units with uncontrolled NOx emissions greater than 10 tons per year.	EPA 2006b, EPA 1998e, EPA 2002a, EPA 1993c
NonEGU Point	Fluid Catalytic Cracking Units - Cracking Unit	Selective Catalytic Reduction	90	$4,167		This control is the selective catalytic reduction of NOx through add-on controls. SCR controls are post-combustion control technologies based on the chemical reduction of nitrogen oxides (NOx) into molecular nitrogen (N2) and water vapor (H2O). The SCR utilizes a catalyst to increase the NOx removal efficiency, which allows the process to occur at lower temperatures.This control is applicable to fluid catalytic cracking units with uncontrolled NOx emissions greater than 10 tons per year.	EPA 2007b
NonEGU Point	Furnaces - Natural Gas	Low NOx Burner	50	$915		This control is the use of low NOx burner (LNB) technology to reduce NOx emissions. LNBs reduce the amount of NOx created from reaction between fuel nitrogen and oxygen by lowering the temperature of one combustion zone and reducing the amount of oxygen available in another. This control applies to natural gas fired equipment with uncontrolled NOx emissions greater than 10 tons per year.	EPA 2006b, EPA 1998e, EPA 2002a, EPA 1994e
NonEGU Point	Glass Manufacturing - Container	Cullet Preheat	25	$1,509		This control is the use of cullet preheat technologies to reduce NOx emissions from glass manufacturing operations. This control is applicable to container glass manufacturing operations.	EPA 2006b, EPA 1998e, EPA 1994f
NonEGU Point	Glass Manufacturing - Container	Electric Boost	10	$11,475		This control is the use of electric boost technologies to reduce NOx emissions from glass manufacturing operations. This control applies to container glass manufacturing operations.	EPA 2006b, EPA 1998e, EPA 1994f
NonEGU Point	Glass Manufacturing - Container	OXY-Firing	85	$7,367		This control is the use of Oxy-firing in container glass manufacturing furnaces to reduce NOx emissions. Oxygen enrichment refers to the substitution of oxygen for nitrogen in the combustion air used to burn the fuel in a glass furnace. Oxygen enrichment above 90 percent is sometimes called "oxy-firing."	EPA 2006b
NonEGU Point	Glass Manufacturing - Container	Selective Catalytic Reduction	75	$3,531		This control is the selective catalytic reduction of NOx through add-on controls. SCR controls are post-combustion control technologies based on the chemical reduction of nitrogen oxides (NOx) into molecular nitrogen (N2) and water vapor (H2O). The SCR utilizes a catalyst to increase the NOx removal efficiency, which allows the process to occur at lower temperatures. This control applies to glass-container manufacturing processes with uncontrolled NOx emissions greater than 10 tons per year.	EPA 2006b, Pechan 2001, EPA 1998e, EPA 2002a, EPA 1994f

Sector	Source Category	Emission Reduction Measure Name	Control Efficiency (%)*	Cost Effectiveness (2006$/ton reduced)	Other pollutants controlled	Description/Notes/Caveats	References
NonEGU Point	Glass Manufacturing - Container	Selective Non-Catalytic Reduction	40	$2,841		This control is the reduction of NOx emission through selective non-catalytic reduction add-on controls. SNCR controls are post-combustion control technologies based on the chemical reduction of nitrogen oxides (NOx) into molecular nitrogen (N2) and water vapor (H2O). This control applies to glass-container manufacturing operations with uncontrolled NOx emissions greater than 10 tons per year.	EPA 2006b, Pechan 2001, EPA 1998e, EPA 2002a, EPA 1994f, EPA 1993c
NonEGU Point	Glass Manufacturing - Container or Flat Glass	Low NOx Burner	40	$1,123		This control is the use of low NOx burner (LNB) technology to reduce NOx emissions. LNBs reduce the amount of NOx created from reaction between fuel nitrogen and oxygen by lowering the temperature of one combustion zone and reducing the amount of oxygen available in another. This control applies to flat glass and container glass manufacturing operations with uncontrolled NOx emissions greater than 10 tons per year.	EPA 2006b, EPA 1998e, EPA 2002a, EPA 1994f
NonEGU Point	Glass Manufacturing - Flat	Electric Boost	10	$3,724		This control is the use of electric boost technologies to reduce NOx emissions from glass manufacturing operations. This control applies to flat glass manufacturing operations.	EPA 2006b, EPA 1998e, EPA 1994f
NonEGU Point	Glass Manufacturing - Flat	OXY-Firing	85	$3,049		This control is the use of Oxy-firing in flat glass manufacturing furnaces to reduce NOx emissions. Oxygen enrichment refers to the substitution of oxygen for nitrogen in the combustion air used to burn the fuel in a glass furnace. Oxygen enrichment above 90 percent is sometimes called "oxy-firing"	EPA 2006b
NonEGU Point	Glass Manufacturing - Flat	Selective Catalytic Reduction	75	$5,409 for NOx<1 tpd and $1,140 for NOx>1 tpd		This control is the selective catalytic reduction of NOx through add-on controls. SCR controls are post-combustion control technologies based on the chemical reduction of nitrogen oxides (NOx) into molecular nitrogen (N2) and water vapor (H2O). The SCR utilizes a catalyst to increase the NOx removal efficiency, which allows the process to occur at lower temperatures. This control applies to flat-glass manufacturing operations with uncontrolled NOx emissions greater than 10 tons per year.	EPA 2006b, Pechan 2001, EPA 1998e, EPA 2002a, EPA 1994f, EPA 1993c
NonEGU Point	Glass Manufacturing - Flat	Selective Non-Catalytic Reduction	40	$1,188		This control is the reduction of NOx emission through selective non-catalytic reduction add-on controls. SNCR controls are post-combustion control technologies based on the chemical reduction of nitrogen oxides (NOx) into molecular nitrogen (N2) and water vapor (H2O). This control applies to flat-glass manufacturing operations with uncontrolled NOx emissions greater than 10 tons per year.	EPA 2006b, Pechan 2001, EPA 1998e, EPA 2002a, EPA 1994f, EPA 1993c
NonEGU Point	Glass Manufacturing - General	OXY-Firing	85	$5,155		This control is the use of Oxy-firing in glass manufacturing furnaces to reduce NOx emissions. Oxygen enrichment refers to the substitution of oxygen for nitrogen in the combustion air used to burn the fuel in a glass furnace. Oxygen enrichment above 90 percent is sometimes called "oxy-firing."	EPA 2007b
NonEGU Point	Glass Manufacturing - Pressed	Cullet Preheat	25	$1,300		This control is the use of cullet preheat technologies to reduce NOx emissions from glass manufacturing operations. This control is applicable to pressed glass manufacturing operations.	EPA 2006b, EPA 1998e, EPA 1994f
NonEGU Point	Glass Manufacturing - Pressed	Electric Boost	10	$3,724 for NOx<1 tpd and $14,059 for NOx>1 tpd		This control is the use of electric boost technologies to reduce NOx emissions from glass manufacturing operations. This control applies to pressed glass manufacturing operations.	EPA 2006b, EPA 1998e, EPA 1994f
NonEGU Point	Glass Manufacturing - Pressed	Low NOx Burner	40	$2,407		This control is the use of low NOx burner (LNB) technology to reduce NOx emissions. LNBs reduce the amount of NOx created from reaction between fuel nitrogen and oxygen by lowering the temperature of one combustion zone and reducing the amount of oxygen available in another. This control is applicable to pressed glass manufactuing operations with uncontrolled NOx emissions greater than 10 tons per year.	EPA 1998e, EPA 2002a, EPA 1994f
NonEGU Point	Glass Manufacturing - Pressed	OXY-Firing	85	$6,259		This control is the use of Oxy-firing in pressed glass manufacturing furnaces to reduce NOx emissions. Oxygen enrichment refers to the substitution of oxygen for nitrogen in the combustion air used to burn the fuel in a glass furnace. Oxygen enrichment above 90 percent is sometimes called "oxy-firing"	EPA 2006b
NonEGU Point	Glass Manufacturing - Pressed	Selective Catalytic Reduction	75	$4,061		This control is the selective catalytic reduction of NOx through add-on controls. SCR controls are post-combustion control technologies based on the chemical reduction of nitrogen oxides (NOx) into molecular nitrogen (N2) and water vapor (H2O). The SCR utilizes a catalyst to increase the NOx removal efficiency, which allows the process to occur at lower temperatures. This control applies to pressed-glass manufacturing operations, and uncontrolled NOx emissions greater than 10 tons per year.	EPA 2006b, Pechan 2001, EPA 1998e, EPA 2002a, EPA 1994f, EPA 1993c
NonEGU Point	Glass Manufacturing - Pressed	Selective Non-Catalytic Reduction	40	$2,632		This control is the reduction of NOx emission through selective non-catalytic reduction add-on controls. SNCR controls are post-combustion control technologies based on the chemical reduction of nitrogen oxides (NOx) into molecular nitrogen (N2) and water vapor (H2O). This control applies to pressed-glass manufacturing operations with uncontrolled NOx emissions greater than 10 tons per year.	EPA 2006b, Pechan 2001, EPA 1998e, EPA 2002a, EPA 1994f, EPA 1993c
NonEGU Point	Industrial Incinerators	Selective Catalytic Reduction	90	Unknown, depends on the exact source. See description.		This control applies to industrial incinerators with uncontrolled NOx emissions greater than 10 tons per year. Although listed here as "industrial incinerators", this source is too vague to provide a reasonnable cost effectiveness estimate. It is required to more accurately identify the emissions sources to make sure that SCR is an adequate control and assess cost. Selective catalytic reduction of NOx through add-on controls is a post-combustion control technology based on the chemical reduction of nitrogen oxides (NOx) into molecular nitrogen (N2) and water vapor (H2O). The SCR utilizes a catalyst to increase the NOx removal efficiency, which allows the process to occur at lower temperatures.	EPA 2007b
NonEGU Point	Industrial Natural Gas Internal Combustion Engines - 2cycle (lean)	Low Emission Combustion	87	$628		This control is the application of low emission combustion firing techniques to natural gas-fired lean burn internal conbustion engines.	EPA 2007c

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NonEGU Point	Industrial Natural Gas Internal Combustion Engines - 4cycle (rich)	Non-Selective Catalytic Reduction	90	$509		NSCR is achieved by placing a catalyst in the exhaust stream of the engine. The exhaust passes over the catalyst, usually a noble metal (platinum, rhodium or palladium) which reduces the reactants to N2, CO2 and H20 (NJDEP, 2003). Typical exhaust temperatures for effective removal of NOx are 800-1200 degrees Fahrenheit. An oxidation catalyst using additional air can be installed downstream of the NSCR catalyst for additional CO and VOC control. This includes 4-cycle naturally aspirated engines and some 4-cycle turbocharged engines. Engines operating with NSCR require air/fuel control to maintain high reduction effectiveness.	EPA 2007c
NonEGU Point	Industrial/ Commercial/ Institutional Boilers - Bagasse	Selective Non-Catalytic Reduction - Urea	55	$2,311 for NOx<1 tpd and $1,493 for NOx>1 tpd		This control is the reduction of NOx emission through urea based selective non-catalytic reduction add-on controls. SNCR controls are post-combustion control technologies based on the chemical reduction of nitrogen oxides (NOx) into molecular nitrogen (N2) and water vapor (H2O). This control applies to bagasse IC boilers with uncontrolled NOx emissions greater than 10 tons per year.	EPA 2006b
NonEGU Point	Industrial/ Commercial/ Institutional Boilers - Coal	Selective Catalytic Reduction	80	$2,373 for NOx<1 tpd and $971 for NOx>1 tpd		This control is the selective catalytic reduction of NOx through add-on controls. SCR controls are post-combustion control technologies based on the chemical reduction of nitrogen oxides (NOx) into molecular nitrogen (N2) and water vapor (H2O). The SCR utilizes a catalyst to increase the NOx removal efficiency, which allows the process to occur at lower temperatures. This control applies to coal ICI boilers with NOx emissions greater than 10 tons per year.	EPA 2003b, EPA 1998e
NonEGU Point	Industrial/ Commercial/ Institutional Boilers - Coal	Selective Non-Catalytic Reduction	40	$2,297 for NOx<1 tpd and $1,424 for NOx>1 tpd		This control is the reduction of NOx emission through selective non-catalytic reduction add-on controls. SNCR controls are post-combustion control technologies based on the chemical reduction of nitrogen oxides (NOx) into molecular nitrogen (N2) and water vapor (H2O). This control applies to coal IC boilers with uncontrolled NOx emissions greater than 10 tons per year.	EPA 2003b, Pechan 2006
NonEGU Point	Industrial/ Commercial/ Institutional Boilers - Coal or Petroleum Coke	Low NOx Burner	50	Cost effectiveness varies by boiler size. - 50 MMBTU/hr: $3,140 - $12,187. - 100 MMBTU/hr: $1,526 - $6,093. - 250 MMBTU/hr: $610 - $2,435. - 750 MMBTU/hr: $202 - 812		This control is the use of low NOx burner (LNB) technology to reduce NOx emissions. LNBs reduce the amount of NOx created from reaction between fuel nitrogen and oxygen by lowering the temperature of one combustion zone and reducing the amount of oxygen available in another. This control is applicable to coal/wall fired ICI boilers and Petroleum coke fired ICI boilers with uncontrolled NOx emissions greater than 10 tons per year. Cost estimates are from the OTC / LADCO Workgroup (OTC / LADCO Control Cost Subgroup), for a single burner (for a 66% capacity factor at 8760 hours/year), and are based on a methodology similar to EPA's methodology provided in the EPA document "Alternative Control Techniques Document – NOx Emissions from Industrial/Commercial/Institutional (ICI) Boilers".	EPA 2006b, Pechan 2001, EPA 1998e, EPA 2002a, EPA 1994g, OTC/LADCO 2010
NonEGU Point	Industrial/ Commercial/ Institutional Boilers - Coal or Petroleum Coke - Wall Fired	Selective Non-Catalytic Reduction	40	Cost effectiveness varies by boiler size. - 50 MMBTU/hr: $7,052 - $9,712. - 100 MMBTU/hr: $4,167 - $5,497. - 250 MMBTU/hr: $2,426 - $2,964. - 750 MMBTU/hr: $1,653 - 1,820		This control is the reduction of NOx emission through selective non-catalytic reduction add-on controls to wall fired (coal) IC boilers. SNCR controls are post-combustion control technologies based on the chemical reduction of nitrogen oxides (NOx) into molecular nitrogen (N2) and water vapor (H2O). This control applies to coal-fired and petroleum coke-fired IC boilers with uncontrolled NOx emissions greater than 10 tons per year. Cost estimates are from the OTC / LADCO Workgroup (OTC / LADCO Control Cost Subgroup), for a single burner (for a 66% capacity factor at 8760 hours/year), and are based on a methodology similar to EPA's methodology provided in the EPA document "Alternative Control Techniques Document – NOx Emissions from Industrial/Commercial/Institutional (ICI) Boilers".	EPA 2006b, Pechan 2001, EPA 1998e, EPA 2002a, EPA 1994g, OTC/LADCO 2010
NonEGU Point	Industrial/ Commercial/ Institutional Boilers - Coal/ Bituminous	Low NOx Burner and Over Fire Air	51	$1,373 for NOx<1 tpd and $434 for NOx>1 tpd		This control is the use of low NOx burner (LNB) technology and Over Fire Air (OFA) to reduce NOx emissions. LNBs reduce the amount of NOx created from reaction between fuel nitrogen and oxygen by lowering the temperature of one combustion zone and reducing the amount of oxygen available in another. This control applies to bituminous coal Industrial/Commercial/Institutional (ICI) boilers.	EPA 2003b, Pechan 2006
NonEGU Point	Industrial/ Commercial/ Institutional Boilers - Coal/ Subbituminous	Low NOx Burner	51	Cost effectiveness varies by boiler size. - 50 MMBTU/hr: $3,140 - $12,187. - 100 MMBTU/hr: $1,526 - $6,093. - 250 MMBTU/hr: $610 - $2,435. - 750 MMBTU/hr: $202 - 812		This control is the use of low NOx burner (LNB) technology to reduce NOx emissions. LNBs reduce the amount of NOx created from reaction between fuel nitrogen and oxygen by lowering the temperature of one combustion zone and reducing the amount of oxygen available in another. This control is applicable to subbituminous coal industrial/commerial/institutional boilers. Cost estimates are from the OTC / LADCO Workgroup (OTC / LADCO Control Cost Subgroup), for a single burner (for a 66% capacity factor at 8760 hours/year), and are based on a methodology similar to EPA's methodology provided in the EPA document "Alternative Control Techniques Document – NOx Emissions from Industrial/Commercial/Institutional (ICI) Boilers".	EPA 2003b, Pechan 2006, OTC/LADCO 2010
NonEGU Point	Industrial/ Commercial/ Institutional Boilers - Coal/ Cyclone	Coal Reburn	50	$2,520 for NOx<1 tpd and $481 for NOx>1 tpd		This control reduces NOx emissions through coal reburn. This control is applicable to coal/cyclone ICI boilers.	EPA 2006b, Pechan 2001, EPA 1998e, EPA 1994g, Cadmus 1995

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NonEGU Point	Industrial/ Commercial/ Institutional Boilers - Coal/ Cyclone	Natural Gas Reburn	55	$2,520 for NOx<1 tpd and $481 for NOx>1 tpd		Natural gas reburning (NGR) involves add-on controls to reduce NOx emissions. NGR is a combustion control technology in which part of the main fuel heat input is diverted to locations above the main burners, called the reburn zone. As flue gas passes through the reburn zone, a portion of the NOx formed in the main combustion zone is reduced by hydrocarbon radicals and converted to molecular nitrogen (N2). This control applies to coal/cyclone ICI boilers with uncontrolled NOx emissions greater than 10 tons per year.	EPA 2006b, Pechan 2001, EPA 1998e, EPA 2002a, ERG 2000, EPA 1994g
NonEGU Point	Industrial/ Commercial/ Institutional Boilers - Coal/ Cyclone	Selective Catalytic Reduction	90	Cost effectiveness is variable and based on plant size & heat rate: total capital cost of $145.61/kW for 1000MW & 9,000Btu/kWh to $255.57/kW for 100MW & 11,000Btu/kWh; fixed O&M costs of $0.40 per kW per year for 1000MW to $2.48 per kW per year for 100MW (do not depend on heat rate); variable O&M costs of $1.14 mills per kWh for 9,000Btu/kWh to 1.32 mills per kWh for 11,000Btu/kWh.		This control is the selective catalytic reduction of NOx through add-on controls. SCR controls are post-combustion control technologies based on the chemical reduction of nitrogen oxides (NOx) into molecular nitrogen (N2) and water vapor (H2O). The SCR utilizes a catalyst to increase the NOx removal efficiency, which allows the process to occur at lower temperatures. This control applies to coal/cyclone ICI boilers with nameplate capacity greater than 25 MW.	EPA 2006b, Pechan 2001, EPA 1998e, EPA 2002a, EPA 1994g, EPA 2010a
NonEGU Point	Industrial/ Commercial/ Institutional Boilers - Coal/ Cyclone	Selective Non-Catalytic Reduction	35	$1,348 for NOx<1 tpd and $1,123 for NOx>1 tpd		This control is the reduction of NOx emission through selective non-catalytic reduction add-on controls. SNCR controls are post-combustion control technologies based on the chemical reduction of nitrogen oxides (NOx) into molecular nitrogen (N2) and water vapor (H2O). This control applies to coal/cyclone IC boilers with uncontrolled NOx emissions greater than 10 tons per year.	EPA 2006b, Pechan 2001, EPA 1998e, EPA 2002a, EPA 1994g
NonEGU Point	Industrial/ Commercial/ Institutional Boilers - Coal/ Fluidized Bed Combustion	Selective Catalytic Reduction	90	$1,397		This control is the selective catalytic reduction of NOx through add-on controls. SCR controls are post-combustion control technologies based on the chemical reduction of nitrogen oxides (NOx) into molecular nitrogen (N2) and water vapor (H2O). The SCR utilizes a catalyst to increase the NOx removal efficiency, which allows the process to occur at lower temperatures. This control applies to fluidized bed combustion coal ICI boilers.	EPA 2007b
NonEGU Point	Industrial/ Commercial/ Institutional Boilers - Coal/ Fluidized Bed Combustion	Selective Non-Catalytic Reduction - Urea	75	$1,444 for NOx<1 tpd and $1,075 for NOx>1 tpd		This control is the reduction of NOx emission through urea based selective non-catalytic reduction add-on controls. SNCR controls are post-combustion control technologies based on the chemical reduction of nitrogen oxides (NOx) into molecular nitrogen (N2) and water vapor (H2O). This control applies to coal-fired/fluidized bed combustion IC boilers with uncontrolled NOx emissions greater than 10 tons per year.	EPA 2006b, Pechan 2001, EPA 1998e, EPA 2002a, EPA 1994g
NonEGU Point	Industrial/ Commercial/ Institutional Boilers - Coal/ Stoker	Selective Catalytic Reduction	90	$3,051		This control is the selective catalytic reduction of NOx through add-on controls. SCR controls are post-combustion control technologies based on the chemical reduction of nitrogen oxides (NOx) into molecular nitrogen (N2) and water vapor (H2O). The SCR utilizes a catalyst to increase the NOx removal efficiency, which allows the process to occur at lower temperatures. This control applies to coal/stoker IC boilers with uncontrolled NOx emissions greater than 10 tons per year.	EPA 2007b
NonEGU Point	Industrial/ Commercial/ Institutional Boilers - Coal/ Stoker	Selective Non-Catalytic Reduction	40	$1,629 for NOx<1 tpd and $1,311 for NOx>1 tpd		This control is the reduction of NOx emission through selective non-catalytic reduction add-on controls to coal/stoker IC boilers. SNCR controls are post-combustion control technologies based on the chemical reduction of nitrogen oxides (NOx) into molecular nitrogen (N2) and water vapor (H2O). This control applies to coal/stoker IC boilers with uncontrolled NOx emissions greater than 10 tons per year.	EPA 2006b, Pechan 2001, EPA 1998e, EPA 2002a, EPA 1994g
NonEGU Point	Industrial/ Commercial/ Institutional Boilers - Coal/ Subbituminous	Low NOx Burner and Over Fire Air	65	$1,077 for NOx<1 tpd and $339 for NOx>1 tpd		This control is the use of low NOx burner (LNB) technology and Over Fire Air (OFA) to reduce NOx emissions. LNBs reduce the amount of NOx created from reaction between fuel nitrogen and oxygen by lowering the temperature of one combustion zone and reducing the amount of oxygen available in another. This control applies to subbituminous coal Industrial/Commercial/Institutional (ICI) boilers.	EPA 2003b, Pechan 2006

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NonEGU Point	Industrial/ Commercial/ Institutional Boilers - Coal/ Wall	Selective Catalytic Reduction	90	Cost effectiveness is variable and based on plant size & heat rate: total capital cost of $145.61/kW for 1000MW & 9,000Btu/kWh to $255.57/kW for 100MW & 11,000Btu/kWh; fixed O&M costs of $0.40 per kW per year for 1000MW to $2.48 per kW per year for 100MW (do not depend on heat rate); variable O&M costs of $1.14 mills per kWh for 9,000Btu/kWh to 1.32 mills per kWh for 11,000Btu/kWh.		This control is the selective catalytic reduction of NOx through add-on controls. SCR controls are post-combustion control technologies based on the chemical reduction of nitrogen oxides (NOx) into molecular nitrogen (N2) and water vapor (H2O). The SCR utilizes a catalyst to increase the NOx removal efficiency, which allows the process to occur at lower temperatures.This control applies to coal/wall IC boilers with nameplate capacity greater than 25 MW.	EPA 2006b, Pechan 2001, EPA 1998e, EPA 2002a, EPA 1994g, EPA 2010a
NonEGU Point	Industrial/ Commercial/ Institutional Boilers - Distillate Oil	Selective Catalytic Reduction	80	Cost effectiveness is variable and based on plant size. For a 25MW plant, capital costs are $74.29 per kW, fixed O&M costs are $1.07 per kW per year. Variable O&M costs are 0.12 mills per kWh (do not depend on plant size). Scaling factor for plants between 25MW and 500MW (Capital Cost and Fixed O&M only) = (200/capacity)^(0.35). After 500MW, costs		This control is the selective catalytic reduction of NOx through add-on controls. SCR controls are post-combustion control technologies based on the chemical reduction of nitrogen oxides (NOx) into molecular nitrogen (N2) and water vapor (H2O). The SCR utilizes a catalyst to increase the NOx removal efficiency, which allows the process to occur at lower temperatures. This control applies to distillate oil-fired ICI boilers with nameplate capacity greater than 25 MW.	EPA 2006b, EPA 1998e, EPA 2002a, EPA 2007d, Sorrels 2007, EPA 2010a
NonEGU Point	Industrial/ Commercial/ Institutional Boilers - Distillate Oil or LPG	Low NOx Burner	50	Cost effectiveness varies by boiler size. - 50 MMBTU/hr: $10,661 - $42,644. - 100 MMBTU/hr: $5,340 - $21,322. - 250 MMBTU/hr: $2,142 - $8,529. - 750 MMBTU/hr: $203 - 812		This control is the use of low NOx burner (LNB) technology to reduce NOx emissions. LNBs reduce the amount of NOx created from reaction between fuel nitrogen and oxygen by lowering the temperature of one combustion zone and reducing the amount of oxygen available in another. This control is applicable to Oil and LPG ICI boilers with uncontrolled NOx emissions greater than 10 tons per year. Cost estimates are from the OTC / LADCO Workgroup (OTC / LADCO Control Cost Subgroup), for a single burner (for a 66% capacity factor at 8760 hours/year), and are based on a methodology similar to EPA's methodology provided in the EPA document "Alternative Control Techniques Document – NOx Emissions from Industrial/Commercial/Institutional (ICI) Boilers".	EPA 2006b, Pechan 2001, EPA 1998e, EPA 2002a, EPA 1994g, OTC/LADCO 2010
NonEGU Point	Industrial/ Commercial/ Institutional Boilers - Distillate Oil or LPG	Low NOx Burner and Flue Gas Recirculation	60	$3,996 for NOx<1 tpd and $1,220 for NOx>1 tpd		This control is the use of low NOx burner (LNB) technology and flue gas recirculation (FGR) to reduce NOx emissions. LNBs reduce the amount of NOx created from reaction between fuel nitrogen and oxygen by lowering the temperature of one combustion zone and reducing the amount of oxygen available in another. This control is applicable to distillate oil-fired ICI boilers and LPG-fired ICI Boilers with uncontrolled NOx emissions greater than 10 tons per year.	EPA 2006b, Pechan 2001, EPA 1998e, EPA 2002a, EPA 1993c
NonEGU Point	Industrial/ Commercial/ Institutional Boilers - Distillate Oil or LPG	Selective Non-Catalytic Reduction	50	$7,447 for NOx<1 tpd and $3,033 for NOx>1 tpd		This control is the reduction of NOx emission through selective non-catalytic reduction add-on controls. SNCR controls are post-combustion control technologies based on the chemical reduction of nitrogen oxides (NOx) into molecular nitrogen (N2) and water vapor (H2O). This control applies to distillate oil and LPG-fired IC boilers with uncontrolled NOx emissions greater than 10 tons per year.	EPA 2006b, Pechan 2001, EPA 1998e, EPA 2002a, EPA 1994g
NonEGU Point	Industrial/ Commercial/ Institutional Boilers - Gas	Low NOx Burner and Flue Gas Recirculation + Over Fire Air	80	$1,416 for NOx<1 tpd and $408 for NOx>1 tpd		This control is the use of low NOx burner (LNB) technology , flue gas recirculation (FGR), and over fire air (OFA) to reduce NOx emissions. LNBs reduce the amount of NOx created from reaction between fuel nitrogen and oxygen by lowering the temperature of one combustion zone and reducing the amount of oxygen available in another. This control applies to gas Industrial/Commercial/Institutional (ICI) boilers.	EPA 2003b, EPA 1998e

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Sector	Source Category	Emission Reduction Measure Name	Control Efficiency (%)*	Cost Effectiveness (2006$/ton reduced)	Other pollutants controlled	Description/Notes/Caveats	References
NonEGU Point	Industrial/ Commercial/ Institutional Boilers - Gas	Low NOx Burner and Over Fire Air	60	$1,166 for NOx<1 tpd and $310 for NOx>1 tpd		This control is the use of low NOx burner (LNB) technology and Over Fire Air (OFA) to reduce NOx emissions. LNBs reduce the amount of NOx created from reaction between fuel nitrogen and oxygen by lowering the temperature of one combustion zone and reducing the amount of oxygen available in another. This control applies to gas Industrial/Commercial/Institutional (ICI) boilers.	EPA 2003b, Pechan 2006
NonEGU Point	Industrial/ Commercial/ Institutional Boilers - Gas	Selective Catalytic Reduction	80	$3,250 for NOx<1 tpd and $1,093 for NOx>1 tpd		This control is the selective catalytic reduction of NOx through add-on controls. SCR controls are post-combustion control technologies based on the chemical reduction of nitrogen oxides (NOx) into molecular nitrogen (N2) and water vapor (H2O). The SCR utilizes a catalyst to increase the NOx removal efficiency, which allows the process to occur at lower temperatures. This control applies to gas-fired ICI boilers with uncontrolled NOx emissions greater than 10 tons per year.	EPA 2003b, EPA 1998e
NonEGU Point	Industrial/ Commercial/ Institutional Boilers - Gas	Selective Non-Catalytic Reduction	40	$1,166 for NOx<1 tpd and $310 for NOx>1 tpd		This control is the reduction of NOx emission through selective non-catalytic reduction add-on controls. SNCR controls are post-combustion control technologies based on the chemical reduction of nitrogen oxides (NOx) into molecular nitrogen (N2) and water vapor (H2O). This control applies to natural gas fired IC boilers with uncontrolled NOx emissions greater than 10 tons per year.	EPA 2003b, Pechan 2006
NonEGU Point	Industrial/ Commercial/ Institutional Boilers - Liquid Waste	Selective Catalytic Reduction	90	$1,890		This control is the selective catalytic reduction of NOx through add-on controls. SCR controls are post-combustion control technologies based on the chemical reduction of nitrogen oxides (NOx) into molecular nitrogen (N2) and water vapor (H2O). The SCR utilizes a catalyst to increase the NOx removal efficiency, which allows the process to occur at lower temperatures. This control applies to liquid waste ICI boilers with NOx emissions greater than 10 tons per year.	EPA 2007b
NonEGU Point	Industrial/ Commercial/ Institutional Boilers - LPG	Selective Catalytic Reduction	90	$4,747		This control is the selective catalytic reduction of NOx through add-on controls. SCR controls are post-combustion control technologies based on the chemical reduction of nitrogen oxides (NOx) into molecular nitrogen (N2) and water vapor (H2O). The SCR utilizes a catalyst to increase the NOx removal efficiency, which allows the process to occur at lower temperatures. This control applies to LPG ICI boilers with NOx emissions greater than 10 tons per year.	EPA 2007b
NonEGU Point	Industrial/ Commercial/ Institutional Boilers - Municipal Solid Waste/ Stoker	Selective Non-Catalytic Reduction - Urea	55	$2,712 for NOx<1 tpd and $2,006 for NOx>1 tpd		This control is the reduction of NOx emission through urea based selective non-catalytic reduction add-on controls. SNCR controls are post-combustion control technologies based on the chemical reduction of nitrogen oxides (NOx) into molecular nitrogen (N2) and water vapor (H2O). This control applies to solid waste/stoker IC boilers with uncontrolled NOx emissions greater than 10 tons per year.	EPA 2006b, Pechan 2001, EPA 1998e, EPA 2002a, EPA 1994g
NonEGU Point	Industrial/ Commercial/ Institutional Boilers - Natural Gas	Selective Non-Catalytic Reduction	50	$6,211 for NOx<1 tpd and $2,520 for NOx>1 tpd		This control is the reduction of NOx emission through selective non-catalytic reduction add-on controls. SNCR controls are post-combustion control technologies based on the chemical reduction of nitrogen oxides (NOx) into molecular nitrogen (N2) and water vapor (H2O). This control applies to natural gas fired IC boilers with uncontrolled NOx emissions greater than 10 tons per year.	EPA 2006b
NonEGU Point	Industrial/ Commercial/ Institutional Boilers - Natural Gas or Process Gas	Low NOx Burner	50	Cost effectiveness varies by boiler size. - 50 MMBTU/hr: $10,661 - $42,644. - 100 MMBTU/hr: $5,340 - $21,322. - 250 MMBTU/hr: $2,142 - $8,529. - 750 MMBTU/hr: $203 - 813		This control is the use of low NOx burner (LNB) technology to reduce NOx emissions. LNBs reduce the amount of NOx created from reaction between fuel nitrogen and oxygen by lowering the temperature of one combustion zone and reducing the amount of oxygen available in another. This control is applicable to natural gas and process gas fired ICI boilers with uncontrolled NOx emissions greater than 10 tons per year. Cost estimates are from the OTC / LADCO Workgroup (OTC / LADCO Control Cost Subgroup), for a single burner (for a 66% capacity factor at 8760 hours/year), and are based on a methodology similar to EPA's methodology provided in the EPA document "Alternative Control Techniques Document – NOx Emissions from Industrial/Commercial/Institutional (ICI) Boilers".	EPA 2006b, Pechan 2001, EPA 1998e, EPA 2002a, EPA 1994g, OTC/LADCO 2010
NonEGU Point	Industrial/ Commercial/ Institutional Boilers - Natural Gas or Process Gas	Low NOx Burner and Flue Gas Recirculation	60	$4,109 for NOx<1 tpd and $947 for NOx>1 tpd		This control is the use of low NOx burner (LNB) technology and flue gas recirculation (FGR) to reduce NOx emissions. LNBs reduce the amount of NOx created from reaction between fuel nitrogen and oxygen by lowering the temperature of one combustion zone and reducing the amount of oxygen available in another. This control is applicable to natural gas-fired and process gas-fired ICI boilers with uncontrolled NOx emissions greater than 10 tons per year.	EPA 2006b, Pechan 2001, EPA 1998e, EPA 2002a, EPA 1993c
NonEGU Point	Industrial/ Commercial/ Institutional Boilers - Natural Gas or Process Gas	Oxygen Trim and Water Injection	65	$1,091 for NOx<1 tpd and $514 for NOx>1 tpd		This control is the use of Oxygen Trim and Water Injection to reduce NOx emissions. Water is injected into the gas turbine, reducing the temperatures in the NOx-forming regions. The water can be injected into the fuel, the combustion air or directly into the combustion chamber. This control applies to natural gas-fired and process gas-fired ICI boilers with uncontrolled NOx emissions greater than 10 tons per year.	EPA 2006b, Pechan 2001, EPA 1998e, EPA 2002a, ERG 2000, EPA 1994g

Sector	Source Category	Emission Reduction Measure Name	Control Efficiency (%)*	Cost Effectiveness (2006$/ton reduced)	Other pollutants controlled	Description/Notes/Caveats	References
NonEGU Point	Industrial/ Commercial/ Institutional Boilers - Natural Gas or Process Gas	Selective Catalytic Reduction	80	Cost effectiveness is variable and based on plant size. For a 25MW plant, capital costs are $74.29 per kW, fixed O&M costs are $1.07 per kW per year. Variable O&M costs are 0.12 mills per kWh (do not depend on plant size). Scaling factor for plants between 25MW and 500MW (Capital Cost and Fixed O&M only) = (200/capacity)^(0.35). After 500MW, costs		This control is the selective catalytic reduction of NOx through add-on controls. SCR controls are post-combustion control technologies based on the chemical reduction of nitrogen oxides (NOx) into molecular nitrogen (N2) and water vapor (H2O). The SCR utilizes a catalyst to increase the NOx removal efficiency, which allows the process to occur at lower temperatures. This control applies to natural gas fired and process gas-fired ICI boilers nameplate capacity greater than 25 MW.	EPA 2006b, EPA 1998e, EPA 2002a, EPA 2007d, Sorrels 2007, EPA 2010a
NonEGU Point	Industrial/ Commercial/ Institutional Boilers - Oil	Low NOx Burner and Over Fire Air	50	$1,166 for NOx<1 tpd and $339 for NOx>1 tpd		This control is the use of low NOx burner (LNB) technology and Over Fire Air (OFA) to reduce NOx emissions. LNBs reduce the amount of NOx created from reaction between fuel nitrogen and oxygen by lowering the temperature of one combustion zone and reducing the amount of oxygen available in another. This control applies to oil Industrial/Commercial/Institutional (ICI) boilers.	EPA 2003b, Pechan 2006
NonEGU Point	Industrial/ Commercial/ Institutional Boilers - Oil	Selective Catalytic Reduction	80	$2,232 for NOx<1 tpd and $842 for NOx>1 tpd		This control is the selective catalytic reduction of NOx through add-on controls. SCR controls are post-combustion control technologies based on the chemical reduction of nitrogen oxides (NOx) into molecular nitrogen (N2) and water vapor (H2O). The SCR utilizes a catalyst to increase the NOx removal efficiency, which allows the process to occur at lower temperatures. This control applies to oil-fired ICI boilers with uncontrolled NOx emissions greater than 10 tons per year.	EPA 2003b, EPA 1998e
NonEGU Point	Industrial/ Commercial/ Institutional Boilers - Oil	Selective Non-Catalytic Reduction	40	$2,623 for NOx<1 tpd and $1,646 for NOx>1 tpd		This control is the reduction of NOx emission through selective non-catalytic reduction add-on controls. SNCR controls are post-combustion control technologies based on the chemical reduction of nitrogen oxides (NOx) into molecular nitrogen (N2) and water vapor (H2O). This control applies to oil IC boilers with uncontrolled NOx emissions greater than 10 tons per year.	EPA 2003b, Pechan 2006
NonEGU Point	Industrial/ Commercial/ Institutional Boilers - Petroleum Coke	Selective Catalytic Reduction	90	$1,941		This control is the selective catalytic reduction of NOx through add-on controls. SCR controls are post-combustion control technologies based on the chemical reduction of nitrogen oxides (NOx) into molecular nitrogen (N2) and water vapor (H2O). The SCR utilizes a catalyst to increase the NOx removal efficiency, which allows the process to occur at lower temperatures. This control applies to coke ICI boilers with NOx emissions greater than 10 tons per year.	EPA 2007b
NonEGU Point	Industrial/ Commercial/ Institutional Boilers - Residual Oil or Liquid Waste	Low NOx Burner	50	Cost effectiveness varies by boiler size. - 50 MMBTU/hr: $5,340 - $21,322. - 100 MMBTU/hr: $2,670 - $10,661. - 250 MMBTU/hr: $1,066 - $4,264. - 750 MMBTU/hr: $356 - $1,418		This control is the use of low NOx burner (LNB) technology to reduce NOx emissions. LNBs reduce the amount of NOx created from reaction between fuel nitrogen and oxygen by lowering the temperature of one combustion zone and reducing the amount of oxygen available in another. This control is applicable to residual oil-fired ICI boilers and liquid waste fired ICI boilers with uncontrolled NOx emissions greater than 10 tons per year. Cost estimates are from the OTC / LADCO Workgroup (OTC / LADCO Control Cost Subgroup), for a single burner (for a 66% capacity factor at 8760 hours/year), and are based on a methodology similar to EPA's methodology provided in the EPA document "Alternative Control Techniques Document – NOx Emissions from Industrial/Commercial/Institutional (ICI) Boilers".	EPA 2006b, Pechan 2001, EPA 1998e, EPA 2002a, EPA 1994g, OTC/LADCO 2010
NonEGU Point	Industrial/ Commercial/ Institutional Boilers - Residual Oil or Liquid Waste	Low NOx Burner and Flue Gas Recirculation	60	$1,798 for NOx<1 tpd and $626 for NOx>1 tpd		This control is the use of low NOx burner (LNB) technology and flue gas recirculation (FGR) to reduce NOx emissions. LNBs reduce the amount of NOx created from reaction between fuel nitrogen and oxygen by lowering the temperature of one combustion zone and reducing the amount of oxygen available in another. This control is applicable to residual oil-fired and liquid waste-fired ICI boilers with uncontrolled NOx emissions greater than 10 tons per year.	EPA 2006b, Pechan 2001, EPA 1998e, EPA 2002a, EPA 1993c
NonEGU Point	Industrial/ Commercial/ Institutional Boilers - Residual Oil or Liquid Waste	Selective Non-Catalytic Reduction	50	$4,141 for NOx<1 tpd and $1,685 for NOx>1 tpd		This control is the reduction of NOx emission through selective non-catalytic reduction add-on controls. SNCR controls are post-combustion control technologies based on the chemical reduction of nitrogen oxides (NOx) into molecular nitrogen (N2) and water vapor (H2O). This control applies to residual oil and liquid waste-fired IC boilers with uncontrolled NOx emissions greater than 10 tons per year.	EPA 2006b, Pechan 2001, EPA 1998e, EPA 2002a, EPA 1994g
NonEGU Point	Industrial/ Commercial/ Institutional Boilers - Wood/ Bark/ Fluidized Bed Combustion	Selective Non-Catalytic Reduction - Ammonia	55	$2,119 for NOx<1 tpd and $1,541 for NOx>1 tpd		This control is the reduction of NOx emission through selective non-catalytic reduction add-on controls. SNCR controls are post-combustion control technologies based on the chemical reduction of nitrogen oxides (NOx) into molecular nitrogen (N2) and water vapor (H2O). This control applies to wood fired IC boilers with uncontrolled NOx emissions greater than 10 tons per year.	EPA 2006b
NonEGU Point	Industrial/ Commercial/ Institutional Boilers - Wood/ Bark/ Stoker	Selective Non-Catalytic Reduction - Urea	55	$2,311 for NOx<1 tpd and $1,493 for NOx>1 tpd		This control is the reduction of NOx emission through urea based selective non-catalytic reduction add-on controls. SNCR controls are post-combustion control technologies based on the chemical reduction of nitrogen oxides (NOx) into molecular nitrogen (N2) and water vapor (H2O). This control applies to wood/bark fired IC boilers with uncontrolled NOx emissions greater than 10 tons per year.	EPA 2006b, Pechan 2001, EPA 1998e, EPA 2002a, EPA 1994g

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NonEGU Point	Industrial/ Commercial/ Institutional Boilers - Wood/ Bark/ Waste	Regenerative Selective Catalytic Reduction	75	$4,500	CO - 50%.	This control is the regenerative selective catalytic reduction of NOx through add-on controls. The RSCR control is a post-combustion control technology that combines a regenerative thermal oxidizer (RTO) (e.g., retention chamber burner) with conventional SCR technology (either anhydrous or aqueous ammonia can be used). The primary application of an RSCR system is the reduction of NOx emissions especially for tail-end, low temperature applications (where the flue gas is typically at 300-400°F). This control applies to industrial/commercial/institutional boilers fired with wood bark or waste.	NESCAUM 2008, WPA 2008
NonEGU Point	Industrial/ Commercial/ Institutional Boilers - Wood/ Bark/ Waste	Selective Catalytic Reduction	90	$3,946		This control is the selective catalytic reduction of NOx through add-on controls. SCR controls are post-combustion control technologies based on the chemical reduction of nitrogen oxides (NOx) into molecular nitrogen (N2) and water vapor (H2O). The SCR utilizes a catalyst to increase the NOx removal efficiency, which allows the process to occur at lower temperatures. This control applies to industrial/commercial/institutional boilers fired with wood bark or waste.	EPA 2007b
NonEGU Point	In-Process - Bituminous Coal - Cement Kilns or Lime Kilns	Selective Catalytic Reduction	90	$2,554		This control is the selective catalytic reduction of NOx through add-on controls. SCR controls are post-combustion control technologies based on the chemical reduction of nitrogen oxides (NOx) into molecular nitrogen (N2) and water vapor (H2O). The SCR utilizes a catalyst to increase the NOx removal efficiency, which allows the process to occur at lower temperatures. This control applies to bituminous coal-fired cement kilns and coal-fired lime kilns with uncontrolled NOx emissions greater than 10 tons per year.	EPA 2007b
NonEGU Point	In-Process - Bituminous Coal - Cement Kilns or Lime Kilns	Selective Non-Catalytic Reduction - Urea	50	$928		This control is the reduction of NOx emission through selective non-catalytic reduction add-on controls. SNCR controls are post-combustion control technologies based on the chemical reduction of nitrogen oxides (NOx) into molecular nitrogen (N2) and water vapor (H2O). This control applies to bituminous coal-fired cement kilns and lime kilns with uncontrolled NOx emissions greater than 10 tons per year.	EPA 2006b, Pechan 2001, EPA 1998e, EPA 2002a, EPA 1994h
NonEGU Point	In-Process - Process Gas - Coke Oven Gas	Selective Catalytic Reduction	90	$7,679		This control is the selective catalytic reduction of NOx through add-on controls. SCR controls are post-combustion control technologies based on the chemical reduction of nitrogen oxides (NOx) into molecular nitrogen (N2) and water vapor (H2O). The SCR utilizes a catalyst to increase the NOx removal efficiency, which allows the process to occur at lower temperatures. This control applies to process gas fired ICI boilers with NOx emissions greater than 10 tons per year.	EPA 2007b
NonEGU Point	In-Process - Process Gas - Coke Oven Gas	Selective Catalytic Reduction	90	$5,970		Application: This control is the selective catalytic reduction of NOx through add-on controls. SCR controls are post-combustion control technologies based on the chemical reduction of nitrogen oxides (NOx) into molecular nitrogen (N2) and water vapor (H2O). The SCR utilizes a catalyst to increase the NOx removal efficiency, which allows the process to occur at lower temperatures. This control is applicable to operations with in-process process gas usage from Coke Oven Gas.	EPA 2007b
NonEGU Point	In-Process -Process Gas -Coke Oven/ Blast Furnace	Low NOx Burner and Flue Gas Recirculation	55	$5,120 for NOx<1 tpd and $3,964 for NOx>1 tpd		This control is the use of low NOx burner (LNB) technology and flue gas recirculation (FGR) to reduce NOx emissions. LNBs reduce the amount of NOx created from reaction between fuel nitrogen and oxygen by lowering the temperature of one combustion zone and reducing the amount of oxygen available in another. This control is applicable to in-process coke/blast furnaces and uncontrolled NOx emissions greater than 10 tons per year.	EPA 2006b, Pechan 2001, EPA 1998e, EPA 2002a, EPA 1993c
NonEGU Point	Internal Combustion Engines - Gasoline	Adjust Air to Fuel Ratio	20	$2,520 for NOx<1 tpd and $610 for NOx>1 tpd		This control is the use of air/fuel ratio adjustment to reduce NOx emissions. This control applies to gasoline powered internal combustion engines with uncontrolled NOx emissions greater than 10 tons per year.	EPA 2006b, EPA 1993a, EPA 1998e, Pechan 2001
NonEGU Point	Internal Combustion Engines - Gasoline	Adjust Air to Fuel Ratio and Ignition Retard	30	$2,311 for NOx<1 tpd and $738 for NOx>1 tpd		This control is the use of air/fuel and ignition retard to reduce NOx emissions. This control applies to gasoline powered internal combustion engines with uncontrolled NOx emissions greater than 10 tons per year.	EPA 2006b, Pechan 2006
NonEGU Point	Internal Combustion Engines - Gasoline	Ignition Retard	20	$1,637 for NOx<1 tpd and $883 for NOx>1 tpd		This applies to gasoline powered IC engines with uncontrolled NOx emissions greater than 10 tons per year.	EPA 2006b, EPA 1993a, Pechan 2001, EPA 1998e
NonEGU Point	Internal Combustion Engines - Gasoline, Diesel, LPG	Non-Selective Catalytic Reduction	90	$412	VOC - 50%, CO - 90%	This control is the application of Non-Selective Catalytic Reduction (NSCR) to reduce NOx emissions. NSCR is achieved by placing a catalyst in the exhaust stream of the engine. The exhaust passes over the catalyst, usually a noble metal (platinum, rhodium or palladium) which reduces the reactants to N2, CO2 and H20. NSCR is also referred to as three-way catalyst because it simultaneously reduces NOx, CO, and HC to water, CO2, and N2. This control applies to Gas-fired, Diesel-fired, and LPG-fired Rich Burn Internal Combustion Engines. Note that the RICE MACT will already require NSCR for engines above 500 hp	EPA 2006b, EPA 1986, EPA 1993a, LADCO 2006a, NJDEP 2003, Pechan 2000
NonEGU Point	Internal Combustion Engines - Gasoline, Diesel, Oil, LPG	Ignition Retard	25	$1,NJDEP 2003 for NOx<1 tpd and $786 for NOx>1 tpd		This control is the use of ignition retard technologies to reduce NOx emissions. This applies to Gasoline, LPG, Diesel, and oil IC engines with NOx emissions greater than 10 tons per year.	EPA 2006b, EPA 1993a, Pechan 2001, EPA 1998e
NonEGU Point	Internal Combustion Engines - Gasoline, Diesel, Oil, LPG	Selective Catalytic Reduction	80	$3,756 for NOx<1 tpd and $1,477 for NOx>1 tpd		This control is the selective catalytic reduction of NOx through add-on controls. SCR controls are post-combustion control technologies based on the chemical reduction of nitrogen oxides (NOx) into molecular nitrogen (N2) and water vapor (H2O). The SCR utilizes a catalyst to increase the NOx removal efficiency, which allows the process to occur at lower temperatures. This control applies to gasoline, diesel, oil and LPG-fired IC engines with uncontrolled NOx emissions greater than 10 tons per year.	EPA 2006b, EPA 1993a, Pechan 2001, EPA 1998e, EPA 2002a
NonEGU Point	Internal Combustion Engines - Natural Gas	Low Emissions Combustion (Low Speed)	87	$2,696 for NOx<1 tpd and $1,011 for NOx>1 tpd		This control is the application of Low Emissions (Low Speed) technology to reduce NOx emissions. This control applies to natural gas powered IC engines with uncontrolled NOx emissions greater than 10 tons per year. The low emissions combustion modification reduces NOx by increasing the Air-to-Fuel ratio through extensive retrofit of the engines and ancillary system. This allows the engine to operate at very lean A/F ratios, which lead to low amounts of NOx formation.	EPA 2006b, EPA 1993a, Pechan 2001, EPA 1998e

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NonEGU Point	Internal Combustion Engines - Natural Gas	Low Emissions Combustion (Medium Speed)	87	$610		This control is the application of Low Emissions (Medium Speed) technology to reduce NOx emissions.This control applies to natural gas powered IC engines with uncontrolled NOx emissions greater than 10 tons per year. The low emissions combustion modification reduces NOx by increasing the Air-to-Fuel ratio through extensive retrofit of the engines and ancillary system. This allows the engine to operate at very lean A/F ratios, which lead to low amounts of NOx formation.	EPA 2006b, EPA 1993a, Pechan 2001, EPA 1998e
NonEGU Point	Internal Combustion Engines - Natural Gas	Non-Selective Catalytic Reduction	90	$628-$836	VOC - 50%, CO - 90%	NSCR is achieved by placing a catalyst in the exhaust stream of the engine. The exhaust passes over the catalyst, usually a noble metal (platinum, rhodium or palladium) which reduces the reactants to N2, CO2 and H20 (NJDEP, 2003). Typical exhaust temperatures for effective removal of NOx are 800-1200 degrees Fahrenheit. An oxidation catalyst using additional air can be installed downstream of the NSCR catalyst for additional CO and VOC control. This includes 4-cycle naturally aspirated engines and some 4-cycle turbocharged engines. Engines operating with NSCR require air/fuel control to maintain high reduction effectiveness. This control applies to natural gas-fired IC engines with uncontrolled NOx emissions greater than 10 tons per year. Note that the RICE MACT will already require NSCR for engines above 500 hp.	EPA 2006b, EPA 1993a, NJDEP 2003, Pechan 2000
NonEGU Point	Internal Combustion Engines - Natural Gas	Selective Catalytic Reduction	90	$4,444		This control is the selective catalytic reduction of NOx through add-on controls. SCR controls are post-combustion control technologies based on the chemical reduction of nitrogen oxides (NOx) into molecular nitrogen (N2) and water vapor (H2O). The SCR utilizes a catalyst to increase the NOx removal efficiency, which allows the process to occur at lower temperatures. This control applies to natural gas-fired IC engines with uncontrolled NOx emissions greater than 10 tons per year.	EPA 2006b, EPA 1993a, Pechan 2001, EPA 1998e, EPA 2002a
NonEGU Point	Iron & Steel - In-Process Combustion - Bituminous Coal	Selective Catalytic Reduction	90	$3,649		This control is the selective catalytic reduction of NOx through add-on controls. SCR controls are post-combustion control technologies based on the chemical reduction of nitrogen oxides (NOx) into molecular nitrogen (N2) and water vapor (H2O). The SCR utilizes a catalyst to increase the NOx removal efficiency, which allows the process to occur at lower temperatures. This control is applicable to operations with in-process combustion (Bituminous Coal) in the Iron & Steel industry with uncontrolled NOx emissions greater than 10 tons per year.	EPA 2010b
NonEGU Point	Iron & Steel - In-Process Combustion - Natural Gas and Process Gas - Coke Oven Gas	Low NOx Burner	50	$3,531 for NOx<1 tpd and $2,889 for NOx>1 tpd		This control is the use of low NOx burner (LNB) technology to reduce NOx emissions. LNBs reduce the amount of NOx created from reaction between fuel nitrogen and oxygen by lowering the temperature of one combustion zone and reducing the amount of oxygen available in another. This control is applicable to operations with in-process combustion (Natural Gas or Coke Oven Process Gas) in the Iron & Steel industry with uncontrolled NOx emissions greater than 10 tons per year.	EPA 2010b
NonEGU Point	Iron & Steel - In-Process Combustion - Natural Gas and Process Gas - Coke Oven Gas	Selective Catalytic Reduction	90	$5,970		This control is the selective catalytic reduction of NOx through add-on controls. SCR controls are post-combustion control technologies based on the chemical reduction of nitrogen oxides (NOx) into molecular nitrogen (N2) and water vapor (H2O). The SCR utilizes a catalyst to increase the NOx removal efficiency, which allows the process to occur at lower temperatures. This control is applicable to operations with in-process combustion (Natural Gas and Process Gas - Coke Oven Gas) in the Iron & Steel industry.	EPA 2010b
NonEGU Point	Iron & Steel - In-Process Combustion - Process Gas -Coke Oven/ Blast Furnace	Low NOx Burner and Flue Gas Recirculation	55	$5,120 for NOx<1 tpd and $3,964 for NOx>1 tpd		This control is the use of low NOx burner (LNB) technology and flue gas recirculation (FGR) to reduce NOx emissions. LNBs reduce the amount of NOx created from reaction between fuel nitrogen and oxygen by lowering the temperature of one combustion zone and reducing the amount of oxygen available in another. This control is applicable to operations with in-process combustion (Process Gas - Coke Oven/ Blast Furnace) in the Iron & Steel industry with uncontrolled NOx emissions greater than 10 tons per year.	EPA 2010b
NonEGU Point	Iron & Steel - In-Process Combustion - Residual Oil	Selective Catalytic Reduction	90	$5,374		This control is the selective catalytic reduction of NOx through add-on controls. SCR controls are post-combustion control technologies based on the chemical reduction of nitrogen oxides (NOx) into molecular nitrogen (N2) and water vapor (H2O). The SCR utilizes a catalyst to increase the NOx removal efficiency, which allows the process to occur at lower temperatures. This control is applicable to operations with in-process combustion (Residual Oil) in the Iron & Steel industry with uncontrolled NOx emissions greater than 10 tons per year.	EPA 2010b
NonEGU Point	Iron & Steel Mills - Annealing	Low NOx Burner	50	$915		This control is the use of low NOx burner (LNB) technology to reduce NOx emissions. LNBs reduce the amount of NOx created from reaction between fuel nitrogen and oxygen by lowering the temperature of one combustion zone and reducing the amount of oxygen available in another. This control is applicable to iron and steel annealing operations with uncontrolled NOx emissions greater than 10 tons per year.	EPA 2006b, Pechan 2001, EPA 1998e, EPA 2002a, EPA 1994e
NonEGU Point	Iron & Steel Mills - Annealing	Low NOx Burner and Flue Gas Recirculation	60	$1,204		This control is the use of low NOx burner (LNB) technology and flue gas recirculation (FGR) to reduce NOx emissions. LNBs reduce the amount of NOx created from reaction between fuel nitrogen and oxygen by lowering the temperature of one combustion zone and reducing the amount of oxygen available in another. This control is applicable to iron and steel annealing operations with uncontrolled NOx emissions greater than 10 tons per year.	EPA 2006b, Pechan 2001, EPA 1998e, EPA 2002a, EPA 1994e
NonEGU Point	Iron & Steel Mills - Annealing	Low NOx Burner and Selective Catalytic Reduction	90	$6,548		This control is the use of low NOx burner (LNB) technology and selective catalytic reduction (SCR) to reduce NOx emissions. LNBs reduce the amount of NOx created from reaction between fuel nitrogen and oxygen by lowering the temperature of one combustion zone and reducing the amount of oxygen available in another. SCR controls are post-combustion control technologies based on the chemical reduction of nitrogen oxides (NOx) into molecular nitrogen (N2) and water vapor (H2O). The SCR utilizes a catalyst to increase the NOx removal efficiency, which allows the process to occur at lower temperatures. This control is applicable to iron and steel annealing operations with uncontrolled NOx emissions greater than 10 tons per year.	EPA 2006b, Pechan 2001, EPA 1998e, EPA 2002a, EPA 1994e

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NonEGU Point	Iron & Steel Mills - Annealing	Low NOx Burner and Selective Non Catalytic Reduction	80	$2,761		This control is the use of low NOx burner (LNB) technology and selective catalytic reduction (SCR) to reduce NOx emissions. LNBs reduce the amount of NOx created from reaction between fuel nitrogen and oxygen by lowering the temperature of one combustion zone and reducing the amount of oxygen available in another. SCR controls are post-combustion control technologies based on the chemical reduction of nitrogen oxides (NOx) into molecular nitrogen (N2) and water vapor (H2O). The SCR utilizes a catalyst to increase the NOx removal efficiency, which allows the process to occur at lower temperatures. This control is applicable to iron and steel annealing operations with uncontrolled NOx emissions greater than 10 tons per year.	EPA 2006b, Pechan 2001, EPA 1998e, EPA 2002a, EPA 1994e
NonEGU Point	Iron & Steel Mills - Annealing	Selective Catalytic Reduction	90-99	$6,384		This control is the selective catalytic reduction of NOx through add-on controls. SCR controls are post-combustion control technologies based on the chemical reduction of nitrogen oxides (NOx) into molecular nitrogen (N2) and water vapor (H2O). The SCR utilizes a catalyst to increase the NOx removal efficiency, which allows the process to occur at lower temperatures. This control applies to iron and steel annealing operations with NOx emissions greater than 10 tons per year.	EPA 2006b, EPA 1998e, EPA 2002a, EPA 1993c, EPA 2007d, Sorrels 2007
NonEGU Point	Iron & Steel Mills - Annealing	Selective Non Catalytic Reduction	60	$2,632		This control is the reduction of NOx emission through selective non-catalytic reduction add-on controls. SNCR controls are post-combustion control technologies based on the chemical reduction of nitrogen oxides (NOx) into molecular nitrogen (N2) and water vapor (H2O). This control applies to iron and steel mill annealing operations with uncontrolled NOx emissions greater than 10 tons per year.	EPA 2006b, Pechan 2001, EPA 1998e, EPA 2002a, EPA 1994e, EPA 1993c
NonEGU Point	Iron & Steel Mills - Cupola Melt Furnaces	Selective Catalytic Reduction	90	$10,000		This control is the selective catalytic reduction of NOx through add-on controls. SCR controls are post-combustion control technologies based on the chemical reduction of nitrogen oxides (NOx) into molecular nitrogen (N2) and water vapor (H2O). The SCR utilizes a catalyst to increase the NOx removal efficiency, which allows the process to occur at lower temperatures. This control applies to NOx emissions from the cupola melt furnaces at iron and steel operations.	RTI 2011
NonEGU Point	Iron & Steel Mills - Galvanizing	Low NOx Burner	50	$786		This control is the use of low NOx burner (LNB) technology to reduce NOx emissions. LNBs reduce the amount of NOx created from reaction between fuel nitrogen and oxygen by lowering the temperature of one combustion zone and reducing the amount of oxygen available in another. This control is applicable to iron and steel galvanizing operations with uncontrolled NOx emissions greater than 10 tons per year.	EPA 2006b, Pechan 2001, EPA 1998e, EPA 2002a, EPA 1994e
NonEGU Point	Iron & Steel Mills - Galvanizing	Low NOx Burner and Flue Gas Recirculation	60	$931		This control is the use of low NOx burner (LNB) technology and flue gas recirculation (FGR) to reduce NOx emissions. LNBs reduce the amount of NOx created from reaction between fuel nitrogen and oxygen by lowering the temperature of one combustion zone and reducing the amount of oxygen available in another. This control is applicable to iron and steel galvanizing operations with uncontrolled NOx emissions greater than 10 tons per year.	EPA 2006b, Pechan 2001, EPA 1998e, EPA 2002a, EPA 1994e
NonEGU Point	Iron & Steel Mills - Reheating	Low Excess Air	13	$2,119		The reduction in NOx emissions is achieved through the use of low excess air techniques, such that there is less available oxygen convert fuel nitrogen to NOx. This control applies to iron & steel reheating furnaces.	EPA 2006b, EPA 1993a, Pechan 2001, EPA 1998e, EPA 1994e, ERG 2000
NonEGU Point	Iron & Steel Mills - Reheating	Low NOx Burner	66	$481		This control is the use of low NOx burner (LNB) technology to reduce NOx emissions. LNBs reduce the amount of NOx created from reaction between fuel nitrogen and oxygen by lowering the temperature of one combustion zone and reducing the amount of oxygen available in another. This control is applicable to iron and steel reheating operations with uncontrolled NOx emissions greater than 10 tons per year.	EPA 2006b, Pechan 2001, EPA 1998e, EPA 2002a, EPA 1994e
NonEGU Point	Iron & Steel Mills - Reheating	Low NOx Burner and Flue Gas Recirculation	77	$610		This control is the use of low NOx burner (LNB) technology and flue gas recirculation (FGR) to reduce NOx emissions. LNBs reduce the amount of NOx created from reaction between fuel nitrogen and oxygen by lowering the temperature of one combustion zone and reducing the amount of oxygen available in another. This control is applicable to reheating processes in iron and steel mills with uncontrolled NOx emissions greater than 10 tons per year.	EPA 2006b, Pechan 2001, EPA 1998e, EPA 2002a, EPA 1994e
NonEGU Point	Iron Production - Blast Furnace - Blast Heating Stoves	Low NOx Burner and Flue Gas Recirculation	77	$610		This control is the use of low NOx burner (LNB) technology and flue gas recirculation (FGR) to reduce NOx emissions. LNBs reduce the amount of NOx created from reaction between fuel nitrogen and oxygen by lowering the temperature of one combustion zone and reducing the amount of oxygen available in another. This control is applicable to reheating processes in iron production operations with blast heating stoves ant uncontrolled NOx emissions greater than 10 tons per year.	EPA 2006b, EPA 1998e, EPA 2002a, EPA 1994e
NonEGU Point	Lime Kilns	Low NOx Burner	30	$899		This control is the use of low NOx burner (LNB) technology to reduce NOx emissions. LNBs reduce the amount of NOx created from reaction between fuel nitrogen and oxygen by lowering the temperature of one combustion zone and reducing the amount of oxygen available in another. This control is applicable to lime kilns with uncontrolled NOx emissions greater than 10 tons per year.	EPA 2006b, EPA 1998e, EPA 2002a, EPA 1994h
NonEGU Point	Medical Waste Incinerators	Selective Non-Catalytic Reduction	45	$7,238		This control is the reduction of NOx emission through selective non-catalytic reduction add-on controls. SNCR controls are post-combustion control technologies based on the chemical reduction of nitrogen oxides (NOx) into molecular nitrogen (N2) and water vapor (H2O). This control applies to medical waste incinerators with uncontrolled NOx emissions greater than 10 tons per year.	EPA 2006b, Pechan 2001, EPA 1998e, EPA 2002a, STAPPA/ALAPCO 1994
NonEGU Point	Natural Gas Production - Compressors	Selective Catalytic Reduction	80	$4,444 for NOx<1 tpd and $855 for NOx>1 tpd		This control is the selective catalytic reduction of NOx through add-on controls. SCR controls are post-combustion control technologies based on the chemical reduction of nitrogen oxides (NOx) into molecular nitrogen (N2) and water vapor (H2O). The SCR utilizes a catalyst to increase the NOx removal efficiency, which allows the process to occur at lower temperatures. This control applies to compressors used in natural gas production operations with NOx emissions greater than 10 tons per year.	EPA 2006b, EPA 1993a, Pechan 2001, EPA 1998e, EPA 2002a

Sector	Source Category	Emission Reduction Measure Name	Control Efficiency (%)*	Cost Effectiveness (2006$/ton reduced)	Other pollutants controlled	Description/Notes/Caveats	References
NonEGU Point	Nitric Acid Manufacturing	Extended Absorption	95	$770		This control is the use of extended absorption technologies to reduce NOx emissions. This control applies to nitric acid manufacturing operations.	EPA 2006b, EPA 1998e, EPA 1991
NonEGU Point	Nitric Acid Manufacturing	Non-Selective Catalytic Reduction	98	$883	VOC - 50%, CO - 90%, N2O	NSCR is achieved by placing a catalyst in the exhaust stream of the engine. The exhaust passes over the catalyst, usually a noble metal (platinum, rhodium or palladium) which reduces the reactants to N2, CO2 and H20 (NJDEP, 2003). Typical exhaust temperatures for effective removal of NOx are 800-1200 degrees Fahrenheit. An oxidation catalyst using additional air can be installed downstream of the NSCR catalyst for additional CO and VOC control. This includes 4-cycle naturally aspirated engines and some 4-cycle turbocharged engines. Engines operating with NSCR require air/fuel control to maintain high reduction effectiveness.	EPA 2006b, EPA 1986, EPA 1998e, EPA 2002a, EPA 1991
NonEGU Point	Nitric Acid Manufacturing	Selective Catalytic Reduction	90	$979		This control is the selective catalytic reduction of NOx through add-on controls. SCR controls are post-combustion control technologies based on the chemical reduction of nitrogen oxides (NOx) into molecular nitrogen (N2) and water vapor (H2O). The SCR utilizes a catalyst to increase the NOx removal efficiency, which allows the process to occur at lower temperatures. This control applies to nitric acid manufacturing operations with NOx emissions greater than 10 tons per year.	EPA 2007b
NonEGU Point	Primary Copper Smelters - Reverberatory Smelter Furnace	Low NOx Burner and Flue Gas Recirculation	60	$1,204		This control is the use of low NOx burner (LNB) technology and flue gas recirculation (FGR) to reduce NOx emissions. LNBs reduce the amount of NOx created from reaction between fuel nitrogen and oxygen by lowering the temperature of one combustion zone and reducing the amount of oxygen available in another. This control is applicable to primary copper smelting operations.	EPA 2006b
NonEGU Point	Process Heaters	Low NOx Burner and Flue Gas Recirculation	50	$915		This control is the use of low NOx burner (LNB) technology and flue gas recirculation (FGR) to reduce NOx emissions. LNBs reduce the amount of NOx created from reaction between fuel nitrogen and oxygen by lowering the temperature of one combustion zone and reducing the amount of oxygen available in another. This control is applicable to process heaters with uncontrolled NOx emissions greater than 10 tons per year.	EPA 2002a, EPA 1998e
NonEGU Point	Process Heaters - Distillate Oil	Low NOx Burner and Selective Catalytic Reduction	90	$10,471		This control is the use of low NOx burner (LNB) technology and selective catalytic reduction (SCR) to reduce NOx emissions. LNBs reduce the amount of NOx created from reaction between fuel nitrogen and oxygen by lowering the temperature of one combustion zone and reducing the amount of oxygen available in another. SCR controls are post-combustion control technologies based on the chemical reduction of nitrogen oxides (NOx) into molecular nitrogen (N2) and water vapor (H2O). The SCR utilizes a catalyst to increase the NOx removal efficiency, which allows the process to occur at lower temperatures. This control is applicable to distillate oil-fired process heaters with uncontrolled NOx emissions greater than 10 tons per year.	EPA 2006b, EPA 2007b, Pechan 2001, EPA 1998e, EPA 2002a, EPA 2007d
NonEGU Point	Process Heaters - Distillate Oil	Selective Catalytic Reduction	75	$14,814 for NOx<1 tpd and $9,678 for NOx>1 tpd		This control is the selective catalytic reduction of NOx through add-on controls. SCR controls are post-combustion control technologies based on the chemical reduction of nitrogen oxides (NOx) into molecular nitrogen (N2) and water vapor (H2O). The SCR utilizes a catalyst to increase the NOx removal efficiency, which allows the process to occur at lower temperatures. This control applies to distillate oil-fired process heaters with NOx emissions greater than 10 tons per year.	EPA 2006b, Pechan 2001, EPA 1998e, EPA 2002a, EPA 1993c
NonEGU Point	Process Heaters - Distillate Oil or LPG	Low NOx Burner	45	$5,569 for NOx<1 tpd and $1,557 for NOx>1 tpd		This control is the use of low NOx burner (LNB) technology to reduce NOx emissions. LNBs reduce the amount of NOx created from reaction between fuel nitrogen and oxygen by lowering the temperature of one combustion zone and reducing the amount of oxygen available in another. This control is applicable to distillate oil-fired process heaters and LPG fired process heaters with uncontrolled NOx emissions greater than 10 tons per year.	EPA 2006b, Pechan 2001, EPA 1998e, EPA 2002a, EPA 1993c
NonEGU Point	Process Heaters - Distillate Oil or LPG	Low NOx Burner and Flue Gas Recirculation	48	$6,821 for NOx<1 tpd and $2,696 for NOx>1 tpd		This control is the use of low NOx burner (LNB) technology and flue gas recirculation (FGR) to reduce NOx emissions. LNBs reduce the amount of NOx created from reaction between fuel nitrogen and oxygen by lowering the temperature of one combustion zone and reducing the amount of oxygen available in another. This control is applicable to distillate-fired process heatersand LPG-fired process heaters with uncontrolled NOx emissions greater than 10 tons per year.	EPA 2006b, Pechan 2001, EPA 1998e, EPA 2002a, EPA 1993c
NonEGU Point	Process Heaters - Distillate Oil or LPG	Low NOx Burner and Selective Noncatalytic Reduction	78	$5,810 for NOx<1 tpd and $3,017 for NOx>1 tpd		This control is the use of low NOx burner (LNB) technology and selective non catalytic reduction (SNCR) to reduce NOx emissions. LNBs reduce the amount of NOx created from reaction between fuel nitrogen and oxygen by lowering the temperature of one combustion zone and reducing the amount of oxygen available in another. SNCR controls are post-combustion control technologies based on the chemical reduction of nitrogen oxides (NOx) into molecular nitrogen (N2) and water vapor (H2O). This control is applicable to LPG-fired and distillate oil-fired process heaters with uncontrolled NOx emissions greater than 10 tons per year.	EPA 2006b, Pechan 2001, EPA 1998e, EPA 2002a, EPA 1993c
NonEGU Point	Process Heaters - Distillate Oil or LPG	Selective Non-Catalytic Reduction	60	$5,104 for NOx<1 tpd and $2,761 for NOx>1 tpd		This control is the reduction of NOx emission through selective non-catalytic reduction add-on controls. SNCR controls are post-combustion control technologies based on the chemical reduction of nitrogen oxides (NOx) into molecular nitrogen (N2) and water vapor (H2O). This control applies to distillate oil-fired and LPG-fired process heaters with uncontrolled NOx emissions greater than 10 tons per year.	EPA 2006b, Pechan 2001, EPA 1998e, EPA 2002a, EPA 1993c

Sector	Source Category	Emission Reduction Measure Name	Control Efficiency (%)*	Cost Effectiveness (2006$/ton reduced)	Other pollutants controlled	Description/Notes/Caveats	References
NonEGU Point	Process Heaters - Distillate Oil or LPG	Ultra-Low NOx Burner	74	$3,435 for NOx<1 tpd and $979 for NOx>1 tpd		This control is the use of ultra-low NOx burner (ULNB) add-on technologies to reduce NOx emissions. LNBs reduce the amount of NOx created from reaction between fuel nitrogen and oxygen by lowering the temperature of one combustion zone and reducing the amount of oxygen available in another. SCR controls are post-combustion control technologies based on the chemical reduction of nitrogen oxides (NOx) into molecular nitrogen (N2) and water vapor (H2O). This control applies to distillate oil-fired process heaters and LPG-fired process heaters with uncontrolled NOx emissions greater than 10 tons per year.	EPA 2006b, Pechan 2001, EPA 1998e, EPA 2002a, EPA 1993c
NonEGU Point	Process Heaters - LPG	Low NOx Burner	50	$6,003		This control is the use of low NOx burner (LNB) technology to reduce NOx emissions. LNBs reduce the amount of NOx created from reaction between fuel nitrogen and oxygen by lowering the temperature of one combustion zone and reducing the amount of oxygen available in another. This control is applicable to LPG-fired process heaters.	EPA 2006b, EPA 1998e
NonEGU Point	Process Heaters - LPG	Low NOx Burner and Flue Gas Recirculation	48	$6,741 for NOx<1 tpd and $5,136 for NOx>1 tpd		This control is the use of low NOx burner (LNB) technology and flue gas recirculation (FGR) to reduce NOx emissions. LNBs reduce the amount of NOx created from reaction between fuel nitrogen and oxygen by lowering the temperature of one combustion zone and reducing the amount of oxygen available in another. This control is applicable to LPG-fired process heaters with uncontrolled NOx emissions greater than 10 tons per year.	EPA 2006b, Pechan 2006, Pechan 2001, EPA 1998e, EPA 2002a, EPA 1993c
NonEGU Point	Process Heaters - LPG	Low NOx Burner and Selective Catalytic Reduction	92	$18,457 for NOx<1 tpd and $14,637 for NOx>1 tpd		This control is the use of low NOx burner (LNB) technology and selective catalytic reduction (SCR) to reduce NOx emissions. LNBs reduce the amount of NOx created from reaction between fuel nitrogen and oxygen by lowering the temperature of one combustion zone and reducing the amount of oxygen available in another. SCR controls are post-combustion control technologies based on the chemical reduction of nitrogen oxides (NOx) into molecular nitrogen (N2) and water vapor (H2O). The SCR utilizes a catalyst to increase the NOx removal efficiency, which allows the process to occur at lower temperatures. This control is applicable to LPG-fired process heaters with uncontrolled NOx emissions greater than 10 tons per year.	EPA 2006b, Pechan 2001, EPA 1998e, EPA 2002a, EPA 1993c
NonEGU Point	Process Heaters - Natural Gas	Low NOx Burner and Selective Catalytic Reduction	80	$14,920		This control is the use of low NOx burner (LNB) technology and selective catalytic reduction (SCR) to reduce NOx emissions. LNBs reduce the amount of NOx created from reaction between fuel nitrogen and oxygen by lowering the temperature of one combustion zone and reducing the amount of oxygen available in another. SCR controls are post-combustion control technologies based on the chemical reduction of nitrogen oxides (NOx) into molecular nitrogen (N2) and water vapor (H2O). The SCR utilizes a catalyst to increase the NOx removal efficiency, which allows the process to occur at lower temperatures. This control is applicable to natural gas-fired process heaters with uncontrolled NOx emissions greater than 10 tons per year.	EPA 2006b, EPA 2007b, Pechan 2001, EPA 1998e, EPA 2002a, EPA 1993c
NonEGU Point	Process Heaters - Natural Gas or Process Gas	Low NOx Burner	50	$3,531 for NOx<1 tpd and $2,889 for NOx>1 tpd		This control is the use of low NOx burner (LNB) technology to reduce NOx emissions. LNBs reduce the amount of NOx created from reaction between fuel nitrogen and oxygen by lowering the temperature of one combustion zone and reducing the amount of oxygen available in another. This control is applicable to natural gas-fired and process gas-fired process heaters with uncontrolled NOx emissions greater than 10 tons per year.	EPA 2006b, Pechan 2001, EPA 1998e, EPA 2002a, EPA 1993c
NonEGU Point	Process Heaters - Natural Gas or Process Gas	Low NOx Burner and Selective Catalytic Reduction	90	$14,920		This control is the use of low NOx burner (LNB) technology and selective catalytic reduction (SCR) to reduce NOx emissions. LNBs reduce the amount of NOx created from reaction between fuel nitrogen and oxygen by lowering the temperature of one combustion zone and reducing the amount of oxygen available in another. SCR controls are post-combustion control technologies based on the chemical reduction of nitrogen oxides (NOx) into molecular nitrogen (N2) and water vapor (H2O). The SCR utilizes a catalyst to increase the NOx removal efficiency, which allows the process to occur at lower temperatures. This control is applicable to natural gas-fired and process gas-fired process heaters with uncontrolled NOx emissions greater than 10 tons per year.	EPA 2006b, EPA 2007b, Pechan 2001, EPA 1998e, EPA 2002a, EPA 1993c
NonEGU Point	Process Heaters - Natural Gas or Process Gas	Low NOx Burner and Selective Noncatalytic Reduction	80	$5,649 for NOx<1 tpd and $4,157 for NOx>1 tpd		This control is the use of low NOx burner (LNB) technology and selective non-catalytic reduction (SNCR) to reduce NOx emissions. LNBs reduce the amount of NOx created from reaction between fuel nitrogen and oxygen by lowering the temperature of one combustion zone and reducing the amount of oxygen available in another. SNCR controls are post-combustion control technologies based on the chemical reduction of nitrogen oxides (NOx) into molecular nitrogen (N2) and water vapor (H2O). This control is applicable to natural gasfi-red dand process gas-fired process heaters with uncontrolled NOx emissions greater than 10 tons per year.	EPA 2006b, Pechan 2001, EPA 1998e, EPA 2002a, EPA 1993c
NonEGU Point	Process Heaters - Natural Gas or Process Gas	Selective Non-Catalytic Reduction	60	$4,574 for NOx<1 tpd and $3,130 for NOx>1 tpd		This control is the reduction of NOx emission through selective non-catalytic reduction add-on controls. SNCR controls are post-combustion control technologies based on the chemical reduction of nitrogen oxides (NOx) into molecular nitrogen (N2) and water vapor (H2O). This control applies to natural gas-fired and process gas-fired process heaters with uncontrolled NOx emissions greater than 10 tons per year.	EPA 2006b, Pechan 2001, EPA 1998e, EPA 2002a, EPA 1993c
NonEGU Point	Process Heaters - Natural Gas or Process Gas	Ultra-Low NOx Burner	75	$2,407 for NOx<1 tpd and $1,926 for NOx>1 tpd		This control is the use of ultra-low NOx burner (ULNB) add-on technologies to reduce NOx emissions. LNBs reduce the amount of NOx created from reaction between fuel nitrogen and oxygen by lowering the temperature of one combustion zone and reducing the amount of oxygen available in another. SCR controls are post-combustion control technologies based on the chemical reduction of nitrogen oxides (NOx) into molecular nitrogen (N2) and water vapor (H2O). This control applies to natural gas-fired and process gas-fired process heaters with uncontrolled NOx emissions greater than 10 tons per year.	EPA 2006b, Pechan 2001, EPA 1998e, EPA 2002a, EPA 1993c

Sector	Source Category	Emission Reduction Measure Name	Control Efficiency (%)*	Cost Effectiveness (2006$/ton reduced)	Other pollutants controlled	Description/Notes/Caveats	References
NonEGU Point	Process Heaters - Natural Gas, Process Gas or LPG	Low NOx Burner and Flue Gas Recirculation	55	$6,741 for NOx<1 tpd and $5,136 for NOx>1 tpd		This control is the use of low NOx burner (LNB) technology and flue gas recirculation (FGR) to reduce NOx emissions. LNBs reduce the amount of NOx created from reaction between fuel nitrogen and oxygen by lowering the temperature of one combustion zone and reducing the amount of oxygen available in another. This control is applicable to natural gas-fired process heaters, process gas- fired and LPG-fired process heaters with uncontrolled NOx emissions greater than 10 tons per year.	EPA 2006b, Pechan 2006, Pechan 2001, EPA 1998e, EPA 2002a, EPA 1993c
NonEGU Point	Process Heaters - Other Fuel	Low NOx Burner and Selective Catalytic Reduction	91	$8,699 for NOx<1 tpd and $5,072 for NOx>1 tpd		This control is the use of low NOx burner (LNB) technology and selective catalytic reduction (SCR) to reduce NOx emissions. LNBs reduce the amount of NOx created from reaction between fuel nitrogen and oxygen by lowering the temperature of one combustion zone and reducing the amount of oxygen available in another. SCR controls are post-combustion control technologies based on the chemical reduction of nitrogen oxides (NOx) into molecular nitrogen (N2) and water vapor (H2O). The SCR utilizes a catalyst to increase the NOx removal efficiency, which allows the process to occur at lower temperatures. This control is applicable to other (not classified) fuel-fired process heaters with uncontrolled NOx emissions greater than 10 tons per year.	EPA 2006b, Pechan 2001, EPA 1998e, EPA 2002a, EPA 1993c
NonEGU Point	Process Heaters - Process Gas	Low NOx Burner and Flue Gas Recirculation	55	$5,120 for NOx<1 tpd and $3,964 for NOx>1 tpd		This control is the use of low NOx burner (LNB) technology and flue gas recirculation (FGR) to reduce NOx emissions. LNBs reduce the amount of NOx created from reaction between fuel nitrogen and oxygen by lowering the temperature of one combustion zone and reducing the amount of oxygen available in another. This control is applicable to process heaters with uncontrolled NOx emissions greater than 10 tons per year.	EPA 2006b, Pechan 2001, EPA 1998e, EPA 2002a, EPA 1993c
NonEGU Point	Process Heaters - Process Gas or Natural Gas or LPG	Selective Catalytic Reduction	75	$19,324 for NOx<1 tpd and $13,096 for NOx>1 tpd		This control is the selective catalytic reduction (SCR) of NOx through add-on controls. SCR controls are post-combustion control technologies based on the chemical reduction of nitrogen oxides (NOx) into molecular nitrogen (N2) and water vapor (H2O). The SCR utilizes a catalyst to increase the NOx removal efficiency, which allows the process to occur at lower temperature. This control applies to natural gas-fired, process gas-fired, or LPG-fired process heaters with NOx emissions greater than 10 tons per year.	EPA 2006b, Pechan 2001, EPA 1998e, EPA 2002a, EPA 1993c
NonEGU Point	Process Heaters - Residual Oil	Low NOx Burner and Selective Catalytic Reduction	90	$6,316		This control is the use of low NOx burner (LNB) technology and selective catalytic reduction (SCR) to reduce NOx emissions. LNBs reduce the amount of NOx created from reaction between fuel nitrogen and oxygen by lowering the temperature of one combustion zone and reducing the amount of oxygen available in another. SCR controls are post-combustion control technologies based on the chemical reduction of nitrogen oxides (NOx) into molecular nitrogen (N2) and water vapor (H2O). The SCR utilizes a catalyst to increase the NOx removal efficiency, which allows the process to occur at lower temperatures. This control is applicable to residual oil-fired process heaters with uncontrolled NOx emissions greater than 10 tons per year.	EPA 2006b, EPA 2007b, Pechan 2001, EPA 1998e, EPA 2002a, EPA 1993c
NonEGU Point	Process Heaters - Residual Oil or Other Fuel	Low NOx Burner	37	$4,045 for NOx<1 tpd and $1,140 for NOx>1 tpd		This control is the use of low NOx burner (LNB) technology to reduce NOx emissions. LNBs reduce the amount of NOx created from reaction between fuel nitrogen and oxygen by lowering the temperature of one combustion zone and reducing the amount of oxygen available in another. This control applies to Residual Oil process heaters and process heaters reporting "Other" for fuel use.	EPA 2006b, Pechan 2001, EPA 1998e, EPA 2002a, EPA 1993c
NonEGU Point	Process Heaters - Residual Oil or Other Fuel	Low NOx Burner and Flue Gas Recirculation	34	$5,601 for NOx<1 tpd and $2,215 for NOx>1 tpd		This control is the use of low NOx burner (LNB) technology and flue gas recirculation (FGR) to reduce NOx emissions. LNBs reduce the amount of NOx created from reaction between fuel nitrogen and oxygen by lowering the temperature of one combustion zone and reducing the amount of oxygen available in another. This control applies to Residual Oil process heaters and process heaters reporting "Other" for fuel use.	EPA 2006b, Pechan 2001, EPA 1998e, EPA 2002a, EPA 1993c
NonEGU Point	Process Heaters - Residual Oil or Other Fuel	Selective Catalytic Reduction	75	$8,587 for NOx<1 tpd and $5,762 for NOx>1 tpd		This control is the selective catalytic reduction of NOx through add-on controls. SCR controls are post-combustion control technologies based on the chemical reduction of nitrogen oxides (NOx) into molecular nitrogen (N2) and water vapor (H2O). The SCR utilizes a catalyst to increase the NOx removal efficiency, which allows the process to occur at lower temperatures. This control applies to residual oil fired process heaters and process heaters with unclassified fuels with NOx emissions greater than 10 tons per year.	EPA 2006b, Pechan 2001, EPA 1998e, EPA 2002a, EPA 1993c
NonEGU Point	Process Heaters - Residual Oil or Other Fuel	Selective Non-Catalytic Reduction	60	$3,098 for NOx<1 tpd and $1,765 for NOx>1 tpd		This control is the reduction of NOx emission through selective non-catalytic reduction add-on controls. SNCR controls are post-combustion control technologies based on the chemical reduction of nitrogen oxides (NOx) into molecular nitrogen (N2) and water vapor (H2O). This control applies to residual oil-fired process heaters and process heaters with unclassified fuel use with uncontrolled NOx emissions greater than 10 tons per year.	EPA 2006b, Pechan 2001, EPA 1998e, EPA 2002a, EPA 1993c
NonEGU Point	Process Heaters - Residual Oil or Other Fuel	Ultra-Low NOx Burner	73	$2,070 for NOx<1 tpd and $578 for NOx>1 tpd		This control is the use of ultra-low NOx burner (ULNB) add-on technologies to reduce NOx emissions. LNBs reduce the amount of NOx created from reaction between fuel nitrogen and oxygen by lowering the temperature of one combustion zone and reducing the amount of oxygen available in another. SCR controls are post-combustion control technologies based on the chemical reduction of nitrogen oxides (NOx) into molecular nitrogen (N2) and water vapor (H2O). This control applies to residual oil-fired process heaters and process heaters with unclassified fuels with uncontrolled NOx emissions greater than 10 tons per year.	EPA 2006b, Pechan 2001, EPA 1998e, EPA 2002a, EPA 1993c
NonEGU Point	Pulp and Paper - Natural Gas - Incinerators	Selective Catalytic Reduction	90	$3,748		This control is the selective catalytic reduction of NOx through add-on controls. SCR controls are post-combustion control technologies based on the chemical reduction of nitrogen oxides (NOx) into molecular nitrogen (N2) and water vapor (H2O). The SCR utilizes a catalyst to increase the NOx removal efficiency, which allows the process to occur at lower temperatures. This control applies to natural gas incinerators at pulp and paper plants.	EPA 2007b

Sector	Source Category	Emission Reduction Measure Name	Control Efficiency (%)*	Cost Effectiveness (2006$/ton reduced)	Other pollutants controlled	Description/Notes/Caveats	References
NonEGU Point	Sand/ Gravel - Dryer	Low NOx Burner and Flue Gas Recirculation	55	$5,120 for NOx<1 tpd and $3,964 for NOx>1 tpd		This control is the use of low NOx burner (LNB) technology and flue gas recirculation (FGR) to reduce NOx emissions. LNBs reduce the amount of NOx created from reaction between fuel nitrogen and oxygen by lowering the temperature of one combustion zone and reducing the amount of oxygen available in another. This control is applicable to sand and gravel drying processes with uncontrolled NOx emissions greater than 10 tons per year.	EPA 2006b, Pechan 2001, EPA 1998e, EPA 2002a, EPA 1993c
NonEGU Point	Secondary Aluminum Production - Smelting Furnace/ Reverberatory	Low NOx Burner	50	$915		This control is the use of low NOx burner (LNB) technology to reduce NOx emissions. LNBs reduce the amount of NOx created from reaction between fuel nitrogen and oxygen by lowering the temperature of one combustion zone and reducing the amount of oxygen available in another. This control is applicable to secondary aluminum production operations with smelting furnaces and uncontrolled NOx emissions greater than 10 tons per year.	EPA 2006b, Pechan 2001, EPA 1998e, EPA 2002a, EPA 1994e
NonEGU Point	Sewage Sludge Incinerators	Selective Catalytic Reduction	90	$3,748		This control is the reduction of NOx emission through selective non-catalytic reduction add-on controls. SNCR controls are post-combustion control technologies based on the chemical reduction of nitrogen oxides (NOx) into molecular nitrogen (N2) and water vapor (H2O). This control applies to solid waste disposal operations with uncontrolled NOx emissions greater than 10 tons per year.	EPA 2007b
NonEGU Point	Space Heaters - Distillate Oil	Low NOx Burner	50	$1,894 for NOx<1 tpd and $3,322 for NOx>1 tpd		This control is the use of low NOx burner (LNB) technology to reduce NOx emissions. LNBs reduce the amount of NOx created from reaction between fuel nitrogen and oxygen by lowering the temperature of one combustion zone and reducing the amount of oxygen available in another. This control is applicable to distillate oil-fired space heaters with uncontrolled NOx emissions greater than 10 tons per year.	EPA 2006b, Pechan 2001, EPA 1998e, EPA 2002a, EPA 1994g
NonEGU Point	Space Heaters - Distillate Oil	Low NOx Burner and Flue Gas Recirculation	60	$4,012 for NOx<1 tpd and $1,220 for NOx>1 tpd		This control is the use of low NOx burner (LNB) technology and flue gas recirculation (FGR) to reduce NOx emissions. LNBs reduce the amount of NOx created from reaction between fuel nitrogen and oxygen by lowering the temperature of one combustion zone and reducing the amount of oxygen available in another. This control is applicable to residual oil-fired process heaters with uncontrolled NOx emissions greater than 10 tons per year.	EPA 2006b, Pechan 2001, EPA 1998e, EPA 2002a, EPA 1993c
NonEGU Point	Space Heaters - Distillate Oil	Selective Catalytic Reduction	80	$4,462 for NOx<1 tpd and $2,423 for NOx>1 tpd		This control is the selective catalytic reduction of NOx through add-on controls. SCR controls are post-combustion control technologies based on the chemical reduction of nitrogen oxides (NOx) into molecular nitrogen (N2) and water vapor (H2O). The SCR utilizes a catalyst to increase the NOx removal efficiency, which allows the process to occur at lower temperatures. This control applies to distillate oil-fired space heaters with NOx emissions greater than 10 tons per year.	EPA 2006b, Pechan 2001, EPA 1998e, EPA 2002a, EPA 1994g
NonEGU Point	Space Heaters - Distillate Oil	Selective Non-Catalytic Reduction	50	$7,447 for NOx<1 tpd and $3,033 for NOx>1 tpd		This control is the reduction of NOx emission through selective non-catalytic reduction add-on controls. SNCR controls are post-combustion control technologies based on the chemical reduction of nitrogen oxides (NOx) into molecular nitrogen (N2) and water vapor (H2O). This control applies to distillate oil-fired space heaters with uncontrolled NOx emissions greater than 10 tons per year.	EPA 2006b, Pechan 2001, EPA 1998e, EPA 2002a, EPA 1994g
NonEGU Point	Space Heaters - Natural Gas	Low NOx Burner	50	$1,316 for NOx<1 tpd and $1,043 for NOx>1 tpd		This control is the use of low NOx burner (LNB) technology to reduce NOx emissions. LNBs reduce the amount of NOx created from reaction between fuel nitrogen and oxygen by lowering the temperature of one combustion zone and reducing the amount of oxygen available in another. This control is applicable to natural gas-fired space heaters with uncontrolled NOx emissions greater than 10 tons per year.	EPA 2006b, Pechan 2001, EPA 1998e, EPA 2002a, EPA 1994g
NonEGU Point	Space Heaters - Natural Gas	Low NOx Burner and Flue Gas Recirculation	60	$4,253 for NOx<1 tpd and $947 for NOx>1 tpd		This control is the use of low NOx burner (LNB) technology and flue gas recirculation (FGR) to reduce NOx emissions. LNBs reduce the amount of NOx created from reaction between fuel nitrogen and oxygen by lowering the temperature of one combustion zone and reducing the amount of oxygen available in another. This control is applicable to LPG-fired process heaters with uncontrolled NOx emissions greater than 10 tons per year.	EPA 2006b, Pechan 2001, EPA 1998e, EPA 2002a, EPA 1994g
NonEGU Point	Space Heaters - Natural Gas	Oxygen Trim and Water Injection	65	$1,091 for NOx<1 tpd and $514 for NOx>1 tpd		This control is the use of Oxygen Trim and Water Injection to reduce NOx emissions. Water is injected into the gas turbine, reducing the temperatures in the NOx-forming regions. The water can be injected into the fuel, the combustion air or directly into the combustion chamber. This control applies to natural gas-fired space heaters with uncontrolled NOx emissions greater than 10 tons per year.	EPA 2006b, Pechan 2001, EPA 1998e, EPA 2002a, ERG 2000, EPA 1994g
NonEGU Point	Space Heaters - Natural Gas	Selective Catalytic Reduction	80	$4,590 for NOx<1 tpd and $1,942 for NOx>1 tpd		This control is the selective catalytic reduction of NOx through add-on controls. SCR controls are post-combustion control technologies based on the chemical reduction of nitrogen oxides (NOx) into molecular nitrogen (N2) and water vapor (H2O). The SCR utilizes a catalyst to increase the NOx removal efficiency, which allows the process to occur at lower temperatures. This control applies to natural gas fired space heaters with NOx emissions greater than 10 tons per year.	EPA 2006b, Pechan 2001, EPA 1998e, EPA 2002a, EPA 1994g
NonEGU Point	Space Heaters - Natural Gas	Selective Non-Catalytic Reduction	50	$6,211 for NOx<1 tpd and $2,520 for NOx>1 tpd		This control is the reduction of NOx emission through selective non-catalytic reduction add-on controls. SNCR controls are post-combustion control technologies based on the chemical reduction of nitrogen oxides (NOx) into molecular nitrogen (N2) and water vapor (H2O). This control applies to natural gas fired space heaters with uncontrolled NOx emissions greater than 10 tons per year.	EPA 2006b, Pechan 2001, EPA 1998e, EPA 2002a, EPA 1994g
NonEGU Point	Steel Foundries - Heat Treating Furnaces	Low NOx Burner	50	$915		This control is the use of low NOx burner (LNB) technology to reduce NOx emissions. LNBs reduce the amount of NOx created from reaction between fuel nitrogen and oxygen by lowering the temperature of one combustion zone and reducing the amount of oxygen available in another. This control is applicable to heat treating operations at steel foundries with uncontrolled NOx emissions greater than 10 tons per year.	EPA 2006b, EPA 1998e, EPA 2002a, EPA 1994e

Sector	Source Category	Emission Reduction Measure Name	Control Efficiency (%)*	Cost Effectiveness (2006$/ton reduced)	Other pollutants controlled	Description/Notes/Caveats	References
NonEGU Point	Steel Production - Soaking Pits	Low NOx Burner and Flue Gas Recirculation	60	$1,204		This control is the use of low NOx burner (LNB) technology and flue gas recirculation (FGR) to reduce NOx emissions. LNBs reduce the amount of NOx created from reaction between fuel nitrogen and oxygen by lowering the temperature of one combustion zone and reducing the amount of oxygen available in another. This control is applicable to soaking pits at steel production operations with uncontrolled NOx emissions greater than 10 tons per year.	EPA 2006b, EPA 1998e, EPA 2002a, EPA 1994e
NonEGU Point	Sulfate Pulping - Recovery Furnaces	Low NOx Burner	50	$1,316 for NOx<1 tpd and $1,043 for NOx>1 tpd		This control is the use of low NOx burner (LNB) technology to reduce NOx emissions. LNBs reduce the amount of NOx created from reaction between fuel nitrogen and oxygen by lowering the temperature of one combustion zone and reducing the amount of oxygen available in another. This control is applicable to recovery furnaces at sulfate pulping operations with uncontrolled NOx emissions greater than 10 tons per year.	EPA 2006b, Pechan 2001, EPA 1998e, EPA 2002a, EPA 1994g
NonEGU Point	Sulfate Pulping - Recovery Furnaces	Low NOx Burner and Flue Gas Recirculation	60	$4,109 for NOx<1 tpd and $947 for NOx>1 tpd		This control is the use of low NOx burner (LNB) technology and flue gas recirculation (FGR) to reduce NOx emissions. LNBs reduce the amount of NOx created from reaction between fuel nitrogen and oxygen by lowering the temperature of one combustion zone and reducing the amount of oxygen available in another. This control is applicable to residual oil-fired process heaters with uncontrolled NOx emissions greater than 10 tons per year.	EPA 2006b, Pechan 2001, EPA 1998e, EPA 2002a, EPA 1994g
NonEGU Point	Sulfate Pulping - Recovery Furnaces	Oxygen Trim and Water Injection	65	$1,091 for NOx<1 tpd and $514 for NOx>1 tpd		This control is the use of Oxygen Trim and Water Injection to reduce NOx emissions. Water is injected into the gas turbine, reducing the temperatures in the NOx-forming regions. The water can be injected into the fuel, the combustion air or directly into the combustion chamber. This control applies to recovery furnaces involved in sulfate pulping operations with uncontrolled NOx emissions greater than 10 tons per year.	EPA 2006b, Pechan 2001, EPA 1998e, EPA 2002a, ERG 2000, EPA 1994g
NonEGU Point	Sulfate Pulping - Recovery Furnaces	Selective Catalytic Reduction	80	$2,761		This control is the selective catalytic reduction of NOx through add-on controls. SCR controls are post-combustion control technologies based on the chemical reduction of nitrogen oxides (NOx) into molecular nitrogen (N2) and water vapor (H2O). The SCR utilizes a catalyst to increase the NOx removal efficiency, which allows the process to occur at lower temperatures. This control applies to recovery furnaces in sulfate pulping operations with NOx emissions greater than 10 tons per year.	EPA 2007b
NonEGU Point	Sulfate Pulping - Recovery Furnaces	Selective Catalytic Reduction	90	$2,852		This control is the selective catalytic reduction of NOx through add-on controls. SCR controls are post-combustion control technologies based on the chemical reduction of nitrogen oxides (NOx) into molecular nitrogen (N2) and water vapor (H2O). The SCR utilizes a catalyst to increase the NOx removal efficiency, which allows the process to occur at lower temperatures. This control applies to recovery furnaces in sulfate pulping operations with NOx emissions greater than 10 tons per year.	EPA 2007b
NonEGU Point	Sulfate Pulping - Recovery Furnaces	Selective Non-Catalytic Reduction	50	$6,211 for NOx<1 tpd and $2,520 for NOx>1 tpd		This control is the reduction of NOx emission through selective non-catalytic reduction add-on controls. SNCR controls are post-combustion control technologies based on the chemical reduction of nitrogen oxides (NOx) into molecular nitrogen (N2) and water vapor (H2O). This control applies to sulfate pulping operations with recovery furnaces and uncontrolled NOx emissions greater than 10 tons per year.	EPA 2006b, Pechan 2001, EPA 1998e, EPA 2002a, EPA 1994g
NonEGU Point	Surface Coating Operations -Coating Oven Heater -Natural Gas	Low NOx Burner	50	$3,531 for NOx<1 tpd and $2,889 for NOx>1 tpd		This control is the use of low NOx burner (LNB) technology to reduce NOx emissions. LNBs reduce the amount of NOx created from reaction between fuel nitrogen and oxygen by lowering the temperature of one combustion zone and reducing the amount of oxygen available in another. This control is applicable to natural gas-fired coating oven heater at surface coating operations with uncontrolled NOx emissions greater than 10 tons per year.	EPA 2006b, EPA 1998e, EPA 2002a, EPA 1993c
NonEGU Point	Taconite Iron Ore Processing - Induration - Coal or Gas	Selective Catalytic Reduction	90	$6,351		This control is the selective catalytic reduction of NOx through add-on controls. SCR controls are post-combustion control technologies based on the chemical reduction of nitrogen oxides (NOx) into molecular nitrogen (N2) and water vapor (H2O). The SCR utilizes a catalyst to increase the NOx removal efficiency, which allows the process to occur at lower temperatures. This control applies to coal or gas induration in taconite iron ore processing.	EPA 2007b
NonEGU Point	Textile-Type Fiberglass Manufacturing - Recuperative Furnace	Low NOx Burner	40	$2,712		This control is the use of low NOx burner (LNB) technology to reduce NOx emissions. LNBs reduce the amount of NOx created from reaction between fuel nitrogen and oxygen by lowering the temperature of one combustion zone and reducing the amount of oxygen available in another. This control is applicable to textile-type fiberglass manufacturing operations with gas- or oil-fired recuperative furnaces and uncontrolled NOx emissions greater than 10 tons per year.	EPA 2006b, EPA 1998e, EPA 2002a, EPA 1994f
NonEGU Point	Waste Incineration - Municipal Waste Combustors or Solid Waste Disposal - Sludge Incinerators (Government)	Selective Non-Catalytic Reduction	45	$1,814		This control is the reduction of NOx emission through selective non-catalytic reduction add-on controls. SNCR controls are post-combustion control technologies based on the chemical reduction of nitrogen oxides (NOx) into molecular nitrogen (N2) and water vapor (H2O). This control applies to municipal waste combustors and government solid waste disposal sludge incineration sources with uncontrolled NOx emissions greater than 10 tons per year.	EPA 2006b, Pechan 2001, EPA 1998e, EPA 2002a, EPA 1994i
EGU	External Combustion Boilers - Electric Generation - Natural Gas (Tangential or Non-Tangential Firing)	Natural Gas Reburn	50	$2,352		Natural gas reburning (NGR) involves add-on controls to reduce NOx emissions. NGR is a combustion control technology in which part of the main fuel heat input is diverted to locations above the main burners, called the reburn zone. As flue gas passes through the reburn zone, a portion of the NOx formed in the main combustion zone is reduced by hydrocarbon radicals and converted to molecular nitrogen (N2). This control applies to Natural Gas external combustion boilers used for electricity generation.	EPA 2007c

Point & NonPoint NOx
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EGU	External Combustion Boilers - Electricity Generation- Anthracite Coal or Subbituminous/ Bituminous Coal	Selective Non-Catalytic Reduction	40	$1,370		This control is the reduction of NOx emission through selective non-catalytic reduction add-on controls to wall fired (coal) utility boilers. SNCR controls are post-combustion control technologies based on the chemical reduction of nitrogen oxides (NOx) with a nitrogen based reducing reagent, such as ammonia or urea, to reduce the NOx into molecular nitrogen (N2) and water vapor (H2O). This control applies to pulverized anthracite coal-fired electricity generation sources and bituminous/subbituminous coal-fired electricity generation sources.	EPA 2007c
EGU	External Combustion Boilers for Electricity Generation - Residual Oil or Solid Waste Combustion	Selective Non-Catalytic Reduction	50	$2,694		This control is the use of selective non-catalytic reduction add-on controls to wall fired (oil/gas) utility boilers for the reduction of NOx emissions. SNCR controls are post-combustion control technologies based on the chemical reduction of nitrogen oxides (NOx) with a nitrogen based reducing reagent, such as ammonia or urea, to reduce the NOx into molecular nitrogen (N2) and water vapor (H2O). The control applies to Residual Oil (Grade 6 oil) burning electricity generation sources, excluding tangentially fired sources and solid waste combustors used for electricity generation.	EPA 2007c
EGU	External Combustion Boilers, Electricity Generation, Distillate Oil	Selective Non-Catalytic Reduction	50	$4,868		This control is the reduction of NOx emission through selective non-catalytic reduction add-on controls to wall fired (coal) utility boilers. SNCR controls are post-combustion control technologies based on the chemical reduction of nitrogen oxides (NOx) with a nitrogen based reducing reagent, such as ammonia or urea, to reduce the NOx into molecular nitrogen (N2) and water vapor (H2O). This control applies to distillate oil external combustion boilers.	EPA 2007c
EGU	External Combusion Boilers for Electricity Generation	Energy Efficiency Policies & Programs	N/A	The cost effectiveness is based on the levelized cost of saved energy (LCSE) for recent utility administered energy efficiency programs of 2.5 cents/Kwh. $0/ton reduced	SO_2, Hg, CO_2	This category is a catch-all for energy efficiency (EE) policies, programs and measures which reduce EGU emissions indirectly by encouraging energy savings and reducing demand for electricity from EGUs. For more information EE policies, programs and measures, see the Roadmap for Incorporating EE/RE Policies and Prograsm in SIPs and TIPs.	ACEEE 2009, EPA 2012a, EPA 2012b
EGU	Utility Boiler - Bituminous Coal Wall Fired	Low NOx Burner and Over Fire Air	72	Cost effectiveness is variable and based on plant size: for a 300MW plant, total capital cost of $60.43 per kW; the fixed O&M costs of $0.40 per kW per year; and variable O&M costs of $0.090 mills per kWh. The scaling factor for plants from 25MW (Capital Cost and Fixed O&M only) = (300/capacity)^(0.359).		This control is the use of low NOx burner (LNB) technology to reduce NOx emissions. LNBs reduce the amount of NOx created from reaction between fuel nitrogen and oxygen by lowering the temperature of one combustion zone and reducing the amount of oxygen available in another. This control applies to wall fired coal utility boilers.	EPA 2006b, EPA 2002a, EPA 2010a
EGU	Utility Boiler - Bituminous Coal/ Wall Fired	Low NOx Burner	57	Cost effectiveness is variable and based on plant size: for a 300MW plant, total capital cost of $44.58 per kW; the fixed O&M costs of $0.30 per kW per year; and variable O&M costs of $0.070 mills per kWh. The scaling factor for plants from 25MW (Capital Cost and Fixed O&M only) = (300/capacity)^(0.359).		This control is the use of low NOx burner (LNB) technology to reduce NOx emissions. LNBs reduce the amount of NOx created from reaction between fuel nitrogen and oxygen by lowering the temperature of one combustion zone and reducing the amount of oxygen available in another. This control applies to wall fired coal utility boilers.	EPA 2006b, EPA 2002a, EPA 2010a
EGU	Utility Boiler - Coal/ Wall	Natural Gas Reburn	50	Cost effectiveness is variable and based on: plant size, the total capital cost of $32.41 per kW, and the fixed O&M of $0.49 per kW per year		Natural gas reburning (NGR) involves add-on controls to reduce NOx emissions. NGR is a combustion control technology in which part of the main fuel heat input is diverted to locations above the main burners, called the reburn zone. As flue gas passes through the reburn zone, a portion of the NOx formed in the main combustion zone is reduced by hydrocarbon radicals and converted to molecular nitrogen (N2). This control applies to pulverized-dry bottom coal-fired electricity generation sources.	EPA 2006b, ERG 2000, EPA 1998b

Sector	Source Category	Emission Reduction Measure Name	Control Efficiency (%)*	Cost Effectiveness (2006$/ton reduced)	Other pollutants controlled	Description/Notes/Caveats	References
EGU	Utility Boiler - Coal/ Tangential	Low NOx Coal-and-Air Nozzles with Cross-Coupled and Separated Overfire Air	62	Cost effectiveness is variable and based on plant size: for a 300MW plant, total capital cost of $37.64 per kW; the fixed O&M costs of $0.30 per kW per year; and variable O&M costs of $0.030 mills per kWh. The scaling factor for plants from 25MW (Capital Cost and Fixed O&M only) = (300/capacity)^(0.359).		This control is the use of low NOx coal and air nozzles coupled with cross-coupled and separated overfire air to reduce NOx emissions. Over-fire air stages combustion by diverting combustion air from the burners to create a fuel rich zone in the furnace. This inhibits fuel-bound nitrogen conversion in coal fired boilers. This control is applicable to tangentially-fired coal utility boilers.	EPA 2006b, EPA 2002a, EPA 2010a
EGU	Utility Boiler - Coal/ Tangential	Low NOx Coal-and-Air Nozzles with cross-Coupled Overfire Air	42	Cost effectiveness is variable and based on plant size: for a 300MW plant, total capital cost of $23.77 per kW; the fixed O&M costs of $0.20 per kW per year; and variable O&M costs of $0.000 mills per kWh. The scaling factor for plants from 25MW (Capital Cost and Fixed O&M only) = (300/capacity)^(0.359).		This control is the use of low NOx coal and air nozzles coupled with cross-coupled overfire air to reduce NOx emissions. Over-fire air stages combustion by diverting combustion air from the burners to create a fuel rich zone in the furnace. This inhibits fuel-bound nitrogen conversion in coal fired boilers. This control is applicable to tangentially-fired coal utility boilers.	EPA 2006b, EPA 2002a, EPA 2010a
EGU	Utility Boiler - Coal/ Tangential	Low NOx Coal-and-Air Nozzles with separated Overfire Air	47	Cost effectiveness is variable and based on plant size: for a 300MW plant, total capital cost of $32.69 per kW; the fixed O&M costs of $0.20 per kW per year; and variable O&M costs of $0.030 mills per kWh. The scaling factor for plants from 25MW (Capital Cost and Fixed O&M only) = (300/capacity)^(0.359).		This control is the use of low NOx coal and air nozzles coupled with separated overfire air to reduce NOx emissions. Over-fire air stages combustion by diverting combustion air from the burners to create a fuel rich zone in the furnace. This inhibits fuel-bound nitrogen conversion in coal fired boilers. This control is applicable to tangentially-fired coal utility boilers.	EPA 2006b, EPA 2002a, EPA 2010a
EGU	Utility Boiler - Coal/ Tangential	Natural Gas Reburn	50	Cost effectiveness is variable and based on: plant size, the total capital cost of $32.41 per kW, and the fixed O&M of $0.49 per kW per year		Natural gas reburning (NGR) involves add-on controls to reduce NOx emissions. NGR is a combustion control technology in which part of the main fuel heat input is diverted to locations above the main burners, called the reburn zone. As flue gas passes through the reburn zone, a portion of the NOx formed in the main combustion zone is reduced by hydrocarbon radicals and converted to molecular nitrogen (N2). This control applies to bituminous/subbituminous coal-fired electricity generation sources, including sources with atmospheric fluidized bed combustion.	EPA 2006b, ERG 2000, EPA 2004b, EPA 1998b, Staudt 1998
EGU	Utility Boiler - Coal/ Tangential	Selective Catalytic Reduction	90	$1550-$2066	Hg - 95%	This control is the use of selective catalytic reduction add-on controls to tangentially coal-fired utility boilers for the reduction of NOx emissions. SCR controls are post-combustion control technologies based on the chemical reduction of nitrogen oxides (NOx) with a nitrogen based reducing reagent, such as ammonia or urea, to reduce the NOx into molecular nitrogen (N2) and water vapor (H2O). The SCR utilizes a catalyst to increase the NOx removal efficiency, which allows the process to occur at lower temperatures. This control applies to bituminous/subbituminous coal-fired electricity generation sources, including sources with atmospheric fluidized bed combustion with nameplate capacity greater than 100 MW	EPA 2006b, EPA 2002a, Massachusetts 2002, EPA 2004b, EPA 2001, EPA 1998b

Sector	Source Category	Emission Reduction Measure Name	Control Efficiency (%)*	Cost Effectiveness (2006$/ton reduced)	Other pollutants controlled	Description/Notes/Caveats	References
EGU	Utility Boiler - Coal/ Tangential	Selective Non-Catalytic Reduction	Pulverized Coal: 35%; Fluidized Bed: 50%	- Pulverized: cost effectiveness is variable and based on heat rate: total capital cost of $44.58/kW for 9,000Btu/kWh to $47.55/kW for 11,000Btu/kWh; fixed O&M costs of $0.99 per kW per year (do not depend on heat rate); variable O&M costs of $0.87 mills per kWh for 9,000Btu/kWh to 1.07 mills per kWh for 11,000Btu/kWh. - Fluidized: cost effectiveness is variable and based on plant size & heat rate: capital cost of $8.92/kW for 1000MW & 9,000Btu/kWh to $35.66/kW for 100MW & 11,000Btu/kWh; fixed O&M costs of $0.99 per kW per year for 1000MW to $0.89per kW per year for 100MW (do not depend on heat rate); variable O&M		This control is the use of selective non-catalytic reduction add-on controls to reduce NOx emissions from tangentially coal-fired utility boilers. SNCR controls are post-combustion control technologies based on the chemical reduction of nitrogen oxides (NOx) with a nitrogen based reducing reagent, such as ammonia or urea, to reduce the NOx into molecular nitrogen (N2) and water vapor (H2O). This control applies to bituminous/subbituminous coal-fired electricity generation sources, including sources with atmospheric fluidized bed combustion.	EPA 2006b, EPA 2010a
EGU	Utility Boiler - Coal/ Wall	Selective Catalytic Reduction	90	Cost effectiveness is variable and based on plant size & heat rate: total capital cost of $145.61/kW for 1000MW & 9,000Btu/kWh to $255.57/kW for 100MW & 11,000Btu/kWh; fixed O&M costs of $0.40 per kW per year for 1000MW to $2.48 per kW per year for 100MW (do not depend on heat rate); variable O&M costs of $1.14 mills per kWh for 9,000Btu/kWh to 1.32 mills per kWh for 11,000Btu/kWh.		This control is the use of selective catalytic reduction add-on controls to coal/wall fired utility boilers for the reduction of NOx emissions. SCR controls are post-combustion control technologies based on the chemical reduction of nitrogen oxides (NOx) with a nitrogen based reducing reagent, such as ammonia or urea, to reduce the NOx into molecular nitrogen (N2) and water vapor (H2O). The SCR utilizes a catalyst to increase the NOx removal efficiency, which allows the process to occur at lower temperatures. This control applies to pulverized-dry bottom coal-fired electricity generation sources with a nameplate capacity greater than 25 MW.	EPA 2006b, EPA 2002a, EPA 1998b, EPA 2010a

Sector	Source Category	Emission Reduction Measure Name	Control Efficiency (%)*	Cost Effectiveness (2006$/ton reduced)	Other pollutants controlled	Description/Notes/Caveats	References
EGU	Utility Boiler - Coal/ Wall	Selective Non-Catalytic Reduction	35	Cost effectiveness is variable and based on heat rate: total capital cost of $44.58/kW for 9,000Btu/kWh to $47.55/kW for 11,000Btu/kWh; fixed O&M costs of $0.99 per kW per year (do not depend on heat rate); variable O&M costs of $0.87 mills per kWh for 9,000Btu/kWh to 1.07 mills per kWh for		This control is the reduction of NOx emission through selective non-catalytic reduction add-on controls to wall fired (coal) utility boilers. SNCR controls are post-combustion control technologies based on the chemical reduction of nitrogen oxides (NOx) with a nitrogen based reducing reagent, such as ammonia or urea, to reduce the NOx into molecular nitrogen (N2) and water vapor (H2O). This control applies to pulverized-dry bottom coal-fired electricity generation sources with a nameplate capacity greater than 25 MW.	EPA 2006b, EPA 2010a
EGU	Utility Boiler - Cyclone	Natural Gas Reburn	50	Cost effectiveness is variable and based on: plant size, the total capital cost of $32.41 per kW, and the fixed O&M of $0.49 per kW per year		Natural gas reburning (NGR) involves add-on controls to reduce NOx emissions. NGR is a combustion control technology in which part of the main fuel heat input is diverted to locations above the main burners, called the reburn zone. As flue gas passes through the reburn zone, a portion of the NOx formed in the main combustion zone is reduced by hydrocarbon radicals and converted to molecular nitrogen (N2). This control applies to pulverized-dry bottom coal-fired electricity generation sources with cyclone furnaces.	EPA 2006b, ERG 2000, EPA 1998b
EGU	Utility Boiler - Cyclone	Selective Catalytic Reduction	90	Cost effectiveness is variable and based on plant size & heat rate: total capital cost of $145.61/kW for 1000MW & 9,000Btu/kWh to $255.57/kW for 100MW & 11,000Btu/kWh; fixed O&M costs of $0.40 per kW per year for 1000MW to $2.48 per kW per year for 100MW (do not depend on heat rate); variable O&M costs of $1.14 mills per kWh for 9,000Btu/kWh to 1.32 mills per kWh for 11,000Btu/kWh.		This control reduces NOx emissions using selective catalytic add-on controls on utility boilers with cyclone burners. SCR controls are post-combustion control technologies based on the chemical reduction of nitrogen oxides (NOx) with a nitrogen based reducing reagent, such as ammonia or urea, to reduce the NOx into molecular nitrogen (N2) and water vapor (H2O). The SCR utilizes a catalyst to increase the NOx removal efficiency, which allows the process to occur at lower temperatures. This control applies to bituminous/subbituminous coal-fired electricity generation sources with cyclone furnaces and nameplate capacity greater than 25 MW.	EPA 2006b, EPA 2002a, EPA 1998b, EPA 2010a
EGU	Utility Boiler - Cyclone	Selective Non-Catalytic Reduction	35	Cost effectiveness is variable and based on heat rate: total capital cost of $44.58/kW for 9,000Btu/kWh to $47.55/kW for 11,000Btu/kWh; fixed O&M costs of $0.99 per kW per year (do not depend on heat rate); variable O&M costs of $0.87 mills per kWh for 9,000Btu/kWh to 1.07 mills per kWh for		This control is the use of selective non-catalytic reduction add-on controls to cyclone utility boilers to reduce NOx emissions. SNCR controls are post-combustion control technologies based on the chemical reduction of nitrogen oxides (NOx) with a nitrogen based reducing reagent, such as ammonia or urea, to reduce the NOx into molecular nitrogen (N2) and water vapor (H2O). This control applies to bituminous/subbituminous coal-fired electricity generation sources with cyclone furnaces with a nameplate capacity greater than 25 MW.	EPA 2006b, EPA 2010a

Sector	Source Category	Emission Reduction Measure Name	Control Efficiency (%)*	Cost Effectiveness (2006$/ton reduced)	Other pollutants controlled	Description/Notes/Caveats	References
EGU	Utility Boiler - Oil-Gas/ Tangential	Natural Gas Reburn	50	Cost effectiveness is variable and based on: plant size, the total capital cost of $32.41 per kW, and the fixed O&M of $0.49 per kW per year		Natural gas reburning (NGR) involves add-on controls to reduce NOx emissions. NGR is a combustion control technology in which part of the main fuel heat input is diverted to locations above the main burners, called the reburn zone. As flue gas passes through the reburn zone, a portion of the NOx formed in the main combustion zone is reduced by hydrocarbon radicals and converted to molecular nitrogen (N2). This control applies to tangentially natural-gas fired electricity generation sources.	EPA 2006b, ERG 2000, EPA 1998b
EGU	Utility Boiler - Oil-Gas/ Tangential	Selective Catalytic Reduction	80	Cost effectiveness is variable and based on plant size. For a 25MW plant, capital costs are $74.29 per kW, fixed O&M costs are $1.07 per kW per year. Variable O&M costs are 0.12 mills per kWh (do not depend on plant size). The scaling factor for plants between 25MW and 500MW (Capital Cost and Fixed O&M only) = (200/capacity)^(0.35). After 500MW, costs		This control is the selective catalytic reduction of NOx through add-on controls to tangentially fired (oil/gas) utility boilers. SCR controls are post-combustion control technologies based on the chemical reduction of nitrogen oxides (NOx) with a nitrogen based reducing reagent, such as ammonia or urea, to reduce the NOx into molecular nitrogen (N2) and water vapor (H2O). The SCR utilizes a catalyst to increase the NOx removal efficiency, which allows the process to occur at lower temperatures. This control applies to tangentially natural-gas fired electricity generation sources with nameplate capacity greater than 25 MW.	EPA 2006b, EPA 2002a, EPA 1998b, EPA 2010a
EGU	Utility Boiler - Oil-Gas/ Tangential	Selective Non-Catalytic Reduction	50	Cost effectiveness is variable and based on plant size. For a 200MW plant, capital costs are $11.5 per kW, fixed O&M costs are $0.18 per kW per year. Variable O&M costs are 0.53 mills per kWh (do not depend on plant size). The scaling factor for plants between 25MW and 500MW (Capital Cost and Fixed O&M only) = (200/capacity)^(0.577). After 500MW, costs		This control reduces NOx emissions using selective non-catalytic reduction add-on controls to tangentially fired (oil/gas) utility boilers. SNCR controls are post-combustion control technologies based on the chemical reduction of nitrogen oxides (NOx) with a nitrogen based reducing reagent, such as ammonia or urea, to reduce the NOx into molecular nitrogen (N2) and water vapor (H2O). The control applies to tangentially natural-gas fired electricity generation sources with nameplate capacity greater than 25 MW.	EPA 2006b, EPA 2006g
EGU	Utility Boiler - Oil-Gas/ Wall	Natural Gas Reburn	50	Cost effectiveness is variable and based on: plant size, the total capital cost of $32.41 per kW, and the fixed O&M of $0.49 per kW per year		Natural gas reburning (NGR) involves add-on controls to reduce NOx emissions. NGR is a combustion control technology in which part of the main fuel heat input is diverted to locations above the main burners, called the reburn zone. As flue gas passes through the reburn zone, a portion of the NOx formed in the main combustion zone is reduced by hydrocarbon radicals and converted to molecular nitrogen (N2). This control applies to natural-gas fired electricity generation sources, excluding tangentially fired sources.	EPA 2006b, ERG 2000, EPA 1998b

Sector	Source Category	Emission Reduction Measure Name	Control Efficiency (%)*	Cost Effectiveness (2006$/ton reduced)	Other pollutants controlled	Description/Notes/Caveats	References
EGU	Utility Boiler - Oil-Gas/ Wall	Selective Catalytic Reduction	80	Cost effectiveness is variable and based on plant size. For a 200MW plant, capital costs are $74.29 per kW, fixed O&M costs are $1.07 per kW per year. Variable O&M costs are 0.12 mills per kWh (do not depend on plant size). The scaling factor for plants between 25MW and 500MW (Capital Cost and Fixed O&M only) = (200/capacity)^(0.35). After 500MW, costs		This control is the selective catalytic reduction of NOx through add-on controls to wall fired (oil/gas) utility boilers. SCR controls are post-combustion control technologies based on the chemical reduction of nitrogen oxides (NOx) with a nitrogen based reducing reagent, such as ammonia or urea, to reduce the NOx into molecular nitrogen (N2) and water vapor (H2O). The SCR utilizes a catalyst to increase the NOx removal efficiency, which allows the process to occur at lower temperatures. This control applies to large (>100 million Btu/hr) natural-gas fired electricity generation sources with nameplate capacity greater than 25 MW, excluding tangentially fired sources.	EPA 2006b, EPA 2002a, EPA 1998b, EPA 2010a
EGU	Utility Boiler - Oil-Gas/ Wall	Selective Non-Catalytic Reduction	50	Cost effectiveness is variable and based on plant size. For a 200MW plant, capital costs are $11.5 per kW, fixed O&M costs are $0.18 per kW per year. Variable O&M costs are 0.53 mills per kWh (do not depend on plant size). The scaling factor for plants between 25MW and 500MW (Capital Cost and Fixed O&M only) = (200/capacity)^(0.577). After 500MW, costs		This control is the use of selective non-catalytic reduction add-on controls to wall fired (oil/gas) utility boilers for the reduction of NOx emissions. SNCR controls are post-combustion control technologies based on the chemical reduction of nitrogen oxides (NOx) with a nitrogen based reducing reagent, such as ammonia or urea, to reduce the NOx into molecular nitrogen (N2) and water vapor (H2O). The control applies to natural-gas fired electricity generation sources with nameplate capacity greater than 25 MW, excluding tangentially fired sources.	EPA 2006b, EPA 2006g
EGU	Utility Boiler - Subbituminous Coal - Wall Fired	Low NOx Burner and Over Fire Air	72	Cost effectiveness is variable and based on plant size. For a 300MW plant, total capital cost of $60.43 per kW; fixed O&M costs of $0.40 per kW per year; and variable O&M costs of $0.09 mills per kW per year. Scaling factor for plants from 25MW (Capital Cost and Fixed O&M only) =		This control is the use of low NOx burner (LNB) technology to reduce NOx emissions. LNBs reduce the amount of NOx created from reaction between fuel nitrogen and oxygen by lowering the temperature of one combustion zone and reducing the amount of oxygen available in another. This control applies to wall fired (coal) utility boilers with nameplate capacity greater than 25 MW.	EPA 2006b, EPA 2002a, EPA 2010a

Sector	Source Category	Emission Reduction Measure Name	Control Efficiency (%)*	Cost Effectiveness (2006$/ton reduced)	Other pollutants controlled	Description/Notes/Caveats	References
EGU	Utility Boiler - Subbituminous Coal/ Wall Fired	Low NOx Burner	57	Cost effectiveness is variable and based on plant size. For a 300MW plant, total capital cost of $44.58 per kW; fixed O&M costs of $0.30 per kW per year; and variable O&M costs of $0.07 mills per kW per year. Scaling factor for plants from 25MW (Capital Cost and Fixed O&M only) =		This control is the use of low NOx burner (LNB) technology to reduce NOx emissions. LNBs reduce the amount of NOx created from reaction between fuel nitrogen and oxygen by lowering the temperature of one combustion zone and reducing the amount of oxygen available in another. This control applies to wall fired coal utility boilers with nameplate capacity greater than 25 MW.	EPA 2006b, EPA 2002a, EPA 2010a

* control efficiencies were rounded up to the closest whole number.

Sector	Source Category	Emission Reduction Measure Name	Control Efficiency (%)*	Cost Effectiveness (2006$/ton reduced)	Description/Notes/Caveats	References
NonPoint	Adhesives - Industrial	Reformulation	73	$3,534	This control is the use of product reformulation and product substitution for industrial adhesives to achieve VOC emissions reductions. It is based on SCAQMD rule 1168, which requires the use of waterborne, hot melt, UV cured or reactive diluent adhesives. Add-on controls such as carbon absorption and afterburners are more costly for this source category and generally not used.	Pechan 1997, SCAQMD 1996a
NonPoint	Aerosol Coatings		19		EPA promulgated national VOC emission standards for aerosol coatings during 2008. EPA estimated that the aerosol coatings rule will achieve the equivalent of a 19 percent reduction in mass VOC emissions from the 1990 baseline. The year 1990 represents the baseline, since there has been no previous Federal rulemaking for aerosol coatings. The creditable reduction that may be claimed is 0.114 pounds per capita. To estimate equivalent VOC mass reductions for credit purposes, EPA computed the VOC reductions that would have been achieved by a mass-based rule equivalent in ozone formation reduction to the reactivity-based rule. This calculation was based in work done by the California ARB. ARB had previously developed a mass-based rule whose limits were later determined to be technically infeasible. The California reactivity-based rule was developed by ARB as an equivalent replacement for the mass-based rule's VOC limits.	
NonPoint	Architectural, Traffic, and Industrial Maintenance Coatings	OTC Model Rule	31	$6,612	The baseline against which the control efficiencies are listed for this source category comes from the existing Federal AIM rule 40CFR Part 59 from 2002, which is estimated to provide a 20 percent VOC reduction from the uncontrolled (1990 baseline) emissions. The OTC developed a Model Rule for AIM Coatings that requires manufacturers to reformulate coatings to meet specified VOC content limits, which are based on the SCM adopted by ARB and the STAPPA/ALAPCO model rule for AIM Coatings.	LADCO 2006b, OTC 2001b
NonPoint	Architectural, Traffic, and Industrial Maintenance Coatings	OTC Model Rule and South Coast -Rule 1113 Phase III VOC limits	40	$20,664	This control is the adoption of SCAQMD Rule 1113 Phase III VOC Emission Limits in addition to the Architectural, Traffic, and Industrial Maintenance (AIM) coatings OTC Model Rule limits. Phase III relies on near-zero or zero VOC formulations for several architectural coating categories including, but not limited to, cleanup and thinning solvents, clear wood finishes, exterior opaque stains, semi-transparent stains, sanding sealers, and waterproofing sealers.	OTC 2001a, LADCO 2006b
NonPoint	Bakery Products	Catalytic Incineration	40	$2,359	The control measure is based on the regulation adopted by the BAAQMD, which assumes emissions reductions from the use of catalytic incinerators. These incinerators use a catalyst to achieve very high control efficiencies at relatively low operating temperatures (320 to 650 °C). The BAAQMD control requirements affect only large, commercial bread bakeries. The equivalent SCAQMD Rule is 1153.	EPA 1990a, EPA 1992c, EPA 1995c, M&S 1991, Schultz 1997
NonPoint	Coating Operations at Aerospace Manufacturing and Rework Operations	Control Technology Guidelines	18-50		This CTG identifies presumptive RACT for controlling VOC emissions from aerospace coatings and cleaning solvents. The baseline against which the control efficiencies are listed for this source category comes from the aerospace manufacturing and rework operations NESHAP federal rule (60 FR 45948). Aerospace manufacturing and rework operations typically consist of the following basic operations: materials receiving, machining and mechanical processing, coating application, chemical milling, heat treating, cleaning, metal processing and finishing, coating removal (depainting), composite processing, and testing. Of these operations, coating application and cleaning are the significant sources of VOC emissions and are the processes covered by this CTG. The principal technique used by the aerospace industry to control VOC emissions is product substitution, which eliminates or reduces the generation of emissions (waterborne and high solids materials used as coating substitution). Several equipment changes can also directly reduce the level of VOC emissions (high transfer efficiency spray guns, spray gun cleaners, and conventional high transfer efficiency methods). The control efficiency range provided if for equipment change.	EPA 1997f
NonPoint	Cold Cleaning Degreasing	Process Modification	95	$15,703	This control is modifications to the cold cleaning process to reduce the fugitive VOC emissions. This is based on SCAQMD Rule 1122, which was most recently amended in 2009.	SCAQMD 1996a, SCAQMD 1997
NonPoint	Cold Cleaning Degreasing	Reformulation-Process Modification (OTC Rule)	8	$1,688	The baseline against which the control efficiencies are listed for this source category comes from the MACT standard for Cold Cleaning processes. This control establishes hardware and operating requirements for specified vapor cleaning machines, as well as solvent volatility limits and operating practices for cold cleaners.	SCAQMD 1997, OTC 2001a

NonPoint	Consumer Products	California Consumer Products Rules Cumulative through 2010 Proposed Amendments	50	$3,498	Over the last 20 years, the California Air Resources Board has taken numberous actions to reduce VOC from consumer products. Five regulations have been adopted which have resulted in a cumulative 50% reduction from VOC projections from 1990 levels. Each of the individual changes to the consumer products rules in California that have been enacted since 2006 have been in pursuit of the long-term committment to reduce emissions from this category by 80 percent.	This control is the use of low NOx burner (LNB) technology and selective non-catalytic reduction (SNCR) to reduce NOx emissions. LNBs reduce the amount of NOx created from reaction between fuel nitrogen and oxygen by lowering the temperature of one combustion zone and reducing the amount of oxygen available in another. SNCR controls are post-combustion control technologies based on the chemical reduction of nitrogen oxides (NOx) into molecular nitrogen (N2) and water vapor (H2O). This control is applicable to process heaters fired with distillate, residual oil, and other unclassified fuels.
NonPoint	Consumer Products	Reformulation (2001 OTC Model Rule)	14	$1,244	The baseline against which the control efficiencies for this category are listed comes from Clean Air Act Section 183(e) VOC Rules, which is considered a 9.7 percent reduction from uncontrolled levels (20% reduction for products covered by the rule; only 48.6% of products are covered.) The OTC model rule regulates approximately 80 consumer product categories, and uses more stringent VOC content limits then the Federal rule. Examples include aerosol adhesives, floor wax strippers, dry cleaning fluids, and general purpose cleaners. It also contains administrative requirements for labeling, reporting, codedating, and a most restrictive limit scenario. There is a reporting requirement, such that manufacturers may be required to submit information to the State upon written notice.	OTC 2001a, ARB 1999
NonPoint	Consumer Products	Reformulation (2006 OTC Model Rule)	16	$4,820	This control was based on a 2% improvement to the 2001 OTC Model rule for this source category. It consists of lower VOC content limits than the 2001 Model Rule.	OTC 2007
NonPoint	Cutback Asphalt	Reformulation-Process Modification	100	$24	This control includes the use of reformulated products and the modification of processes associated with cutback asphalt manufacturing to reduce the fugitive VOC emissions.	EPA 1997c
NonPoint	Flexographic Printing	Permanent Total Enclosure (PTE)	90	$15,074	A permanent total enclosure (PTE) completely surrounds a source of emissions such that all VOC emissions are captured and contained for discharge to a control device. Flexographic printing is classified into two categories: wide-web and narrow-web flexographic printing. Wide-web flexographic printing is used to print flexible and rigid paper, plastic and aluminum foil packaging, newspapers, magazines, directories, paper towels, etc. Narrow-web flexographic printing is primarily used for printing and adhesive application on paper, foil and film tags and labels. The EPA evaluated VOC emission control options for the flexographic printing industry including the use of a PTE in conjunction with a thermal oxidizer in the MACT standard-setting process for this source category. The option presented here has applicability to flexographic printing that uses "high" VOC content materials.	EPA 2006b
NonPoint	Metal Can Surface Coating	Incineration	84	$14,344	This control measure based on the use of incineration to reduce VOC emissions from metal can coating facilities .Coatings are applied to metal cans to improve appearance and prevent corrosion. This rule is assumed to cover both two and three piece can coating. This control applies to area source VOC emissions for the metal can coating source category. The option presented here has applicability to processes that use "high" VOC content materials (solvent-borne materials).	EPA 1998d

NonPoint	Metal Can Surface Coating	Permanent Total Enclosure (PTE)	92	$9,621	A permanent total enclosure (PTE) completely surrounds a source of emissions such that all VOC emissions are captured and contained for discharge to a control device. A metal can is defined as a usually cylindrical metal container, but governmental agencies and industry groups use differing criteria to identify cans including shape, materials, capacity, phase of product contained, and material thickness (gauge). Decorative tins, bottle caps and jar lids are also included in the can coating category since many of these items are coated on the same line where can coating takes place. Cans consist of can bodies and can ends. Metal can surface coating facilities include two-piece beverage can body facilities, twopiece food can body facilities, one-piece aerosol can body facilities, sheetcoating facilities, three-piece food can body assembly facilities, three-piece non-food can body assembly facilities, and end lining facilities. EPA evaluated VOC emission control options for the two-piece beverage can, twopiece food can and sheetcoating facilities using a PTE in conjunction with a thermal oxidizer in the MACT standard-setting process for this source category. The option presented here has applicability to processes that use "high" VOC content materials (solvent-borne materials).	EPA 2006b
NonPoint	Metal Can Surface Coating	Process Modification	9	$3,221	The baseline against which the control efficiencies are listed for this source category comes from the Metal Can Surface Coating NESHAP federal rule (68 FR 64432). This control includes modifications to the metal can coating process to reduce the fugitive VOC emissions. This control measure is based on the 1997 amendment to the San Francisco Bay Area AQMD rule which defined VOC content limits for body spray coatings for both two and three piece cans and set VOC limits for end sealing compounds for non-food products; and set limits for interior and exterior body sprays used on drums, pails, and lids (BAAQMD, 1999).	BAAQMD 1999
NonPoint	Metal Coil Surface Coating	Incineration	84	$14,344	This control measure based on the use of incineration to reduce VOC emissions from metal coil coating facilities. Coatings are applied to metal coils to improve appearance and prevent corrosion. This rule is assumed to cover both two and three piece coil coating. This control applies to area source VOC emissions for the metal coil coating source category. The option presented here has applicability to processes that use "high" VOC content materials (solvent-borne materials).	EPA 1998d
NonPoint	Metal Coil Surface Coating	Permanent Total Enclosure (PTE)	92	$9,621	A permanent total enclosure (PTE) completely surrounds a source of emissions such that all VOC emissions are captured and contained for discharge to a control device. A metal can is defined as a usually cylindrical metal container, but governmental agencies and industry groups use differing criteria to identify cans including shape, materials, capacity, phase of product contained, and material thickness (gauge). Decorative tins, bottle caps and jar lids are also included in the can coating category since many of these items are coated on the same line where can coating takes place. Cans consist of can bodies and can ends. Metal can surface coating facilities include two-piece beverage can body facilities, twopiece food can body facilities, one-piece aerosol can body facilities, sheetcoating facilities, three-piece food can body assembly facilities, three-piece non-food can body assembly facilities, and end lining facilities. EPA evaluated VOC emission control options for the two-piece beverage can, twopiece food can and sheetcoating facilities using a PTE in conjunction with a thermal oxidizer in the MACT standard-setting process for this source category. The option presented here has applicability to processes that use "high" VOC content materials (solvent-borne materials).	EPA 2006b
NonPoint	Metal Coil Surface Coating	Process Modification	9	$3,221	The baseline against which the control efficiencies are listed for this source category comes from the Metal Coil Surface Coating NESHAP federal rule (68 FR 39793). This control includes modifications to the metal coil coating process to reduce the fugitive VOC emissions. This control measure is based on the 1997 amendment to the San Francisco Bay Area AQMD rule which defined VOC content limits for body spray coatings for both two and three piece cans and set VOC limits for end sealing compounds for non-food products; and set limits for interior and exterior body sprays used on drums, pails, and lids (BAAQMD, 1999).	BAAQMD 1999
NonPoint	Metal Furniture Surface Coating	Reduced Solvent Utilization	84	$118	The baseline against which the control efficiencies are listed for this source category comes from the Metal Furniture Surface Coating NESHAP federal rule (68 FR 28605). This control is the implementation of reduced solvent utilization to reduce VOC emissions from metal furniture surface coating.	STAPPA/ALAPCO 1993, CDPR 1999
NonPoint	Metal Furniture, Appliances, Parts	Reformulation-Process Modification	36	$4,043	The SCAQMD amended rule 1107 sets stringent VOC emission limits for metal coatings. VOC emissions can be reduced by using reformulated low-VOC content compliant coatings, powder coating for both general and high gloss coatings, UV curable coatings, high transfer efficiency coating applications, and increased effectiveness of add-on control equipment. The metal coating source category classifies emissions that result from the coating of metal parts and products including machinery and equipment and railroad rolling stock. In 2006, this rule was amended again, ratcheting down the VOC limits on certain categories of coatings and making HVLP sprayers mandatory for all end users.	SCAQMD 1996a, EPA 1995h, SCAQMD 2005b

NonPoint	Metal part and Products coating	Reformulation-Process Modification	36	$4,043	The baseline against which the control efficiencies are listed for this source category comes from the Miscellaneous Metal Parts and Products Surface Coating NESHAP federal rule (69 FR 22601). The SCAQMD amended rule 1107 sets stringent VOC emission limits for metal coatings. VOC emissions can be reduced by using reformulated low-VOC content compliant coatings, powder coating for both general and high gloss coatings, UV curable coatings, high transfer efficiency coating applications, and increased effectiveness of add-on control equipment. The metal coating source category classifies emissions that result from the coating of metal parts and products including machinery and equipment and railroad rolling stock. In 2006, this rule was amended again, ratcheting down the VOC limits on certain categories of coatings and making HVLP sprayers mandatory for all end users.	SCAQMD 1996a, SCAQMD 2001, SCAQMD 2005b
NonPoint	Mobile Equipment Repair and Refinishing	California Air Resources Board - Suggested Control Measures for Automotive Coatings	89	$6,400	This control is the implementation of suggested control measures developed by ARB for the various air districts. The SCM proposes VOC limit standards for various coating categories. Any coating that can be used in more than one category is subject ot the most restrictive VOC content limit. The proposed SCM also prohibits anyone from applying, manufacturing, blending, repackaging for sale, supplying, offering for sale, distributing, possessing (at an automotive refinishing facility) or selling any coating that does not meet the VOC limits. It also specifies the manner in which coatings may be applies, restricting application to brushing, dipping, rolling, electrostatic spraying, or spraying with a high-volume, low-pressure spray gun or an approved equivalent.	OTC 2001a, ARB 2005b
NonPoint	Mobile Equipment Repair and Refinishing	OTC Model Rule	38	$1,850	The baseline against which the control efficiencies are listed for this source category come from the EPA's published standards limiting VOC content in coatings sold for automobile refinishing published in 1998, which represent a 37% reduction from uncontrolled levels. In 2001, the Ozone Transport Commission (OTC) developed a model rule based on the use of high transfer-efficiency painting methods (e.g., high volume low pressure spray guns), and controls on emissions from equipment (e.g., spray gun) cleaning, housekeeping activities (e.g., use of sealed containers for clean-up rags), and operator training. The OTC model rule has the same VOC content limits as the federal rule except for slightly more stringent limits for primer/surfacer coatings and three- or four-stage topcoats. An incremental control effectiveness of 38 percent was estimated for the OTC model rule relative to the National Rule (or 60 percent reduction from uncontrolled levels). This estimate includes a 35 percent reduction from the use of high transfer efficiency spray guns and another 3 percent from the use of enclosed spray gun cleaners.	OTC 2001a, LADCO 2006c, OTC 2007
NonPoint	Municipal Solid Waste Landfill	Gas Recovery	70	$1,089	This control is the application of gas capture systems to cappable landfills to reduce the VOC emissions from decaying organic matter. The majority of the VOC captured is methane.	CDPR 1999
NonPoint	Open Top Degreasing	Process Modification	97	$15,711	This control is modifications to the open top degreasing process to reduce the fugitive VOC emissions.	SCAQMD 1996a, SCAQMD 1997
NonPoint	Open Top Degreasing	Reformulation-Process Modification	65	$2,003	VOC emissions from degreasing operations can be reduced by the use of low-VOC content solvents, and by changes in operating practices. This rule was originally adopted in 1979, but has since been amended to specify maximum ventilating conditions, minimize drag-out losses, eliminate some rule exemptions, expand the rule to smaller cold degreasers, and further limit the solvent content of waste materials.	SCAQMD 1996a, SCAQMD 1997
NonPoint	Pesticide Application	Reformulation	20	$14,926	The California Federal Implementation Plan (FIP) rule intends to reach the VOC limits by switching to and/or encouraging the use of low-VOC pesticides and better Integrated Pest Management (IPM) practices. All types of pesticide applications are affected by this rule.	Radian 1994b
NonPoint	Petroleum Refinery Fugitives	Process Modification	78	$1,290	This control is modifications to the petroleum refining process to reduce the fugitive VOC emissions.	EPA 2006b
NonPoint	Pharmaceutical and Cosmetic Manufacturing Operations	SCAQMD Rule 1103	90		This rule applies to the manufacture of pharmaceutical and cosmetic products by chemical processes including medicinal chemicals such as antibiotics and vitamins, botanical and biological products. VOC emissions reduction is achieved through a combination of Equipment Requirements and Operating Requirements. Equipment Requirements include limits on VOC emissions from reactors, distillation columns, crystallizers, or centrifuges and/or requires control devices to be used in combination with these pieces of equipment. Operating Requirements focus on VOC emissions limits for production equipment such as air dryers, or during transfers from trucks into storage tanks, as well as requires repairing all liquid leaks within 24 hours of detection.	SCAQMD 1999c
NonPoint	Polystyrene Foam Manufacturing	Control Technology Guidelines	95-99	$2,070-$10,898 for carbon adsorption $6,500-$17,815 for incinerators	This CTG identifies measures for controlling VOC emissions from Polystyrene Foam Manufacturing. Controls include incineration and carbon adsorption. For the range of VOC concentrations encountered in Polystyrene Foam Manufacturing, thermal incinerators can achieve 99% efficiency while catalytic incinerators can achieve 95% efficiency. As for carbon adsorption devices, the expected removal efficiency is 99%.	EPA 1990b
NonPoint	Rubber/Plastics Coating	Reformulation-Process Modification	60	$7,350	SCAQMD Rule 1145 - Plastic, Rubber, and Glass Coatings was adopted to reduce VOC emissions from plastic, rubber, and glass operations. Since its adoption, this rule has been amended numerous times incorporating more stringent VOC limits as the technology and low VOC coatings have become available. The last amendment in March 1996 was to exempt aerosol coatings and to provide rule consistency with the recently adopted ARB Aerosol Coating Products Rule. There are a variety of control methods to reduce VOCs from plastic, rubber, and glass coatings operations. VOC emissions can be reduced by using reformulated low-VOC content compliant coatings, UV curable coatings, high transfer efficiency coating applications and increased effectiveness of add-on control equipment.	SCAQMD 1996a

NonPoint	Shipbuilding and Ship Repair (Surface Coating)	Incineration	87	$14,344	Four California air quality districts have adopted more stringent VOC marine coating emission limits than those specified in the 1995 Shipbuilding and Ship Repair (Surface Coating) MACT standard. However, the California limits are not uniformly applied across each coating category or in each of the four districts. Since the California limits do not allowances for cold weather coating limits that are less strinegnt than the warm weather ones, the ability to apply coatings effectively could be compromised in areas of the country with colder climates if the more stringent California limits are applied as is.	EPA 1998d
NonPoint	Stage II Service Stations - Underground Tanks (Breathing and Emptying)	LPV Relief Valve	73	$1,736	This control measure is the addition of low pressure/vacuum (LP/V) relief valves to underground gasoline storage tanks at service stations with Stage II control systems. LP/V relief valves prevent breathing emissions from gasoline storage tank vent pipes. This control measure applies to all gasoline service stations with underground gasoline storage tanks.	EPA 1995e, SCAQMD 1995b
NonPoint	Storage Tanks at Petroleum Facilities	SCAQMD Rule 1178	95	$10,387 - $12,695 per ton ROG	Large storage tanks of high volatile VOC compounds having true vapor pressure greater or equal to 3 psia at refineries are major source of ROG. The purpose of this rule is to reduce emissions of volatile organic compounds (VOC) from storage tanks located at petroleum facilities. Geodesic doming is an achieved-in-practice control option. Cost effectiveness for doming is about $9,000 - $11,000 per ton (2001$, DCF, ROG). The lower end cost effectiveness is without foam suppressant, and the upper end is with foam suppressant. Rule 1178 also includes other control options for seals, guidepoles etc. to reduce evaporation losses from external floating roof tanks, internal floating roof tanks, and fixed roof tanks. The tank emissions are vented to an emission control system with an overall control efficiency of at least 95% by weight.	SCAQMD 2012
NonPoint	Wood Furniture Surface Coating	Add-On Controls	64	$32,099	This control measure is generic in that it represents potential add-on controls available for this source category. Add-on controls include thermal incinerators, catalytic incinerators, and a combination of carbon absorbers and catalytic incinerators. This control applies to all wood furniture coating applications.	EPA 1999e, EPA 1996c
NonPoint	Wood Furniture Surface Coating	Control Technology Guidelines	24	$1,552	The baseline against which the control efficiencies are listed for this source category comes from the Wood Furniture Surface Coating NESHAP federal rule (40 CFR 63,subpart JJ). The Wood Furniture Coating CTG, published in 1996, applies to ozone nonattainment areas and the Ozone Transport Region (OTR). This will affect facilities emitting 25 tons per year or more. The Wood furniture coating industry covers 10 SIC codes including: Wood Kitchen Cabinets; Wood Household Furniture (except upholstered); Wood Household Furniture (upholstered); Wood Television, Radios, Phonograph, and Sewing Machine Cabinets; Household Furniture Not Classified Elsewhere; Wood Office Furniture; Public Building and Related Furniture; Wood Office and Store Fixtures; Furniture and Fixtures Not Elsewhere Classified; and Custom Kitchen Cabinets.	EPA 1996c
NonPoint	Wood Product Surface Coating	Incineration	80	ARB estimates $2,219/ton, Others estimate $6,340 to $16,840/ton)	This is a generic control measure based on the use of incineration to reduce VOC emissions from wood product surface coating facilities. This control measure applies to sources classified as factory finished wood producers.	EPA 2006b
NonPoint	Wood Product Surface Coating	Reformulation	33	$1,414	This control is the use of product reformulation and product substitution for wood product surface coatings to achieve VOC emissions reductions.	SCAQMD 1996b, SCAQMD 1999b
Non-EGU Point	Auto and Light-Duty Truck Assembly Coatings	Control Technology Guidelines	0	0	EPA issued a CTG during 2008 for automobile and light-duty truck assembly coatings. Auto and light--duty truck coating facilities have reduced the VOC emission from their coating operations to comply with the NSPS, NESHAP and State rules. The CTG recommended VOC emission limits are already being implemented in these facilities in order to meet existing requirements. Therefore, there are not quantifiable VOC emission reductions or costs associated with implementing the CTG recommendations. However, the CTG also recommends work practices for reducing VOC emissions from both coatings and cleaning materials. EPA estimates that its work practice recommendations will save costs. Implementing these work practices, such as covering open containers, reduces the amount of coating and cleaning materials used by decreasing evaporation.	EPA 2008c
Non-EGU Point	Fiberglass Boat Manufacturing	Solvent substitution, non-atomized resin application methods	35	$4,200	EPA issued a CTG during 2008 that provides control recommendations for reducing VOC emissions from the use of gel coats, resins, and materials used to clean application equipment in fiberglass boat manufacturing operations. The CTG recommends the use of low-VOC content (monomer and non-monomer VOC) resin and gel coats with specified application methods. The CTG recommends the use of covers on mixing containers to further reduce VOC emissions from gel coats and resins. The CTG also recommends the use of low-VOC and low vapor pressure cleaning materials. Because the CTG recommendations are based on the 2001 NESHAP for boat manufacturing, those facilities that are major sources of HAP are already complying with the 2001 NESHAP and have already adopted these control measures. Because the 2001 NESHAP does not apply to area sources, area source fiberglass boat manufacturing facilities are not currently required to implement the measures provided in the NESHAP and recommended in the CTG. There are boat manufacturing facilities in ozone nonattainment areas that meet the applicability threshold in the CTG and would provide VOC emission reductions when the CTG recommended controls are applied. These control approaches are recommended for all fiberglass boat manufacturing facilities where total actual VOC emissions from all fiberglass boat manufacturing operations are equal to or exceed 15 lb/day.	EPA 2008d

Non-EGU Point	Flat Wood Paneling Coatings	Low-VOC materials coatings	60-91	$1,900-2,600	EPA issued a new CTG for flat wood paneling coating facilities in 2006. The 2006 CTG recommends emission limits for the inks, coatings and adhesives used by the flat wood paneling coating facilities and work practices for cleaning materials used. The low-VOC materials recommendation for inks, coatings and adhesives include an emission limit of 2.1 lbs. per gallon of materials. Should product performance requirements or other needs dictate the use of higher-VOC Coatings than this, a facility could choose to use add-on control equipment to meet an overall control efficiency of 90 percent. Add-on devices include oxidizers and solvent recovery systems. The CTG also recommends work practices for use in all flat wood paneling coating facilities meeting the 15 lb per day threshold. The new CTG emission limits for this source category are based on the rules in Placer County (Rule 238) and SCAQMD (Rule 1104) in California.	EPA 2006i
Non-EGU Point	Flexible Package Printing	Add-on controls, work practices, and material reformulation / substitution.	67	$2,800	EPA issued a CTG for Flexible Package Printing in 2006 that includes recommended control techniques. EPA's recommended emission limits are based on the 1978 CTG for graphic arts (which included rotogravure printing and flexographic printing) and on the 1996 NESHAP. This CTG provides control recommendations for reducing VOC emissions from (1) inks, coatings, adhesives and (2) cleaning materials used in flexible packaging printing. EPA recommends applying the recommendations for operations that emit at least (1) 25 tpy of VOC from inks, coatings and adhesives combined, and (2) 15 lb/day of VOC due to cleaning materials (before consideration of controls). The approach to reducing VOC emissions from inks, coatings, and adhesives includes adding/improving add-on controls with an overall emission reduction of 65 to 80 percent (depending on the first installation date of the equipment) and material reformulation/substitution (low- and no-VOC inks, coatings, and adhesives) with an 80 percent overall emissions reduction level. The recommended approach to reduce VOC emissions from cleaning materials includes use of work practices (keeping solvent containers closed, conducting cleaning operations, conveying cleaning materials in closed containers, etc.)	EPA 2006k
Non-EGU Point	Industrial Cleaning Solvents	Work practice standards, solvent substitution, and add-on controls	94	($1,134)	EPA issued a CTG for industrial cleaning solvents in 2006 that includes recommended control techniques. This category includes the industrial cleaning solvents used by many industries. It includes a variety of products that are used to remove contaminants such as adhesives, inks, paint, dirt, soil, oil and grease. The recommended measures for controlling VOC emissions from the use, storage and disposal of industrial cleaning solvents includes work practice standards, limitations on VOC content of the cleaning materials, and an optional alternative limit on composite vapor pressure of the cleaning materials. They also include the use of add-on controls with an overall emission reduction of at least 85 percent by mass. The first two recommendations and the last one are based on the Bay Area AQMD rule.	EPA 2006h
Non-EGU Point	Large Appliance Surface Coating	Low-VOC coating materials	30	$500	In 2007, EPA issued a CTG for large appliance coatings. EPA developed this new CTG after considering the 1977 CTG, the 1982 NSPS, the 2002 NESHAP, and existing State and local VOC emission reduction approaches for this category. The new CTG applies the facilities with 15 lbs per day or more of VOC emissions from large appliance coating operations. There are two main sources of VOC emissions from large appliance coating operations: (1) evaporation of VOC from the coatings; and (2) evaporation of VOC from the cleaning materials. To control VOC emissions from large appliance coatings, EPA recommended three alternatives: (1) emission limits that can be achieved through the use of low-VOC coatings; (2) equivalent emission limits that can be achieved through the use of low-VOC coatings or a combination of coatings and add-on controls; and (3) an overall control efficiency of 90 percent for add-on controls. EPA expects that in practice, facilities will choose the low-VOC coating materials alternative. EPA recommends work practices to reduce VOC emissions. The recommendations in this CTG are similar to the South Coast regulations for this source category (SCAQMD Rule 1107).	EPA 2007e
Non-EGU Point	Lithographic Printing & Letterpress Printing	Add-on controls, work practices, and material reformulation/substitution.	75	$155	EPA issued a CTG for Lithographic Printing & Letterpress Printing in 2006 that includes recommended control techniques (although offset lithographic printing and letterpress printing are two distinct product categories, they have many similarities in the types of materials used, sources of VOC emissions, and controls available). EPA's recommended emission limits are based on the 1993 draft CTG and 1994 ACT. This CTG provides control recommendations for reducing VOC emissions from (1) evaporation of VOC from the inks, (2) evaporation of VOC from the fountain solution (offset lithographic printing only), and (3) evaporation of VOC from the cleaning materials. EPA recommends applying the recommendations for operations that emit at least (1) 25 tpy of VOC from inks, and (2) 15 lb/day of VOC due to fountain solutions and cleaning materials (before consideration of controls). The approach to reducing VOC emissions from heatset web offset lithographic and heatset letterpress inks and dryers consists of installing control devices with an overall emission reduction of 90 to 95 percent (depending on the first installation date of the equipment). The recommended approach to reduce VOC emissions from the fountain solution focuses on controlling the concentration of alcohol in the fountain solution at less than 5% (weight) of alcohol. Finally, EPA recommends using cleaning materials with a VOC composite vapor pressure less than 10 mm Hg at 20 ºC and proposes using work practices (keeping cleaning materials and used shop towels in closed containers).	EPA 2006j

Non-EGU Point	Metal Furniture Coatings	Low-VOC coating materials	35	$200	EPA issued a 2007 CTG for metal furniture coatings. Previous federal actions that affected this source category include a 1977 CTG, a 1982 NSPS and a 2003 NESHAP (Surface Coating of Metal Furniture). In the 2007 CTG, EPA recommended three alternatives: (1) emission limits that can be achieved through the use of low VOC Coatings; (2) equivalent emission limits that can be achieved through the use of low-VOC coatings and add-on controls, (3) an overall control efficiency of 90 percent for add-on controls. The low-VOC coatings recommendation consists of emission limits in terms of mass of VOC per volume of coating, excluding water and exempt compounds, as applied and the use of specified application methods. the equivalent emission limit recommendation consists of emission limits in terms of mass of VOC per volume of coating solids, as applied, and the use of specific. The CTG recommendations are similar to the South Coast regulations governing metal furniture surface coating operations.	EPA 2007f
Non-EGU Point	Miscellaneous Industrial Adhesives	Solvent substitution	64	$265	EPA issued a CTG for miscellaneous industrial adhesives in 2008. This provides information for states to consider in determining RACT. EPA's recommended emission limits are based on the OTC Model Rule for Adhesives and Sealants. The emission limits in the OTC rule were the same as California ARB RACT standards, which were based on numerous California district rules. EPA recommends that the control approaches suggested apply to each miscellaneous industrial adhesive application process at a facility where the total actual VOC emissions from all application processes, including related cleaning activities at that facility are equal to or exceed 15 lbs per day before consideration of controls. EPA recommends specific VOC emission limits based on application processes. There are two options for achieving recommended emission limits: (1) through the use of low-VOC content adhesives and specified application methods with good adhesive transfer efficiency; or (2) through the use of a combination of low-VOC adhesives, specified methods and add-on controls. As an alternative to the emission limits, an overall 85 percent control efficiency is recommended.	EPA 2008a
Non-EGU Point	Miscellaneous Metal and Plastic Parts Coatings	Coating Reformulation	35	1,758	In the 2008 EPA CTG for miscellaneous metal and plastic parts coatings three options were recommended for controlling VOC emissions: (1) VOC content limits for each coating category based on the use of low-VOC content coatings and specified application methods to achieve good transfer efficiency; (2) equivalent VOC emission rate limits based on the use of a combination of low-VOC coatings, specified application methods, and add-on controls; or (3) an overall VOC control efficiency of 90 percent for facilities that choose to use add-on controls instead of low-VOC Content coatings and specified application methods. In addition, EPA recommended work practices to further reduce VOC emissions from coatings as well as to minimize emissions from cleaning materials used in miscellaneous metal product and plastic part surface coating processes. The recommendations in this CTG are similar to the South Coast regulations governing miscellaneous metal product and plastic part surface coating operations, and Michigan Rule 336.1632.	EPA 2008b
Non-EGU Point	Paper Film and Foil Coatings	Low-VOC coating materials and/or add-on controls	90	1,200	EPA issued a 2007 CTG for paper, film and foil coatings. Previous federal actions that affected this source category included a 1977 CTG for controlling VOC emissions from surface coating of paper, the 1983 NSPS for surface coating of pressure sensitive tape and labels (a subset of this category), and a 2002 NESHAP for paper and other web coating. EPA recommends applying the control recommendations for coatings only o individual paper, film and foil surface coating lines with the potential to emit at least 25 tpy of VOC from coatings, prior to controls. EPA recommends an overall VOC control efficiency of 90% as RACT for each coating line. This level of control is based on current rules in San Diego and Ventura air districts in California, as well as the NSPS. The CTG does not recommend the 95 percent control level that is currently required by the NESHAP and seven State's regulations.	EPA 2007g
NonEGU Point	Fabric Printing and Coating	Permanent Total Enclosure (PTE)	97	$1,761	A permanent total enclosure (PTE) completely surrounds a source of emissions such that all VOC emissions are captured and contained for discharge to a control device. Fabric printing and coating is performed in the textile manufacturing industry in order to: --prepare fiber and subsequently manufacture yarn, threads, braids, twine, and cordage --manufacture broadwoven fabrics, narrow woven fabrics, knit fabrics, and carpets and rugs from yarn -- finish fiber, yarn, fabrics, and knit apparel --coat, waterproof, or otherwise treat fabrics --perform integrated manufacturing of knit apparel and other finished articles from yarn --manufacture felt goods, lace goods, nonwoven fabrics, and miscellaneous textiles. The EPA evaluated VOC emission control options for the fabric printing and coating industry including the use of a PTE in conjunction with a thermal oxidizer in the MACT standard-setting process for this source category. The option presented here has applicability to fabric printing/coating processes that use "high" VOC content materials.	EPA 2006b
NonEGU Point	Industrial Cleaning Solvents - Non-Halogenated Solvent - Parts Cleaners	Low VOC Cleaning Materials and Improved Work Practices	<85	$2,082	This control includes work practice standards, limitations on VOC content of the cleaning materials, and an optional alternative limit on composite vapor pressure of the cleaning materials. They also include the use of add-on controls with an overall emission reduction of at least 85 percent by mass. It applies to industrial solvent cleaning operations using non-halogenated solvents, identified as either degreasing or cold cleaning. Though the efficiency from this control is 85%, there are exceptions for a number of sources within the category.	EPA 2006h
NonEGU Point	Industrial Cleaning Solvents - Other Non-Halogenated Solvent Cleaning Operations	Low VOC Cleaning Materials and Improved Work Practices	<85	($1,657)	This control includes work practice standards, limitations on VOC content of the cleaning materials, and an optional alternative limit on composite vapor pressure of the cleaning materials. They also include the use of add-on controls with an overall emission reduction of at least 85 percent by mass. It applies to industrial solvent cleaning operations using non-halogenated solvents, not identified as either degreasing or cold cleaning. Though the efficiency from this control is 85%, there are exceptions for a number of sources within the category.	EPA 2006h

NonEGU Point	Metal Furniture Surface Coating	Permanent Total Enclosure (PTE)	95	$24,325	A permanent total enclosure (PTE) completely surrounds a source of emissions such that all VOC emissions are captured and contained for discharge to a control device. Metal furniture surface coating operations involve: --Surface preparation of the metal furniture prior to coating application --Preparation of a coating for application (e.g., mixing in additives, dissolving resins) --Application of a coating to metal furniture --Flashoff, drying, and curing following coating application --Cleaning of equipment used in the coating application operation --Storage of coatings, additives, and cleaning materials --Conveyance of coatings, additives, and cleaning materials from storage areas to mixing areas or to coating application areas, either manually or by automated means --Handling and conveyance of waste materials generated by the surface coating operation. The EPA evaluated VOC emission control options for the metal furniture coating industry including the use of a PTE in conjunction with a thermal oxidizer in the MACT standard-setting process for this source category. The option presented here has applicability to processes that use "high" VOC content materials (solvent-borne materials).	EPA 2006b
NonEGU Point	Miscellaneous Industrial Adhesives	Low VOC Adhesives and Improved Application Methods	64	$263	This control is based on EPA's 2008 Control Techniques Guidelines for Miscellaneous Industrial Adhesives. It recommends 85 percent VOC reduction through the use of low-VOC content adhesives and specified application methods with good adhesive transfer efficiency; or through the use of a combination of low-VOC adhesives, specified application methods, and add-on controls. The control efficiency is not 85 percent because there are a number of exceptions for certain types of adhesives and adhesives primer application processes.	EPA 1995a, EPA 2008a
NonEGU Point	Oil and Natural Gas Production - Fugitive Emissions	SCAQMD Rule 1148.1	14	$2,648	The purpose of this rule is to reduce emissions of volatile organic compounds (VOCs) from the wellheads, the well cellars and the handling of produced gas at oil and gas production facilities. This rule applies to onshore oil producing wells, well cellars and produced gas handling activities at onshore facilities where petroleum and processed gas are produced, gathered, separated, processed and stored. This rule was adopted March 5, 2004.	EPA 2006b
NonEGU Point	Petroleum Flare	Flare	98	$3,255	This control is the application of improved flaring technology to reduce VOC emissions at petroleum flares.	EPA 2007c
NonEGU Point	Petroleum Wastewater	Wastewater	65	$3,315	This control is the application of wastewater treatment controls to petroleum wastewater sources to reduce VOC emissions.	EPA 2007c
NonEGU Point	Semi-Conductor Manufacturing	Reformulation-Process Modification	53	$9,591	The baseline against which the control efficiencies for this category are listed comes from the federal MACT rule (NESHAP rule 69 FR 129). SCAQMD Rule 1164 requires: a fully covered area, low/no-VOC solvents, or an approved emissions control system for solvent cleaning operations, photoresist operations and solvent clean-up operations. This control applies to the miscellaneous electronic equipment coating source category, including VOC emissions resulting from the manufacture of circuit boards and components, including resistors, transistors, semiconductors, coils, and transformers.	Pechan 1997, SCAQMD 1996a, EPA 1994d, SCAQMD 1998, SCAQMD 1995a
NonEGU Point	Shipbuilding and Ship Repair (Surface Coating)	Reformulation-Process Modification	49	$3,054	EPA's 2010 (FR Vol. 75, No. 244) proposed rule identified an add-on control device, a concentrator/Regenerative Thermal Oxidizer (RTO), recently installed at one shipbuilding and ship repair facility in California. The control device consists of rotary concentrators followed by RTOs on five large, custom-built spray booths to control volatile organic emissions from some of the coating operations. The system is capable of achieving 95 percent control efficiency for volatile organic HAP emissions captured by the spray booths (which are estimated to capture 90 percent of the VOHAP emissions). For this type of add-on control to be effective, a facility must perform regular or continuous modular (ship sections or components) coating operations, a process that is normally performed at large shipyards during new ship construction. Due to the size of the booths required to handle large ship modules, a facility would also require a large physical land space to build or retrofit the spray booths. Such spray booths must be located near the final ship assembly area (e.g., dry-dock or graving dock) to facilitate the logistics of moving the ship modules into place and attaching them to other modules. Large coating booths would not be effective at shipyards that perform repairs on finished vessels or during dockside coating, since only a small amount of the total coating could be applied in such spray booths.	OTC 2001a

* control efficiencies were rounded up to the closest whole number.

Source Category	Emission Reduction Measure Name	Control Efficiency (%)*	Cost Effectiveness (2006$/ton)**	Other Pollutants Controlled	Description/Notes/Caveats	References
Asphalt Manufacture	CEM Upgrade and Increased Monitoring Frequency of PM Controls	8	$5,763 per ton PM		This measure examines the impacts of improving the PM monitoring technique at units currently using an ESP, scrubber, or fabric filter. In this improved technique scenario, the monitoring technique is upgraded to a PM continuous emission monitor. This improved monitoring technique also results in an increase to the monitoring frequency because a PM CEMS can make a measurement every 7.5 minutes. The monitoring frequency increases from once per day to eight times per hour.	Barr and Schaffner, 2003, EPA 2000a
Asphalt Manufacture	Fabric Filter	99	$147-$186 per ton PM10		A fabric filter, or baghouse, consists of a number of fabric bags placed in parallel inside of an enclosure. Particulate matter is collected on the surface of the bags as the gas stream passes through them. The particulate is periodically removed from the bags and collected in hoppers located beneath the bags. A number of methods are employed to facilitate the removal of particulate from the bags, including shaking, reverse air flow, and pulse air flow. The only potential drawback to a fabric filter would be when used in conjunction with a high moisture flue gas stream or with extremely high temperatures. If moisture levels in the flue gas stream are too high then filter caking can occur. Cost-effectiveness varies depending on the type of filter (Reverse-Air Cleaned Type, Mech. Shaker Type, Pulse Jet Type) and is based on EPA's cost-estimating spreadsheet for fabric filters.	EPA 1998a; EPA 2000b; EPA 2000c; EPA 2000d;
Asphalt Manufacture	Increased Monitoring Frequency (IMF) of PM Controls	7	$687 per ton PM		This measure is to conduct improved monitoring for PM2.5 emissions at stationary sources. Improved monitoring in this case means increasing the monitoring frequency of electrostatic precipitators, scrubbers, and fabric filters from once per day to four times per hour, with no change in monitoring technique. The incremental costs included a one-time cost for development of the improved monitoring and recurring annual burden costs for incremental record keeping, reporting, and certification activities.	Barr and Schaffner, 2003, EPA 2000a
Catalytic Cracking Units	Venturi scrubber	90	$1,567		In a Venturi scrubber, water is injected into the flue gas stream at the Venturi throat to form droplets. Fly ash particles impact with the droplets to form a wet by-product which is then disposed of. The forceful contact resulting from the droplet dispersal (spray tower), contraction of the gas stream (Venturi) or counter current flow (collision), removes PM as well as SO2 from the flue gas. Condensation scrubbers are designed to control PM with a diameter of 0.25–1.0 µm. Venturi scrubbers are effective in controlling both PM10 and PM2.5.	EPA 2007a
Catalytic Cracking Units	SCAQMD Rule 1105.1	80	$5,805 per ton PM10	SO2	Rule 1105.1 for Fluid Catalytic Cracking Units sets emission limits for filterable PM10 at 0.005 grain/dscf, 2.8 lbs/1000 barrels of fresh feed, or 3.6 lbs/hour. The rule uses ammonia as a surrogate for condensable PM10, and sets the ammonia slip limit at 10 ppmv. Dry ESPs and wet gas scrubber are the control options to meet the rule emission limits (the wet gas scrubber is also used to control SO2.) The overall control efficiency for both filterable and condensable PM10 is 80%. The cost effectiveness is $5,238 per ton (2003$, DCF, Filterable & Condensable PM10), which was converted to 2006$.	SCAQMD 2012
Cement Manufacturing	Paper/Nonwoven Filters - Cartridge Collector Type	99	$179 per ton PM10		This control is the use of paper or non-woven filters (cartridge collector type) to reduce PM emissions. The waste gas stream is passed through the fibrous filter media causing PM in the gas stream to be collected on the media by sieving and other mechanisms. In general, the filter media is pleated to provide a larger surface area to volume flow rate. There are variety of cartridge designs and dimensions. Typical designs include flat panels, V-shaped packs or cylindrical packs. For certain applications, two cartridges may be placed in series. This control measure applies to cement manufacturing operations.	STAPPA/ALAPCO 2006; EPA 1998a; EPA 2000e
Cement Manufacturing - Internal roadways / areas	SCAQMD Rule 1156	50 - 80 for PM10			The purpose of this rule is to further reduce PM emissions from cement manufacturing facilities. This rule applies to all operations, materials handling, and transport at a cement manufacturing facility, including, but not limited to, kiln and clinker cooler, material storage, crushing, drying, screening, milling, conveying, bulk loading and unloading systems, internal roadways, material transport, and track-out. R1156 establishes opacity performance standards for all operations, and future PM emission limits for process equipment vented to baghouses. Additional features of the proposed rule are to specify compliance options for open storage piles, primary crushing operations, conveying systems, and a method of verifying and assuring compliance with the rule requirements. There are various control options to reduce track-out and fugitive dust (e.g. chemical suppressant).	STAPPA/ALAPCO 2006; SCAQMD 2005a, SCAQMD 2012
Cement Manufacturing - Primary crusher	SCAQMD Rule 1156	50 - 80 for PM10			The purpose of this rule is to further reduce PM emissions from cement manufacturing facilities. This rule applies to all operations, materials handling, and transport at a cement manufacturing facility, including, but not limited to, kiln and clinker cooler, material storage, crushing, drying, screening, milling, conveying, bulk loading and unloading systems, internal roadways, material transport, and track-out. R1156 establishes opacity performance standards for all operations, and future PM emission limits for process equipment vented to baghouses. Additional features of the proposed rule are to specify compliance options for open storage piles, primary crushing operations, conveying systems, and a method of verifying and assuring compliance with the rule requirements. For this specific source, the control options used in the SCAQMD rule include a wind fence and wetting.	STAPPA/ALAPCO 2006; SCAQMD 2005a, SCAQMD 2012
Cement Manufacturing - rushing, milling, grinding	SCAQMD Rule 1156	80 - 99.5 for PM10			The purpose of this rule is to further reduce PM emissions from cement manufacturing facilities. This rule applies to all operations, materials handling, and transport at a cement manufacturing facility, including, but not limited to, kiln and clinker cooler, material storage, crushing, drying, screening, milling, conveying, bulk loading and unloading systems, internal roadways, material transport, and track-out. R1156 establishes opacity performance standards for all operations, and future PM emission limits for process equipment vented to baghouses. Additional features of the proposed rule are to specify compliance options for open storage piles, primary crushing operations, conveying systems, and a method of verifying and assuring compliance with the rule requirements. For this specific source, the control options used in the SCAQMD rule include enclosing and venting emissions to baghouses.	This control is the use of low NOx burner (LNB) technology and selective non-catalytic reduction (SNCR) to reduce NOx emissions. LNBs reduce the amount of NOx created

Point & NonPoint PM
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Source Category	Emission Reduction Measure Name	Control Efficiency (%)*	Cost Effectiveness (2006$/ton)**	Other Pollutants Controlled	Description/Notes/Caveats	References
Cement Manufacturing - Storage piles	SCAQMD Rule 1156	95 - 99.5 for PM10			The purpose of this rule is to further reduce PM emissions from cement manufacturing facilities. This rule applies to all operations, materials handling, and transport at a cement manufacturing facility, including, but not limited to, kiln and clinker cooler, material storage, crushing, drying, screening, milling, conveying, bulk loading and unloading systems, internal roadways, material transport, and track-out. R1156 establishes opacity performance standards for all operations, and future PM emission limits for process equipment vented to baghouses. Additional features of the proposed rule are to specify compliance options for open storage piles, primary crushing operations, conveying systems, and a method of verifying and assuring compliance with the rule requirements. For this specific source, the control options used in the SCAQMD rule include enclosing and venting emissions to baghouses.	STAPPA/ALAPCO 2006; SCAQMD 2005a, SCAQMD 2012
Cement Manufacturing - Storage piles	SCAQMD Rule 1156	50 - 80 for PM10			The purpose of this rule is to further reduce PM emissions from cement manufacturing facilities. This rule applies to all operations, materials handling, and transport at a cement manufacturing facility, including, but not limited to, kiln and clinker cooler, material storage, crushing, drying, screening, milling, conveying, bulk loading and unloading systems, internal roadways, material transport, and track-out. R1156 establishes opacity performance standards for all operations, and future PM emission limits for process equipment vented to baghouses. Additional features of the proposed rule are to specify compliance options for open storage piles, primary crushing operations, conveying systems, and a method of verifying and assuring compliance with the rule requirements. For this specific source, the control options used in the SCAQMD rule include chemical suppressant, three-sided barriers with roof, or tarp	STAPPA/ALAPCO 2006; SCAQMD 2005a, SCAQMD 2012
Cement Manufacturing - Kilns/Clinker Coolers	SCAQMD Rule 1156	95 - 99.5 for PM10	$2,066 per ton PM10		The purpose of this rule is to further reduce PM emissions from cement manufacturing facilities. This rule applies to all operations, materials handling, and transport at a cement manufacturing facility, including, but not limited to, kiln and clinker cooler, material storage, crushing, drying, screening, milling, conveying, bulk loading and unloading systems, internal roadways, material transport, and track-out. R1156 establishes opacity performance standards for all operations, and future PM emission limits for process equipment vented to baghouses. Additional features of the proposed rule are to specify compliance options for open storage piles, primary crushing operations, conveying systems, and a method of verifying and assuring compliance with the rule requirements. For this specific source, the control option used in the SCAQMD rule is a baghouse.	STAPPA/ALAPCO 2006; SCAQMD 2005a, SCAQMD 2012
Cement Manufacturing - Cement Kiln	ESP (Electrostatic Precipitator)	90-99	$27-$86	Hg	An electrostatic precipitator applies electrical forces to separate suspended particles from the flue gas stream. The suspended particles are given an electrical charge by passing through a high voltage DC corona region in which gaseous ions flow. There are two general types of ESP: wire/plate and wire/pipe types. Further, ESPs come in both wet and dry configurations. Given the high pollutant loadings associated with cement operations, ESPs must be relatively large compared to the same technology used for utility boilers, and are more cost-effective.	STAPPA/ALAPCO 2006; LADCO 2005b
Cement Manufacturing - Cement Kiln	Fabric Filter	95-99.9	$34-$74		A fabric filter, or baghouse, consists of a number of fabric bags placed in parallel inside of an enclosure. Particulate matter is collected on the surface of the bags as the gas stream passes through them. The particulate is periodically removed from the bags and collected in hoppers located beneath the bags. A number of methods are employed to facilitate the removal of particulate from the bags, including shaking, reverse air flow, and pulse air flow. The only potential drawback to a fabric filter would be when used in conjunction with a high moisture flue gas stream or with extremely high temperatures. If moisture levels in the flue gas stream are too high then filter caking can occur. Given the high pollutant loadings associated with cement operations, fabric filters must be relatively large compared to the same technology used for utility boilers, and are more cost-effective.	STAPPA/ALAPCO 2006; LADCO 2005b
Cement Manufacturing - Non-Kiln PM Sources	Dust Collector	99			In order to capture fugitive PM emissions, material handling, grinding and storage operations must be enclosed and vented to the control device. Dust collectors are similar to fabric filters but have temperature restrictions (a limit of 200°F or 400°F, depending on the filter media) and are effective only on low-flow applications. However, dust collectors require less room than fabric filters or ESPs and are therefore useful for areas with space restrictions. For Portland cement facilities, dust cartridges are likely to only be technically feasible for lower temperature operations such as finish grinding mill weigh hoppers and air separators, coal kiln feed units, cement silos, clinker grinding, and primary and secondary crushing operations.	STAPPA/ALAPCO 2006; LADCO 2005b
Chemical Manufacture	CEM Upgrade and Increased Monitoring Frequency of PM Controls	8	$5,763 per ton PM		This measure examines the impacts of improving the PM monitoring technique at units currently using an ESP, scrubber, or fabric filter. In this improved technique scenario, the monitoring technique is upgraded to a PM continuous emission monitor. This improved monitoring technique also results in an increase to the monitoring frequency because a PM CEMS can make a measurement every 7.5 minutes. The monitoring frequency increases from once per day to eight times per hour.	Barr and Schaffner, 2003, EPA 2000a
Chemical Manufacture	Increased Monitoring Frequency (IMF) of PM Controls	7	$687 per ton PM		This measure is to conduct improved monitoring for PM2.5 emissions at stationary sources. Improved monitoring in this case means increasing the monitoring frequency of electrostatic precipitators, scrubbers, and fabric filters from once per day to four times per hour, with no change in monitoring technique. The incremental costs included a one-time cost for development of the improved monitoring and recurring annual burden costs for incremental record keeping, reporting, and certification activities.	Barr and Schaffner, 2003, EPA 2000a

Source Category	Emission Reduction Measure Name	Control Efficiency (%)*	Cost Effectiveness (2006$/ton)**	Other Pollutants Controlled	Description/Notes/Caveats	References
Chemical Manufacture	Wet Electrostatic Precipitator (ESP) - Wire Plate Type	95	$313 per ton PM10		An electrostatic precipitator applies electrical forces to separate suspended particles from the flue gas stream. The suspended particles are given an electrical charge by passing through a high voltage DC corona region in which gaseous ions flow. There are two general types of ESP: wire/plate and wire/pipe types. Further, ESPs come in both wet and dry configurations. This control is the use of Wet ESP Wire Plate Type. Unlike dry ESPs, resistivity of the collected material is not a major factor in performance. Because of the high humidity in a wet ESP, the resistivity of particles is lowered, eliminating the "back corona" condition. The frequent washing of the plates also limits particle buildup on the collectors. This control applies to various chemical manufacturing operations, including (but not limited to) adipic acid, ammonia, carbon black, charcoal, cleaners, phosphoric acids, plastics, sulfuric acid, sodium carbonate, ammonium nitrate, rubbers, ammonium phosphates, and inorganic pigments.	EPA1998a; EPA 1999a
Chemical Manufacture	Wet Electrostatic Precipitator (ESP) - Wire Plate Type	99.5			This control measure is the same as the dry ESP for this source category with a control efficiency of 95%. It is expected that by 2020, the control efficiency for this sytem will increase to 99.5% for PM2.5.	EPA1998a; EPA 1999a
Commercial Cooking	Catalytic Oxidizer	83	$3,252 per ton PM+VOC	VOC	This measure focuses on the control of PM (and VOC) emissions from chain driven charbroilers. The use of a catalytic oxidizer, placed above the charbroiler in the stack and activated by heat from the cooking, appears to be the best and most costeffective emission control device for chain-driven charbroilers. Testing in the South Coast has shown that the majority of PM10 emissions from charbroilers are measured at 2.5 microns and below.	Ventura County 2004; CE-CERT 2002; ARB 2005
Construction Activities	Dust Control Plan	37 (PM10 mainly)	$5,778 per ton PM10		The dust control plan includes chemical suppression and water treatment of disturbed soil at construction sites.	EPA 1974; Pechan 1997
Electric Generation	CEM Upgrade and Increased Monitoring Frequency of PM Controls	8	$5,763 per ton PM		This measure examines the impacts of improving the PM monitoring technique at units currently using an ESP, scrubber, or fabric filter. In this improved technique scenario, the monitoring technique is upgraded to a PM continuous emission monitor. This improved monitoring technique also results in an increase to the monitoring frequency because a PM CEMS can make a measurement every 7.5 minutes. The monitoring frequency increases from once per day to eight times per hour.	Barr and Schaffner, 2003, EPA 2000a
Electric Generation	Increased Monitoring Frequency (IMF) of PM Controls	7	$687 per ton PM		This measure is to conduct improved monitoring for PM2.5 emissions at stationary sources. Improved monitoring in this case means increasing the monitoring frequency of electrostatic precipitators, scrubbers, and fabric filters from once per day to four times per hour, with no change in monitoring technique. The incremental costs included a one-time cost for development of the improved monitoring and recurring annual burden costs for incremental record keeping, reporting, and certification activities.	Barr and Schaffner, 2003, EPA 2000a
Electric Generation - Coal	Indigo Agglomerator	40	Cost effectiveness is variable and based on plant size: - total capital cost of $12.8 per kW - fixed O&M costs of $0 per kW per year - variable O&M costs of $0.03 mills per kW per year		This device is installed in the high velocity duct ahead of an ESP and agglomerates the smaller particles with the larger particles, increasing the collection efficiency of the ESP for PM2.5. The estimate of control efficiency 40%, incremental to ESP controls. The capital and O&M costs are proportional to the capacity of the controlled unit.	Sorrels 2006
Electric Generation - Coal - bituminous	ESP upgrade - Level 1	5	Cost effectiveness is variable and based on plant size. Capital Cost: $55/kW.		The PM2.5 collection efficiency of an ESP can be increased by increasing the specific collecting area (SCA). The key technologies employed in the ESP level 1 upgrade include High Frequency transformer-rectifier (TR) sets. The capital costs associated with this control measure var depending on the capacity of the controlled unit. Costs listed here assume upgrading the specific collection area (SCA) to 250 square-feet/1000 afm (actual feet per minute). The percentage improvements in collection efficiency are additive in the sense that the values are added to the pre-upgrade collection efficiency to obtain the after-upgrade collection efficiency.	EPA 2011c
Electric Generation - Coal - bituminous	ESP upgrade - Level 2	10	Cost effectiveness is variable and based on plant size. Capital Cost: $80/kW.		The PM2.5 collection efficiency of an ESP can be increased by increasing the specific collecting area (SCA). The key technologies employed in the ESP level 2 upgrade include High Frequency transformer-rectifier (TR) sets and new internals (rigid electrodes, increased plate spacing, increased plate height). The capital costs associated with this control measure var depending on the capacity of the controlled unit. Costs listed here assume upgrading the specific collection area (SCA) to 300 square-feet/1000 afm (actual feet per minute). The percentage improvements in collection efficiency are additive in the sense that the values are added to the pre-upgrade collection efficiency to obtain the after-upgrade collection efficiency.	EPA 2011c
Electric Generation - Coal - bituminous	ESP upgrade - Level 3	20	Cost effectiveness is variable and based on plant size. Capital Cost: $100/kW.		The PM2.5 collection efficiency of an ESP can be increased by increasing the specific collecting area (SCA). The key technologies employed in the ESP level 3 upgrade include High Frequency transformer-rectifier (TR) sets, new internals (rigid electrodes, increased plate spacing, increased plate height), and an additional field. The capital costs associated with this control measure var depending on the capacity of the controlled unit. Costs listed here assume upgrading the existing specific collection area (SCA) by 100 square-feet/1000 afm (actual feet per minute), a 20% height increase, and an additional field. The percentage improvements in collection efficiency are additive in the sense that the values are added to the pre-upgrade collection efficiency to obtain the after-upgrade collection efficiency.	EPA 2011c

Source Category	Emission Reduction Measure Name	Control Efficiency (%)*	Cost Effectiveness (2006$/ton)**	Other Pollutants Controlled	Description/Notes/Caveats	References
Electric Generation - Coal - lignite	ESP upgrade - Level 1	1	Cost effectiveness is variable and based on plant size. Capital Cost: $55/kW.		The PM2.5 collection efficiency of an ESP can be increased by increasing the specific collecting area (SCA). The key technologies employed in the ESP level 1 upgrade include High Frequency transformer-rectifier (TR) sets. The capital costs associated with this control measure var depending on the capacity of the controlled unit. Costs listed here assume upgrading the specific collection area (SCA) to 250 square-feet/1000 afm (actual feet per minute). The percentage improvements in collection efficiency are additive in the sense that the values are added to the pre-upgrade collection efficiency to obtain the after-upgrade collection efficiency.	EPA 2011c
Electric Generation - Coal - lignite	ESP upgrade - Level 2	2	Cost effectiveness is variable and based on plant size. Capital Cost: $80/kW.		The PM2.5 collection efficiency of an ESP can be increased by increasing the specific collecting area (SCA). The key technologies employed in the ESP level 2 upgrade include High Frequency transformer-rectifier (TR) sets and new internals (rigid electrodes, increased plate spacing, increased plate height). The capital costs associated with this control measure var depending on the capacity of the controlled unit. Costs listed here assume upgrading the specific collection area (SCA) to 300 square-feet/1000 afm (actual feet per minute). The percentage improvements in collection efficiency are additive in the sense that the values are added to the pre-upgrade collection efficiency to obtain the after-upgrade collection efficiency.	EPA 2011c
Electric Generation - Coal - lignite	ESP upgrade - Level 3	5	Cost effectiveness is variable and based on plant size. Capital Cost: $100/kW.		The PM2.5 collection efficiency of an ESP can be increased by increasing the specific collecting area (SCA). The key technologies employed in the ESP level 3 upgrade include High Frequency transformer-rectifier (TR) sets, new internals (rigid electrodes, increased plate spacing, increased plate height), and an additional field. The capital costs associated with this control measure var depending on the capacity of the controlled unit. Costs listed here assume upgrading the existing specific collection area (SCA) by 100 square-feet/1000 afm (actual feet per minute), a 20% height increase, and an additional field. The percentage improvements in collection efficiency are additive in the sense that the values are added to the pre-upgrade collection efficiency to obtain the after-upgrade collection efficiency.	EPA 2011c
Electric Generation - Coal - subbituminous	ESP upgrade - Level 1	12	Cost effectiveness is variable and based on plant size. Capital Cost: $55/kW.		The PM2.5 collection efficiency of an ESP can be increased by increasing the specific collecting area (SCA). The key technologies employed in the ESP level 1 upgrade include High Frequency transformer-rectifier (TR) sets. The capital costs associated with this control measure var depending on the capacity of the controlled unit. Costs listed here assume upgrading the specific collection area (SCA) to 250 square-feet/1000 afm (actual feet per minute). The percentage improvements in collection efficiency are additive in the sense that the values are added to the pre-upgrade collection efficiency to obtain the after-upgrade collection efficiency.	EPA 2011c
Electric Generation - Coal - subbituminous	ESP upgrade - Level 2	25	Cost effectiveness is variable and based on plant size. Capital Cost: $80/kW.		The PM2.5 collection efficiency of an ESP can be increased by increasing the specific collecting area (SCA). The key technologies employed in the ESP level 2 upgrade include High Frequency transformer-rectifier (TR) sets and new internals (rigid electrodes, increased plate spacing, increased plate height). The capital costs associated with this control measure var depending on the capacity of the controlled unit. Costs listed here assume upgrading the specific collection area (SCA) to 300 square-feet/1000 afm (actual feet per minute). The percentage improvements in collection efficiency are additive in the sense that the values are added to the pre-upgrade collection efficiency to obtain the after-upgrade collection efficiency.	EPA 2011c
Electric Generation - Coal - subbituminous	ESP upgrade - Level 3	50	Cost effectiveness is variable and based on plant size. Capital Cost: $100/kW.		The PM2.5 collection efficiency of an ESP can be increased by increasing the specific collecting area (SCA). The key technologies employed in the ESP level 3 upgrade include High Frequency transformer-rectifier (TR) sets, new internals (rigid electrodes, increased plate spacing, increased plate height), and an additional field. The capital costs associated with this control measure var depending on the capacity of the controlled unit. Costs listed here assume upgrading the existing specific collection area (SCA) by 100 square-feet/1000 afm (actual feet per minute), a 20% height increase, and an additional field. The percentage improvements in collection efficiency are additive in the sense that the values are added to the pre-upgrade collection efficiency to obtain the after-upgrade collection efficiency.	EPA 2011c
External Combustion Boilers	Fuel Switching	80		SO2	This control transfers a home-heating oil fuel control to industrial boilers by substituting "red dye" distillate oil for high-sulfur fuel. Distillate has 500 ppm versus 2,500 to 3,000 ppm for high-sulfur diesel.The control applies to external combustion boilers.	EPA 2007a
Fabricated Metal Products - Abrasive Blasting	Paper/Nonwoven Filters - Cartridge Collector Type	99	$311 per ton PM10		This control is the use of paper or non-woven filters (cartridge collector type) to reduce PM emissions. The waste gas stream is passed through the fibrous filter media causing PM in the gas stream to be collected on the media by sieving and other mechanisms. In general, the filter media is pleated to provide a larger surface area to volume flow rate. There are variety of cartridge designs and dimensions. Typical designs include flat panels, V-shaped packs or cylindrical packs. For certain applications, two cartridges may be placed in series. This control measure applies to abrasive blasting operations as a part of fabricated metal products processing and production.	STAPPA/ALAPCO 2006; EPA 1998a; EPA 2000e
Fabricated Metal Products - Machining	Paper/Nonwoven Filters - Cartridge Collector Type	99	$244 per ton PM10		This control is the use of paper or non-woven filters (cartridge collector type) to reduce PM emissions. The waste gas stream is passed through the fibrous filter media causing PM in the gas stream to be collected on the media by sieving and other mechanisms. In general, the filter media is pleated to provide a larger surface area to volume flow rate. There are variety of cartridge designs and dimensions. Typical designs include flat panels, V-shaped packs or cylindrical packs. For certain applications, two cartridges may be placed in series. This control measure applies to machining operations as a part of fabricated metal products processing and production.	STAPPA/ALAPCO 2006; EPA 1998a; EPA 2000e

Source Category	Emission Reduction Measure Name	Control Efficiency (%)*	Cost Effectiveness (2006$/ton)**	Other Pollutants Controlled	Description/Notes/Caveats	References
Fabricated Metal Products - Welding	Paper/Nonwoven Filters - Cartridge Collector Type	99	$244 per ton PM10		This control is the use of paper or non-woven filters (cartridge collector type) to reduce PM emissions. The waste gas stream is passed through the fibrous filter media causing PM in the gas stream to be collected on the media by sieving and other mechanisms. In general, the filter media is pleated to provide a larger surface area to volume flow rate. There are variety of cartridge designs and dimensions. Typical designs include flat panels, V-shaped packs or cylindrical packs. For certain applications, two cartridges may be placed in series. This control measure applies to welding operations as a part of fabricated metal products processing and production.	STAPPA/ALAPCO 2006; EPA 1998a; EPA 2000e
Ferrous Metals Processing	CEM Upgrade and Increased Monitoring Frequency of PM Controls	8	$5,763 per ton PM		This measure examines the impacts of improving the PM monitoring technique at units currently using an ESP, scrubber, or fabric filter. In this improved technique scenario, the monitoring technique is upgraded to a PM continuous emission monitor. This improved monitoring technique also results in an increase to the monitoring frequency because a PM CEMS can make a measurement every 7.5 minutes. The monitoring frequency increases from once per day to eight times per hour.	Barr and Schaffner, 2003, EPA 2000a
Ferrous Metals Processing	Increased Monitoring Frequency (IMF) of PM Controls	7	$687 per ton PM		This measure is to conduct improved monitoring for PM2.5 emissions at stationary sources. Improved monitoring in this case means increasing the monitoring frequency of electrostatic precipitators, scrubbers, and fabric filters from once per day to four times per hour, with no change in monitoring technique. The incremental costs included a one-time cost for development of the improved monitoring and recurring annual burden costs for incremental record keeping, reporting, and certification activities.	Barr and Schaffner, 2003, EPA 2000a
Ferrous Metals Processing - Coke	Fabric Filter	99	$159-$186 per ton PM10		A fabric filter, or baghouse, consists of a number of fabric bags placed in parallel inside of an enclosure. Particulate matter is collected on the surface of the bags as the gas stream passes through them. The particulate is periodically removed from the bags and collected in hoppers located beneath the bags. A number of methods are employed to facilitate the removal of particulate from the bags, including shaking, reverse air flow, and pulse air flow. The only potential drawback to a fabric filter would be when used in conjunction with a high moisture flue gas stream or with extremely high temperatures. If moisture levels in the flue gas stream are too high then filter caking can occur. Cost-effectiveness varies depending on the type of filter (Reverse-Air Cleaned Type or Mech. Shaker Type) and is based on EPA's cost-estimating spreadsheet for fabric filters.	EPA 1998a; EPA 2000b; EPA 2000c
Ferrous Metals Processing - Coke	Venturi Scrubber	89	$1067 per ton PM10		In a Venturi scrubber, water is injected into the flue gas stream at the Venturi throat to form droplets. Fly ash particles impact with the droplets to form a wet by-product which is then disposed of. The forceful contact resulting from the droplet dispersal (spray tower), contraction of the gas stream (Venturi) or counter current flow (collision), removes PM as well as SO2 from the flue gas. Condensation scrubbers are designed to control PM with a diameter of 0.25–1.0 µm. Venturi scrubbers are effective in controlling both PM10 and PM2.5.	STAPPA/ALAPCO 2006; EPA 1998a; EPA 1999b
Ferrous Metals Processing - Ferroalloy Production	Dry Electrostatic Precipitator (ESP) - Wire Plate Type	95	$156 per ton PM10		An electrostatic precipitator applies electrical forces to separate suspended particles from the flue gas stream. The suspended particles are given an electrical charge by passing through a high voltage DC corona region in which gaseous ions flow. There are two general types of ESP: wire/plate and wire/pipe types. Further, ESPs come in both wet and dry configurations. This control is the use of Dry ESP Wire Plate Type. In dry ESPs, the collectors are knocked by various mechanical means to dislodge the particulate, which slides downward into a hopper. This control applies to ferroalloy production operations, including (but not limited to) several processes within this industry were selected for control, basic oxygen process furnace (SCC 30300914) and EAF argon O2 decarb vessels (SCC 30300928).	EPA 1998a; EPA 1999c
Ferrous Metals Processing - Ferroalloy Production	Dry Electrostatic Precipitator (ESP) - Wire Plate Type	99.5			This control measure is the same as the dry ESP for this source category with a control efficiency of 95%. It is expected that by 2020, the control efficiency for this sytem will increase to 99.5% for PM2.5.	EPA 1998a; EPA 1999c
Ferrous Metals Processing - Ferroalloy Production	Fabric Filter	99	$159-$186 per ton PM10		A fabric filter, or baghouse, consists of a number of fabric bags placed in parallel inside of an enclosure. Particulate matter is collected on the surface of the bags as the gas stream passes through them. The particulate is periodically removed from the bags and collected in hoppers located beneath the bags. A number of methods are employed to facilitate the removal of particulate from the bags, including shaking, reverse air flow, and pulse air flow. The only potential drawback to a fabric filter would be when used in conjunction with a high moisture flue gas stream or with extremely high temperatures. If moisture levels in the flue gas stream are too high then filter caking can occur. Cost-effectiveness varies depending on the type of filter (Reverse-Air Cleaned Type or Mech. Shaker Type) and is based on EPA's cost-estimating spreadsheet for fabric filters.	EPA 1998a; EPA 2000b; EPA 2000c
Ferrous Metals Processing - Gray Iron Foundaries	Fabric Filter	99	$159-$186 per ton PM10		A fabric filter, or baghouse, consists of a number of fabric bags placed in parallel inside of an enclosure. Particulate matter is collected on the surface of the bags as the gas stream passes through them. The particulate is periodically removed from the bags and collected in hoppers located beneath the bags. A number of methods are employed to facilitate the removal of particulate from the bags, including shaking, reverse air flow, and pulse air flow. The only potential drawback to a fabric filter would be when used in conjunction with a high moisture flue gas stream or with extremely high temperatures. If moisture levels in the flue gas stream are too high then filter caking can occur. Cost-effectiveness varies depending on the type of filter (Reverse-Air Cleaned Type or Mech. Shaker Type) and is based on EPA's cost-estimating spreadsheet for fabric filters.	EPA 1998a; EPA 2000b; EPA 2000c

Source Category	Emission Reduction Measure Name	Control Efficiency (%)*	Cost Effectiveness (2006$/ton)**	Other Pollutants Controlled	Description/Notes/Caveats	References
Ferrous Metals Processing - Gray Iron Foundaries	Impingement-Plate Scrubber	64	$613 per ton PM10		This control is the use of an impingement-plate scrubber to reduce PM emissions. An impingement-plate scrubber is a vertical chamber with plates mounted horizontally inside a hollow shell. Impingement-plate scrubbers operate as countercurrent PM collection devices. The scrubbing liquid flows down the tower while the gas stream flows upward. Contact between the liquid and the particle-laden gas occurs on the plates. The plates are equipped with openings that allow the gas to pass through. Some plates are perforated or slotted, while more complex plates have valve-like openings.	EPA 1998a; EPA 1999d
Ferrous Metals Processing - Gray Iron Foundaries	Venturi Scrubber	94	$1067 per ton PM10		In a Venturi scrubber, water is injected into the flue gas stream at the Venturi throat to form droplets. Fly ash particles impact with the droplets to form a wet by-product which is then disposed of. The forceful contact resulting from the droplet dispersal (spray tower), contraction of the gas stream (Venturi) or counter current flow (collision), removes PM as well as SO2 from the flue gas. Condensation scrubbers are designed to control PM with a diameter of 0.25–1.0 µm. Venturi scrubbers are effective in controlling both PM10 and PM2.5.	STAPPA/ALAPCO 2006; EPA 1998a; EPA 1999b
Ferrous Metals Processing - Iron & Steel Production	Dry Electrostatic Precipitator (ESP) - Wire Plate Type	95	$156 per ton PM10		An electrostatic precipitator applies electrical forces to separate suspended particles from the flue gas stream. The suspended particles are given an electrical charge by passing through a high voltage DC corona region in which gaseous ions flow. There are two general types of ESP: wire/plate and wire/pipe types. Further, ESPs come in both wet and dry configurations. This control is the use of Dry ESP Wire Plate Type. In dry ESPs, the collectors are knocked by various mechanical means to dislodge the particulate, which slides downward into a hopper.	EPA 1998a; EPA 1999c
Ferrous Metals Processing - Iron & Steel Production	Dry Electrostatic Precipitator (ESP) - Wire Plate Type	99.5			This control measure is the same as the dry ESP for this source category with a control efficiency of 95%. It is expected that by 2020, the control efficiency for this sytem will increase to 99.5% for PM2.5.	EPA 1998a; EPA 1999c
Ferrous Metals Processing - Iron & Steel Production	Fabric Filter	99	$147-$186 per ton PM10		A fabric filter, or baghouse, consists of a number of fabric bags placed in parallel inside of an enclosure. Particulate matter is collected on the surface of the bags as the gas stream passes through them. The particulate is periodically removed from the bags and collected in hoppers located beneath the bags. A number of methods are employed to facilitate the removal of particulate from the bags, including shaking, reverse air flow, and pulse air flow. The only potential drawback to a fabric filter would be when used in conjunction with a high moisture flue gas stream or with extremely high temperatures. If moisture levels in the flue gas stream are too high then filter caking can occur. Cost-effectiveness varies depending on the type of filter (Reverse-Air Cleaned Type, Mech. Shaker Type, Pulse Jet Type) and is based on EPA's cost-estimating spreadsheet for fabric filters.	EPA 1998a; EPA 2000b; EPA 2000c; EPA 2000d;
Ferrous Metals Processing - Iron & Steel Production	Venturi Scrubber	25	$1067 per ton PM10		In a Venturi scrubber, water is injected into the flue gas stream at the Venturi throat to form droplets. Fly ash particles impact with the droplets to form a wet by-product which is then disposed of. The forceful contact resulting from the droplet dispersal (spray tower), contraction of the gas stream (Venturi) or counter current flow (collision), removes PM as well as SO2 from the flue gas. Condensation scrubbers are designed to control PM with a diameter of 0.25–1.0 µm. Venturi scrubbers are effective in controlling both PM10 and PM2.5.	STAPPA/ALAPCO 2006; EPA 1998a; EPA 1999b
Ferrous Metals Processing - Iron & Steel Production	Wet Electrostatic Precipitator (ESP) - Wire Plate Type	95	$313 per ton PM10		An electrostatic precipitator applies electrical forces to separate suspended particles from the flue gas stream. The suspended particles are given an electrical charge by passing through a high voltage DC corona region in which gaseous ions flow. There are two general types of ESP: wire/plate and wire/pipe types. Further, ESPs come in both wet and dry configurations. This control is the use of Wet ESP Wire Plate Type. Unlike dry ESPs, resistivity of the collected material is not a major factor in performance. Because of the high humidity in a wet ESP, the resistivity of particles is lowered, eliminating the "back corona" condition. The frequent washing of the plates also limits particle buildup on the collectors.	EPA1998a; EPA 1999a
Ferrous Metals Processing - Iron & Steel Production	Wet Electrostatic Precipitator (ESP) - Wire Plate Type	99.5			This control measure is the same as the dry ESP for this source category with a control efficiency of 95%. It is expected that by 2020, the control efficiency for this sytem will increase to 99.5% for PM2.5.	EPA1998a; EPA 1999a
Ferrous Metals Processing - Iron and Steel Production	Capture Hood Vented to a Baghouse	85	Not available		This control is the addition of a capture hood to a preinstalled baghouse. The cost effectiveness is variable depending on the emissions. Uncertainty relatively high. Based on engineering judgments and MACT data which for some plants may be outdated.	Pechan 2008
Ferrous Metals Processing - Iron and Steel Production	Secondary Capture and Control System	85	Not available		This control is the addition of a secondary capture and control system for PM. The cost effectiveness is variable depending on the emissions. Uncertainty relatively high. Based on engineering judgments and MACT data which for some plants may be outdated.	Pechan 2008
Ferrous Metals Processing - Iron and Steel Production	Sinter Cooler	99	$5,771		The cost effectiveness is variable depending on the emissions. Uncertainty relatively high. Based on engineering judgments and MACT data which for some plants may be outdated.	Pechan 2008
Ferrous Metals Processing - Steel Foundaries	Venturi Scrubber	25	$1067 per ton PM10		In a Venturi scrubber, water is injected into the flue gas stream at the Venturi throat to form droplets. Fly ash particles impact with the droplets to form a wet by-product which is then disposed of. The forceful contact resulting from the droplet dispersal (spray tower), contraction of the gas stream (Venturi) or counter current flow (collision), removes PM as well as SO2 from the flue gas. Condensation scrubbers are designed to control PM with a diameter of 0.25–1.0 µm. Venturi scrubbers are effective in controlling both PM10 and PM2.5.	STAPPA/ALAPCO 2006; EPA 1998a; EPA 1999b

Source Category	Emission Reduction Measure Name	Control Efficiency (%)*	Cost Effectiveness (2006$/ton)**	Other Pollutants Controlled	Description/Notes/Caveats	References
Ferrous Metals Processing - Steel Foundries	Fabric Filter	99	$147-$186 per ton PM10		A fabric filter, or baghouse, consists of a number of fabric bags placed in parallel inside of an enclosure. Particulate matter is collected on the surface of the bags as the gas stream passes through them. The particulate is periodically removed from the bags and collected in hoppers located beneath the bags. A number of methods are employed to facilitate the removal of particulate from the bags, including shaking, reverse air flow, and pulse air flow. The only potential drawback to a fabric filter would be when used in conjunction with a high moisture flue gas stream or with extremely high temperatures. If moisture levels in the flue gas stream are too high then filter caking can occur. Cost-effectiveness varies depending on the type of filter (Reverse-Air Cleaned Type, Mech. Shaker Type, Pulse Jet Type) and is based on EPA's cost-estimating spreadsheet for fabric filters.	EPA 1998a; EPA 2000b; EPA 2000c; EPA 2000d;
Fireplaces	Install EPA Phase 2 Qualified Units	70	$9,500 (2012$)	CO2, VOC's,CO CH4, Toxics	If new wood-burning fireplace construction is allowed, only allow EPA Phase 2 qualified models. A Partnership Agreement (PA) is in place between EPA and wood-burning fireplace manufacturers. Under this PA, cleaner wood-burning fireplaces are qualified when their PM2.5 emissions are at or below the Phase 2 PM2.5 emissions level. Control effeciency (%) applies to an individual fireplace. Cost effectiveness is based on the incremental cost of installing a Phase 2 qualified fireplace instead of a non-Phase 2 fireplace. For a list of EPA Phase 2 qualified fireplaces go to: http://www.epa.gov/burnwise/fireplacelist.html.	http://epa.gov/burnwise/resources.html
Fireplaces	Install Gas Logs in Existing Wood-burning Fireplaces	100	$11,000 (2012$)	CO2, VOC's,CO CH4, Toxics, BC	Incentives by various air districts in CA have helped retrofit thousands of wood-burning fireplaces to gas log sets. Control efficiency (%) applies to an individual fireplace. Cost-effectiveness reflects converrting a wood-burning fireplace to a gas log burning fireplace.	http://epa.gov/burnwise/resources.html
Fireplaces	Install Retrofit Devices into Wood-burning Fireplaces	70	$9,500 (2012$)	CO2, VOC's,CO CH4, Toxics	Provide incentives to encourage the installation of fireplace retrofit devices. Under the EPA Wood-burning fireplace PA, a retrofit devices is qualified when it lowers fireplace PM2.5 emissions to at or below the program Phase 2 PM2.5 emissions level. Conntrol efficiency (%) applies to an individual fireplace retrofit device. For a list of EPA Phase 2 qualified fireplace retrofit devices go to: http://www.epa.gov/burnwise/fireplacelist.html.	http://epa.gov/burnwise/resources.html
Fireplaces, Hydronic Heaters, Wood Stoves	Curtailment Program ("Burn Ban")	75	$8,700 (2010$)	CO2, VOC's,CO CH4, Toxics, BC	State and local air quality agencies forecast next day air quality levels. When it is expected to be near or above the 24-hr PM2.5 NAAQS, limited (e.g., wood pellet only) or full curtailment of wood burning is required. A public awareness campaign and enforcement are critical. Control efficiency (%) applies to the entire local area where the cutailment program is implemented.	http://epa.gov/burnwise/resources.html
Fireplaces, Hydronic Heaters, Wood Stoves	Burn Dry Seasoned Wood	n/a	n/a	CO2, VOC's,CO CH4, Toxics, BC	Implement a program to only allow the sale of and/or burning of dry seasoned wood (e.g., <20% moisture content) in wood-burning appliances.	http://epa.gov/burnwise/resources.html
Fireplaces, Hydronic Heaters, Wood Stoves	No visible Emissions	n/a	n/a	CO2, VOC's,CO CH4, Toxics, BC	Implement a local program that allows no visible wood smoke. This option is typically easier to enforce/implement than an opacity program	http://epa.gov/burnwise/resources.html
Fireplaces, Hydronic Heaters, Wood Stoves	Opacity Program	n/a	n/a	CO2, VOC's,CO CH4, Toxics, BC	Implement a local program that limits opacity from individual residential wood combustion appliances.	http://epa.gov/burnwise/resources.html
Grain Milling	Fabric Filter	99 (PM10 mainly)	$147-$186 per ton PM10		A fabric filter, or baghouse, consists of a number of fabric bags placed in parallel inside of an enclosure. Particulate matter is collected on the surface of the bags as the gas stream passes through them. The particulate is periodically removed from the bags and collected in hoppers located beneath the bags. A number of methods are employed to facilitate the removal of particulate from the bags, including shaking, reverse air flow, and pulse air flow. The only potential drawback to a fabric filter would be when used in conjunction with a high moisture flue gas stream or with extremely high temperatures. If moisture levels in the flue gas stream are too high then filter caking can occur. Cost-effectiveness varies depending on the type of filter (Reverse-Air Cleaned Type, Pulse Jet Type) and is based on EPA's cost-estimating spreadsheet for fabric filters. This control applies to grain milling operations, including (but not limited to), wheat, dry corn, wet corn, rice, and soybean operations.	EPA 1998a; EPA 2000b; EPA 2000d;
Grain Milling	Paper/Nonwoven Filters - Cartridge Collector Type	99 (PM10 mainly)	$179 per ton PM10		This control is the use of paper or non-woven filters (cartridge collector type) to reduce PM emissions. The waste gas stream is passed through the fibrous filter media causing PM in the gas stream to be collected on the media by sieving and other mechanisms. In general, the filter media is pleated to provide a larger surface area to volume flow rate. There are variety of cartridge designs and dimensions. Typical designs include flat panels, V-shaped packs or cylindrical packs. For certain applications, two cartridges may be placed in series. This control measure applies to machining operations as a part of fabricated metal products processing and production. This control applies to grain milling operations, including (but not limited to), wheat, dry corn, wet corn, rice, and soybean operations.	STAPPA/ALAPCO 2006; EPA 1998a; EPA 2000e
Hydronic Heaters (OWHH, OWB)	Install Cleaner Wood-burning Hydronic Heaters vs. Old Technology	90	$740 (2012)	CO2, VOC's,CO CH4, Toxics	If hydronic heaters are allowed, only allow EPA Phase 2 qualified models. A Partnership Agreement (PA) is in place between EPA and wood-burning hydronic heater manufacturers. Under this PA, cleaner burning hydronic heaters are qualified at or below the Phase 2 particulate emissions level. Control effeciency (%) applies to an individual hydronic heater. Cost effectiveness is based on the incremental cost of installing a Phase 2 qualified hydronic heater instead of a non-Phase 2 hydronic heater. For a list of Phase 2 qualified hydronic heaters, go to: http://www.epa.gov/burnwise/owhhlist.html.	http://epa.gov/burnwise/resources.html

Source Category	Emission Reduction Measure Name	Control Efficiency (%)*	Cost Effectiveness (2006$/ton)**	Other Pollutants Controlled	Description/Notes/Caveats	References
Hydronic Heaters (OWHH, OWB)	Install Retrofit Devices in Existing Hydronic Heaters	60	$980 (2012)	CO2, VOC's,CO CH4, Toxics	Provide incentives to encourage the installation of hydronic heater retrofit devices. Retrofits may significantly reduce and even eliminate visible smoke emissions. Control efficiency (%) applies to an individual hydronic heater.	http://epa.gov/burnwise/resources.html
IC Engine- diesel generator	Diesel Oxidation Catalyst (DOC)	20 for PM2.5	$1,108-$2,216 per ton combined CO, HC, NOx, PM	VOC, CO	The principle behind oxidation catalysts is that they reduce emissions by causing chemical reactions without themselves being changed or consumed. A DOC system typically consists of a steel housing that contains a metal or ceramic structure which acts as a catalyst support or substrate. Catalysts transform pollutants into harmless gases by causing chemical reactions in the exhaust stream. Diesel oxidation catalysts serve to reduce PM, CO, HC and toxic HC emissions. PM emissions are reduced by the chemical transformation of their soluble organic fraction to carbon dioxide and water.	NESCAUM 2003a
IC Engine- diesel generator	Diesel Oxidation Catalyst (DOC)	20 for PM10	$1,108-$2,216 per ton combined CO, HC, NOx, PM	VOC, CO	The principle behind oxidation catalysts is that they reduce emissions by causing chemical reactions without themselves being changed or consumed. A DOC system typically consists of a steel housing that contains a metal or ceramic structure which acts as a catalyst support or substrate. Catalysts transform pollutants into harmless gases by causing chemical reactions in the exhaust stream. Diesel oxidation catalysts serve to reduce PM, CO, HC and toxic HC emissions. PM emissions are reduced by the chemical transformation of their soluble organic fraction to carbon dioxide and water.	NESCAUM 2003a
IC Engine- diesel generator	Diesel Particulate Filter (DPF)	80-90	$5,540-$21,055 per ton combined CO, HC, PM	VOC, CO	Diesel particulate filters remove particulate matter in diesel exhaust by filtering exhaust from the engine. Since a filter can fill up over time, these systems must provide a means of burning off or removing accumulated particulate matter. A convenient means of accomplishing this is to burn or oxidize accumulated particulate matter on the filter when exhaust temperatures are adequate. By burning off trapped material, the filter is cleaned or "regenerated." Filters that regenerate in this fashion cannot be used in all situations. Both exhaust gas temperature and fuel sulfur level must be taken into consideration. DPFs can only be used with engines using ultra low sulfur diesel and thus do not apply to all vintage engines	NESCAUM 2003a
IC Engine- diesel generator	DPF + SCR (Selective Catalytic Reduction)	80-90	$25,488-$99,736 per ton combined CO, HC, NOx, PM	VOC, NOx, CO	This measure is the combination of a DPF and a Selective Catalytic Reduction (SCR) system, which reduces NOx emissions (as well as HC, CO, and PM emissions). DPFs can only be used with engines using ultra low sulfur diesel and thus do not apply to all vintage engines.	NESCAUM 2003a
ICI Boilers - Coal, Wood, Oil	CEM Upgrade and Increased Monitoring Frequency of PM Controls	8	$5,763 per ton PM		This measure examines the impacts of improving the PM monitoring technique at units currently using an ESP, scrubber, or fabric filter. In this improved technique scenario, the monitoring technique is upgraded to a PM continuous emission monitor. This improved monitoring technique also results in an increase to the monitoring frequency because a PM CEMS can make a measurement every 7.5 minutes. The monitoring frequency increases from once per day to eight times per hour.	Barr and Schaffner, 2003, EPA 2000a
ICI Boilers - Coal, Wood, Oil	Increased Monitoring Frequency (IMF) of PM Controls	7	$687 per ton PM		This measure is to conduct improved monitoring for PM2.5 emissions at stationary sources. Improved monitoring in this case means increasing the monitoring frequency of electrostatic precipitators, scrubbers, and fabric filters from once per day to four times per hour, with no change in monitoring technique. The incremental costs included a one-time cost for development of the improved monitoring and recurring annual burden costs for incremental record keeping, reporting, and certification activities.	Barr and Schaffner, 2003, EPA 2000a
ICI Boilers-Coal	ESP (Electrostatic Precipitator)	96-99	$40-$591	Hg	An electrostatic precipitator applies electrical forces to separate suspended particles from the flue gas stream. The suspended particles are given an electrical charge by passing through a high voltage DC corona region in which gaseous ions flow. There are two general types of ESP: wire/plate and wire/pipe types. Further, ESPs come in both wet and dry configurations. Efficiency and cost-effectiveness are based on utility boiler estimates.	STAPPA/ALAPCO 2006; LADCO 2005b
ICI Boilers-Coal	Fabric Filter	95-99.9	$42-$383		A fabric filter, or baghouse, consists of a number of fabric bags placed in parallel inside of an enclosure. Particulate matter is collected on the surface of the bags as the gas stream passes through them. The particulate is periodically removed from the bags and collected in hoppers located beneath the bags. A number of methods are employed to facilitate the removal of particulate from the bags, including shaking, reverse air flow, and pulse air flow. The only potential drawback to a fabric filter would be when used in conjunction with a high moisture flue gas stream or with extremely high temperatures. If moisture levels in the flue gas stream are too high then filter caking can occur. Efficiency and cost-effectiveness are based on utility boiler estimates.	STAPPA/ALAPCO 2006; LADCO 2005b
ICI Boilers-Coal	Fuel switching away from coal: bituminous coal to distillate oil	99		SO2, NOx	Development measure from PM NAAQS RIA. Fuel substitution involves replacing the current fuel with a fuel which emits less of a given pollutant when burned. For many older boilers, fuel switching is an especially attractive option because the capital investment is usually small when compared to that of control devices. This control measure involves switching from bituminous coal to distillate oil (Distillate Oil is No. 2 fuel oil)	EPA 1998a
ICI Boilers-Coal	Fuel switching away from coal: bituminous coal to natural gas	93		SO2, NOx	Development measure from PM NAAQS RIA. Fuel substitution involves replacing the current fuel with a fuel which emits less of a given pollutant when burned. For many older boilers, fuel switching is an especially attractive option because the capital investment is usually small when compared to that of control devices. This control measure involves switching from bituminous coal to natural gas.	EPA 1998a
ICI Boilers-Coal	Fuel switching away from coal: bituminous coal to residual oil	7		SO2, NOx	Development measure from PM NAAQS RIA. Fuel substitution involves replacing the current fuel with a fuel which emits less of a given pollutant when burned. For many older boilers, fuel switching is an especially attractive option because the capital investment is usually small when compared to that of control devices. This control measure involves switching from bituminous coal to residual oil (Residual Oil includes No. 4, 5, and 6 fuel oil.)	EPA 1998a

Source Category	Emission Reduction Measure Name	Control Efficiency (%)*	Cost Effectiveness (2006$/ton)**	Other Pollutants Controlled	Description/Notes/Caveats	References
ICI Boilers-Coal	Fuel switching away from coal: bituminous coal to subbituminous	21		SO2, NOx	Development measure from PM NAAQS RIA. Fuel substitution involves replacing the current fuel with a fuel which emits less of a given pollutant when burned. For many older boilers, fuel switching is an especially attractive option because the capital investment is usually small when compared to that of control devices. This control measure involves switching from bituminous coal to subbituminous.	EPA 1998a
ICI Boilers-Coal	Fuel switching away from coal: residual oil to distillate oil	99		SO2, NOx	Development measure from PM NAAQS RIA. Fuel substitution involves replacing the current fuel with a fuel which emits less of a given pollutant when burned. For many older boilers, fuel switching is an especially attractive option because the capital investment is usually small when compared to that of control devices. This control measure involves switching from residual oil to distillate oil.	EPA 1998a
ICI Boilers-Coal	Fuel switching away from coal: residual oil to natural gas	93		SO2, NOx	Development measure from PM NAAQS RIA. Fuel substitution involves replacing the current fuel with a fuel which emits less of a given pollutant when burned. For many older boilers, fuel switching is an especially attractive option because the capital investment is usually small when compared to that of control devices. This control measure involves switching from residual oil to natural gas.	EPA 1998a
ICI Boilers-Coal	Fuel switching away from coal: subbituminous coal to distillate oil	99		SO2, NOx	Development measure from PM NAAQS RIA. Fuel substitution involves replacing the current fuel with a fuel which emits less of a given pollutant when burned. For many older boilers, fuel switching is an especially attractive option because the capital investment is usually small when compared to that of control devices. This control measure involves switching from subbituminous coal to distillate oil.	EPA 1998a
ICI Boilers-Coal	Fuel switching away from coal: subbituminous coal to natural gas	91		SO2, NOx	Development measure from PM NAAQS RIA. Fuel substitution involves replacing the current fuel with a fuel which emits less of a given pollutant when burned. For many older boilers, fuel switching is an especially attractive option because the capital investment is usually small when compared to that of control devices. This control measure involves switching from subbituminous coal to natural gas.	EPA 1998a
ICI Boilers-Wood	ESP (Electrostatic Precipitator)	95-99	$118-$614		An electrostatic precipitator applies electrical forces to separate suspended particles from the flue gas stream. The suspended particles are given an electrical charge by passing through a high voltage DC corona region in which gaseous ions flow. There are two general types of ESP: wire/plate and wire/pipe types. Further, ESPs come in both wet and dry configurations.	STAPPA/ALAPCO 2006
ICI Boilers-Wood	Fabric Filter	95-99.9	$94-$990		A fabric filter, or baghouse, consists of a number of fabric bags placed in parallel inside of an enclosure. Particulate matter is collected on the surface of the bags as the gas stream passes through them. The particulate is periodically removed from the bags and collected in hoppers located beneath the bags. A number of methods are employed to facilitate the removal of particulate from the bags, including shaking, reverse air flow, and pulse air flow. The only potential drawback to a fabric filter would be when used in conjunction with a high moisture flue gas stream or with extremely high temperatures. If moisture levels in the flue gas stream are too high then filter caking can occur.	STAPPA/ALAPCO 2006
ICI Boilers-Wood	Wet Scrubber	90	$41-$1,270	SO2	The two most frequently utilized wet scrubbers for PM control are condensation scrubbers and venturi scrubbers. In a Venturi scrubber, water is injected into the flue gas stream at the Venturi throat to form droplets. Fly ash particles impact with the droplets to form a wet by-product which is then disposed of. The forceful contact resulting from the droplet dispersal (spray tower), contraction of the gas stream (Venturi) or counter current flow (collision), removes PM as well as SO2 from the flue gas. Condensation scrubbers are designed to control PM with a diameter of 0.25–1.0 µm. Venturi scrubbers are effective in controlling both PM10 and PM2.5.	STAPPA/ALAPCO 2006
Industrial Boilers - Liquid Waste	Dry Electrostatic Precipitator (ESP) - Wire Plate Type	95	$156 per ton PM10		An electrostatic precipitator applies electrical forces to separate suspended particles from the flue gas stream. The suspended particles are given an electrical charge by passing through a high voltage DC corona region in which gaseous ions flow. There are two general types of ESP: wire/plate and wire/pipe types. Further, ESPs come in both wet and dry configurations. This control is the use of Dry ESP Wire Plate Type. In dry ESPs, the collectors are knocked by various mechanical means to dislodge the particulate, which slides downward into a hopper. This control applies operations that have industrial boilers fired with liquid waste, including waste oil.	EPA 1998a; EPA 1999c
Industrial Boilers - Liquid Waste	Dry Electrostatic Precipitator (ESP) - Wire Plate Type	99.5			This control measure is the same as the dry ESP for this source category with a control efficiency of 95%. It is expected that by 2020, the control efficiency for this sytem will increase to 99.5% for PM2.5.	EPA 1998a; EPA 1999c
Industrial Boilers - Oil	Dry Electrostatic Precipitator (ESP) - Wire Plate Type	95	$156 per ton PM10		An electrostatic precipitator applies electrical forces to separate suspended particles from the flue gas stream. The suspended particles are given an electrical charge by passing through a high voltage DC corona region in which gaseous ions flow. There are two general types of ESP: wire/plate and wire/pipe types. Further, ESPs come in both wet and dry configurations. This control is the use of Dry ESP Wire Plate Type. In dry ESPs, the collectors are knocked by various mechanical means to dislodge the particulate, which slides downward into a hopper. This control applies operations with oil-fired boilers.	EPA 1998a; EPA 1999c
Industrial Boilers - Oil	Dry Electrostatic Precipitator (ESP) - Wire Plate Type	99.5			This control measure is the same as the dry ESP for this source category with a control efficiency of 95%. It is expected that by 2020, the control efficiency for this sytem will increase to 99.5% for PM2.5.	EPA 1998a; EPA 1999c
Industrial Boilers - Oil	Venturi Scrubber	25	$1067 per ton PM10		In a Venturi scrubber, water is injected into the flue gas stream at the Venturi throat to form droplets. Fly ash particles impact with the droplets to form a wet by-product which is then disposed of. The forceful contact resulting from the droplet dispersal (spray tower), contraction of the gas stream (Venturi) or counter current flow (collision), removes PM as well as SO2 from the flue gas. Condensation scrubbers are designed to control PM with a diameter of 0.25–1.0 µm. Venturi scrubbers are effective in controlling both PM10 and PM2.5. This control applies operations with oil-fired boilers.	STAPPA/ALAPCO 2006; EPA 1998a; EPA 1999b

Source Category	Emission Reduction Measure Name	Control Efficiency (%)*	Cost Effectiveness (2006$/ton)**	Other Pollutants Controlled	Description/Notes/Caveats	References
Mineral Products	CEM Upgrade and Increased Monitoring Frequency of PM Controls	8	$5,763 per ton PM		This measure examines the impacts of improving the PM monitoring technique at units currently using an ESP, scrubber, or fabric filter. In this improved technique scenario, the monitoring technique is upgraded to a PM continuous emission monitor. This improved monitoring technique also results in an increase to the monitoring frequency because a PM CEMS can make a measurement every 7.5 minutes. The monitoring frequency increases from once per day to eight times per hour.	Barr and Schaffner, 2003, EPA 2000a
Mineral Products	Increased Monitoring Frequency (IMF) of PM Controls	7	$687 per ton PM		This measure is to conduct improved monitoring for PM2.5 emissions at stationary sources. Improved monitoring in this case means increasing the monitoring frequency of electrostatic precipitators, scrubbers, and fabric filters from once per day to four times per hour, with no change in monitoring technique. The incremental costs included a one-time cost for development of the improved monitoring and recurring annual burden costs for incremental record keeping, reporting, and certification activities.	Barr and Schaffner, 2003, EPA 2000a
Mineral Products - Coal Cleaning	Fabric Filter	99	$147-$186 per ton PM10		A fabric filter, or baghouse, consists of a number of fabric bags placed in parallel inside of an enclosure. Particulate matter is collected on the surface of the bags as the gas stream passes through them. The particulate is periodically removed from the bags and collected in hoppers located beneath the bags. A number of methods are employed to facilitate the removal of particulate from the bags, including shaking, reverse air flow, and pulse air flow. The only potential drawback to a fabric filter would be when used in conjunction with a high moisture flue gas stream or with extremely high temperatures. If moisture levels in the flue gas stream are too high then filter caking can occur. Cost-effectiveness varies depending on the type of filter (Reverse-Air Cleaned Type, Mech. Shaker Type, Pulse Jet Type) and is based on EPA's cost-estimating spreadsheet for fabric filters. This control applies to coal cleaning at coal mining operations. Coal mining, cleaning and material handling (305010) consists of the preparation and handling of coal to upgrade its value.	EPA 1998a; EPA 2000b; EPA 2000c; EPA 2000d;
Mineral Products - Coal Cleaning	Paper/Nonwoven Filters - Cartridge Collector Type	99	$179 per ton PM10		This control is the use of paper or non-woven filters (cartridge collector type) to reduce PM emissions. The waste gas stream is passed through the fibrous filter media causing PM in the gas stream to be collected on the media by sieving and other mechanisms. In general, the filter media is pleated to provide a larger surface area to volume flow rate. There are variety of cartridge designs and dimensions. Typical designs include flat panels, V-shaped packs or cylindrical packs. For certain applications, two cartridges may be placed in series. This control measure applies to machining operations as a part of fabricated metal products processing and production. This control applies to coal cleaning at coal mining operations. Coal mining, cleaning and material handling (305010) consists of the preparation and handling of coal to upgrade its value.	STAPPA/ALAPCO 2006; EPA 1998a; EPA 2000e
Mineral Products - Coal Cleaning	Venturi Scrubber	98	$1067 per ton PM10		In a Venturi scrubber, water is injected into the flue gas stream at the Venturi throat to form droplets. Fly ash particles impact with the droplets to form a wet by-product which is then disposed of. The forceful contact resulting from the droplet dispersal (spray tower), contraction of the gas stream (Venturi) or counter current flow (collision), removes PM as well as SO2 from the flue gas. Condensation scrubbers are designed to control PM with a diameter of 0.25–1.0 µm. Venturi scrubbers are effective in controlling both PM10 and PM2.5. This control applies to coal cleaning processes at coal mining operations. Coal mining, cleaning and material handling (305010) consists of the preparation and handling of coal to upgrade its value. For the purpose of this study, thermal dryers, pneumatic coal cleaning and truck/vehicle travel are the sources considered.	STAPPA/ALAPCO 2006; EPA 1998a; EPA 1999b
Mineral Products - Miscellaneous Mineral Production Operations	Dry Electrostatic Precipitator (ESP) - Wire Plate Type	95	$156 per ton PM10		An electrostatic precipitator applies electrical forces to separate suspended particles from the flue gas stream. The suspended particles are given an electrical charge by passing through a high voltage DC corona region in which gaseous ions flow. There are two general types of ESP: wire/plate and wire/pipe types. Further, ESPs come in both wet and dry configurations. This control is the use of Dry ESP Wire Plate Type. In dry ESPs, the collectors are knocked by various mechanical means to dislodge the particulate, which slides downward into a hopper. This control applies to miscellaneous mineral production operations including (but not limited to) brick manufacture, calcium carbide operations, clay and fly ash sintering, concrete batching, gypsum manufacturing, lime production, phosphate rock operations, sand production, fiberglass manufacturing and glass manufacturing operations. Materials handling operations including crushing, grinding, and screening, can produce significant PM emissions.	EPA 1998a; EPA 1999c
Mineral Products - Miscellaneous Mineral Production Operations	Dry Electrostatic Precipitator (ESP) - Wire Plate Type	99.5			This control measure is the same as the dry ESP for this source category with a control efficiency of 95%. It is expected that by 2020, the control efficiency for this sytem will increase to 99.5% for PM2.5.	EPA 1998a; EPA 1999c
Mineral Products - Miscellaneous Mineral Production Operations	Fabric Filter	99	$147-$186 per ton PM10		A fabric filter, or baghouse, consists of a number of fabric bags placed in parallel inside of an enclosure. Particulate matter is collected on the surface of the bags as the gas stream passes through them. The particulate is periodically removed from the bags and collected in hoppers located beneath the bags. A number of methods are employed to facilitate the removal of particulate from the bags, including shaking, reverse air flow, and pulse air flow. The only potential drawback to a fabric filter would be when used in conjunction with a high moisture flue gas stream or with extremely high temperatures. If moisture levels in the flue gas stream are too high then filter caking can occur. Cost-effectiveness varies depending on the type of filter (Reverse-Air Cleaned Type, Mech. Shaker Type, Pulse Jet Type) and is based on EPA's cost-estimating spreadsheet for fabric filters. This control applies to miscellaneous mineral production operations including (but not limited to) brick manufacture, calcium carbide operations, clay and fly ash sintering, concrete batching, gypsum manufacturing, lime production, phosphate rock operations, sand production, fiberglass manufacturing and glass manufacturing operations. Materials handling operations including crushing, grinding, and screening, can produce significant PM emissions.	EPA 1998a; EPA 2000b; EPA 2000c; EPA 2000d;

Source Category	Emission Reduction Measure Name	Control Efficiency (%)*	Cost Effectiveness (2006$/ton)**	Other Pollutants Controlled	Description/Notes/Caveats	References
Mineral Products - Miscellaneous Mineral Production Operations	Paper/Nonwoven Filters - Cartridge Collector Type	99	$179 per ton PM10		This control is the use of paper or non-woven filters (cartridge collector type) to reduce PM emissions. The waste gas stream is passed through the fibrous filter media causing PM in the gas stream to be collected on the media by sieving and other mechanisms. In general, the filter media is pleated to provide a larger surface area to volume flow rate. There are variety of cartridge designs and dimensions. Typical designs include flat panels, V-shaped packs or cylindrical packs. For certain applications, two cartridges may be placed in series. This control measure applies to machining operations as a part of fabricated metal products processing and production. This control applies to miscellaneous mineral production operations including (but not limited to) brick manufacture, calcium carbide operations, clay and fly ash sintering, concrete batching, gypsum manufacturing, lime production, phosphate rock operations, sand production, fiberglass manufacturing and glass manufacturing operations. Materials handling operations including crushing, grinding, and screening, can produce significant PM emissions.	STAPPA/ALAPCO 2006; EPA 1998a; EPA 2000e
Mineral Products - Miscellaneous Mineral Production Operations	Wet Electrostatic Precipitator (ESP) - Wire Plate Type	95	$313 per ton PM10		An electrostatic precipitator applies electrical forces to separate suspended particles from the flue gas stream. The suspended particles are given an electrical charge by passing through a high voltage DC corona region in which gaseous ions flow. There are two general types of ESP: wire/plate and wire/pipe types. Further, ESPs come in both wet and dry configurations. This control is the use of Wet ESP Wire Plate Type. Unlike dry ESPs, resistivity of the collected material is not a major factor in performance. Because of the high humidity in a wet ESP, the resistivity of particles is lowered, eliminating the "back corona" condition. The frequent washing of the plates also limits particle buildup on the collectors. This control applies to miscellaneous mineral production operations including (but not limited to) brick manufacture, calcium carbide operations, clay and fly ash sintering, concrete batching, gypsum manufacturing, lime production, phosphate rock operations, sand production, fiberglass manufacturing and glass manufacturing operations. Materials handling operations including crushing, grinding, and screening, can produce significant PM emissions.	EPA1998a; EPA 1999a
Mineral Products - Miscellaneous Mineral Production Operations	Wet Electrostatic Precipitator (ESP) - Wire Plate Type	99.5			This control measure is the same as the dry ESP for this source category with a control efficiency of 95%. It is expected that by 2020, the control efficiency for this sytem will increase to 99.5% for PM2.5.	EPA1998a; EPA 1999a
Mineral Products - Stone Quarrying & Processing	Dry Electrostatic Precipitator (ESP) - Wire Plate Type	95 (PM10 mainly)	$156 per ton PM10		An electrostatic precipitator applies electrical forces to separate suspended particles from the flue gas stream. The suspended particles are given an electrical charge by passing through a high voltage DC corona region in which gaseous ions flow. There are two general types of ESP: wire/plate and wire/pipe types. Further, ESPs come in both wet and dry configurations. This control is the use of Dry ESP Wire Plate Type. In dry ESPs, the collectors are knocked by various mechanical means to dislodge the particulate, which slides downward into a hopper. This control applies to stone quarrying and processing operations. Nonmetallic Mineral Processing (305020) - ore crushing, grinding, and screening, and Calciners (SCC 305150) and Dryers (SCC 30502012) are considered in this category. Materials handling operations including crushing, grinding, and screening, can produce significant PM emissions.	EPA 1998a; EPA 1999c
Mineral Products - Stone Quarrying & Processing	Dry Electrostatic Precipitator (ESP) - Wire Plate Type	99.5 (PM10 mainly)			This control measure is the same as the dry ESP for this source category with a control efficiency of 95%. It is expected that by 2020, the control efficiency for this sytem will increase to 99.5% for PM2.5.	EPA 1998a; EPA 1999c
Mineral Products - Stone Quarrying & Processing	Fabric Filter	99 (PM10 mainly)	$147-$186 per ton PM10		A fabric filter, or baghouse, consists of a number of fabric bags placed in parallel inside of an enclosure. Particulate matter is collected on the surface of the bags as the gas stream passes through them. The particulate is periodically removed from the bags and collected in hoppers located beneath the bags. A number of methods are employed to facilitate the removal of particulate from the bags, including shaking, reverse air flow, and pulse air flow. The only potential drawback to a fabric filter would be when used in conjunction with a high moisture flue gas stream or with extremely high temperatures. If moisture levels in the flue gas stream are too high then filter caking can occur. Cost-effectiveness varies depending on the type of filter (Reverse-Air Cleaned Type, Mech. Shaker Type, Pulse Jet Type) and is based on EPA's cost-estimating spreadsheet for fabric filters. This control applies to stone quarrying and processing operations. Nonmetallic Mineral Processing (305020) - ore crushing, grinding, and screening, and Calciners (SCC 305150) and Dryers (SCC 30502012) are considered in this category. Materials handling operations including crushing, grinding, and screening, can produce significant PM emissions.	EPA 1998a; EPA 2000b; EPA 2000c; EPA 2000d;
Mineral Products - Stone Quarrying & Processing	Paper/Nonwoven Filters - Cartridge Collector Type	99 (PM10 mainly)	$179 per ton PM10		This control is the use of paper or non-woven filters (cartridge collector type) to reduce PM emissions. The waste gas stream is passed through the fibrous filter media causing PM in the gas stream to be collected on the media by sieving and other mechanisms. In general, the filter media is pleated to provide a larger surface area to volume flow rate. There are variety of cartridge designs and dimensions. Typical designs include flat panels, V-shaped packs or cylindrical packs. For certain applications, two cartridges may be placed in series. This control applies to stone quarrying and processing operations. Nonmetallic Mineral Processing (305020) - ore crushing, grinding, and screening, and Calciners (SCC 305150) and Dryers (SCC 30502012) are considered in this category. Materials handling operations including crushing, grinding, and screening, can produce significant PM emissions.	STAPPA/ALAPCO 2006; EPA 1998a; EPA 2000e
Mineral Products - Stone Quarrying & Processing	Venturi Scrubber	90 (PM10 mainly)	$1067 per ton PM10		In a Venturi scrubber, water is injected into the flue gas stream at the Venturi throat to form droplets. Fly ash particles impact with the droplets to form a wet by-product which is then disposed of. The forceful contact resulting from the droplet dispersal (spray tower), contraction of the gas stream (Venturi) or counter current flow (collision), removes PM as well as SO2 from the flue gas. Condensation scrubbers are designed to control PM with a diameter of 0.25–1.0 µm. Venturi scrubbers are effective in controlling both PM10 and PM2.5. This control applies to stone quarrying and processing operations. Nonmetallic Mineral Processing (305020) - ore crushing, grinding, and screening, and Calciners (SCC 305150) and Dryers (SCC 30502012) are considered in this category. Materials handling operations including crushing, grinding, and screening, can produce significant PM emissions.	STAPPA/ALAPCO 2006; EPA 1998a; EPA 1999b

Source Category	Emission Reduction Measure Name	Control Efficiency (%)*	Cost Effectiveness (2006$/ton)**	Other Pollutants Controlled	Description/Notes/Caveats	References
Mineral Products - Stone Quarrying & Processing	Wet Electrostatic Precipitator (ESP) - Wire Plate Type	95 (PM10 mainly)	$313 per ton PM10		An electrostatic precipitator applies electrical forces to separate suspended particles from the flue gas stream. The suspended particles are given an electrical charge by passing through a high voltage DC corona region in which gaseous ions flow. There are two general types of ESP: wire/plate and wire/pipe types. Further, ESPs come in both wet and dry configurations. This control is the use of Wet ESP Wire Plate Type. Unlike dry ESPs, resistivity of the collected material is not a major factor in performance. Because of the high humidity in a wet ESP, the resistivity of particles is lowered, eliminating the "back corona" condition. The frequent washing of the plates also limits particle buildup on the collectors. This control applies to stone quarrying and processing operations. Nonmetallic Mineral Processing (305020) - ore crushing, grinding, and screening, and Calciners (SCC 305150) and Dryers (SCC 30502012) are considered in this category. Materials handling operations including crushing, grinding, and screening, can produce significant PM emissions.	EPA1998a; EPA 1999a
Mineral Products - Stone Quarrying & Processing	Wet Electrostatic Precipitator (ESP) - Wire Plate Type	99.5 (PM10 mainly)			This control measure is the same as the dry ESP for this source category with a control efficiency of 95%. It is expected that by 2020, the control efficiency for this sytem will increase to 99.5% for PM2.5.	EPA1998a; EPA 1999a
Municipal Waste Incineration	Dry Electrostatic Precipitator (ESP) - Wire Plate Type	95	$156 per ton PM10		An electrostatic precipitator applies electrical forces to separate suspended particles from the flue gas stream. The suspended particles are given an electrical charge by passing through a high voltage DC corona region in which gaseous ions flow. There are two general types of ESP: wire/plate and wire/pipe types. Further, ESPs come in both wet and dry configurations. This control is the use of Dry ESP Wire Plate Type. In dry ESPs, the collectors are knocked by various mechanical means to dislodge the particulate, which slides downward into a hopper. This control applies to municipal waste incineration operations classified under SCCs: 50100101, 50100102, 50100103, 50100105, and 50100107.	EPA 1998a; EPA 1999c
Municipal Waste Incineration	Dry Electrostatic Precipitator (ESP) - Wire Plate Type	99.5			This control measure is the same as the dry ESP for this source category with a control efficiency of 95%. It is expected that by 2020, the control efficiency for this sytem will increase to 99.5% for PM2.5.	EPA 1998a; EPA 1999c
Non-Ferrous Metals Processing	CEM Upgrade and Increased Monitoring Frequency of PM Controls	8	$5,763 per ton PM		This measure examines the impacts of improving the PM monitoring technique at units currently using an ESP, scrubber, or fabric filter. In this improved technique scenario, the monitoring technique is upgraded to a PM continuous emission monitor. This improved monitoring technique also results in an increase to the monitoring frequency because a PM CEMS can make a measurement every 7.5 minutes. The monitoring frequency increases from once per day to eight times per hour.	Barr and Schaffner, 2003, EPA 2000a
Non-Ferrous Metals Processing	Increased Monitoring Frequency (IMF) of PM Controls	7	$687 per ton PM		This measure is to conduct improved monitoring for PM2.5 emissions at stationary sources. Improved monitoring in this case means increasing the monitoring frequency of electrostatic precipitators, scrubbers, and fabric filters from once per day to four times per hour, with no change in monitoring technique. The incremental costs included a one-time cost for development of the improved monitoring and recurring annual burden costs for incremental record keeping, reporting, and certification activities.	Barr and Schaffner, 2003, EPA 2000a
Non-Ferrous Metals Processing - Aluminum	Dry Electrostatic Precipitator (ESP) - Wire Plate Type	95	$156 per ton PM10		An electrostatic precipitator applies electrical forces to separate suspended particles from the flue gas stream. The suspended particles are given an electrical charge by passing through a high voltage DC corona region in which gaseous ions flow. There are two general types of ESP: wire/plate and wire/pipe types. Further, ESPs come in both wet and dry configurations. This control is the use of Dry ESP Wire Plate Type. In dry ESPs, the collectors are knocked by various mechanical means to dislodge the particulate, which slides downward into a hopper. This control applies to aluminum processing operations.	EPA 1998a; EPA 1999c
Non-Ferrous Metals Processing - Aluminum	Dry Electrostatic Precipitator (ESP) - Wire Plate Type	99.5			This control measure is the same as the dry ESP for this source category with a control efficiency of 95%. It is expected that by 2020, the control efficiency for this sytem will increase to 99.5% for PM2.5.	EPA 1998a; EPA 1999c
Non-Ferrous Metals Processing - Aluminum	Fabric Filter	99	$159-$186 per ton PM10		A fabric filter, or baghouse, consists of a number of fabric bags placed in parallel inside of an enclosure. Particulate matter is collected on the surface of the bags as the gas stream passes through them. The particulate is periodically removed from the bags and collected in hoppers located beneath the bags. A number of methods are employed to facilitate the removal of particulate from the bags, including shaking, reverse air flow, and pulse air flow. The only potential drawback to a fabric filter would be when used in conjunction with a high moisture flue gas stream or with extremely high temperatures. If moisture levels in the flue gas stream are too high then filter caking can occur. Cost-effectiveness varies depending on the type of filter (Reverse-Air Cleaned Type or Mech. Shaker Type) and is based on EPA's cost-estimating spreadsheet for fabric filters. This control applies to aluminum processing operations.	EPA 1998a; EPA 2000b; EPA 2000c
Non-Ferrous Metals Processing - Aluminum	Wet Electrostatic Precipitator (ESP) - Wire Plate Type	95	$313 per ton PM10		An electrostatic precipitator applies electrical forces to separate suspended particles from the flue gas stream. The suspended particles are given an electrical charge by passing through a high voltage DC corona region in which gaseous ions flow. There are two general types of ESP: wire/plate and wire/pipe types. Further, ESPs come in both wet and dry configurations. This control is the use of Wet ESP Wire Plate Type. Unlike dry ESPs, resistivity of the collected material is not a major factor in performance. Because of the high humidity in a wet ESP, the resistivity of particles is lowered, eliminating the "back corona" condition. The frequent washing of the plates also limits particle buildup on the collectors. This control applies to aluminum processing operations.	EPA1998a; EPA 1999a
Non-Ferrous Metals Processing - Aluminum	Wet Electrostatic Precipitator (ESP) - Wire Plate Type	99.5			This control measure is the same as the dry ESP for this source category with a control efficiency of 95%. It is expected that by 2020, the control efficiency for this sytem will increase to 99.5% for PM2.5.	EPA1998a; EPA 1999a

Source Category	Emission Reduction Measure Name	Control Efficiency (%)*	Cost Effectiveness (2006$/ton)**	Other Pollutants Controlled	Description/Notes/Caveats	References
Non-Ferrous Metals Processing - Copper	Dry Electrostatic Precipitator (ESP) - Wire Plate Type	95	$156 per ton PM10		An electrostatic precipitator applies electrical forces to separate suspended particles from the flue gas stream. The suspended particles are given an electrical charge by passing through a high voltage DC corona region in which gaseous ions flow. There are two general types of ESP: wire/plate and wire/pipe types. Further, ESPs come in both wet and dry configurations. This control is the use of Dry ESP Wire Plate Type. In dry ESPs, the collectors are knocked by various mechanical means to dislodge the particulate, which slides downward into a hopper. This control applies to copper alloy processing operations.	EPA 1998a; EPA 1999c
Non-Ferrous Metals Processing - Copper	Dry Electrostatic Precipitator (ESP) - Wire Plate Type	99.5			This control measure is the same as the dry ESP for this source category with a control efficiency of 95%. It is expected that by 2020, the control efficiency for this sytem will increase to 99.5% for PM2.5.	EPA 1998a; EPA 1999c
Non-Ferrous Metals Processing - Copper	Fabric Filter	99	$159-$186 per ton PM10		A fabric filter, or baghouse, consists of a number of fabric bags placed in parallel inside of an enclosure. Particulate matter is collected on the surface of the bags as the gas stream passes through them. The particulate is periodically removed from the bags and collected in hoppers located beneath the bags. A number of methods are employed to facilitate the removal of particulate from the bags, including shaking, reverse air flow, and pulse air flow. The only potential drawback to a fabric filter would be when used in conjunction with a high moisture flue gas stream or with extremely high temperatures. If moisture levels in the flue gas stream are too high then filter caking can occur. Cost-effectiveness varies depending on the type of filter (Reverse-Air Cleaned Type or Mech. Shaker Type) and is based on EPA's cost-estimating spreadsheet for fabric filters. This control applies to copper alloy processing operations.	EPA 1998a; EPA 2000b; EPA 2000c
Non-Ferrous Metals Processing - Copper	Wet Electrostatic Precipitator (ESP) - Wire Plate Type	95	$313 per ton PM10		An electrostatic precipitator applies electrical forces to separate suspended particles from the flue gas stream. The suspended particles are given an electrical charge by passing through a high voltage DC corona region in which gaseous ions flow. There are two general types of ESP: wire/plate and wire/pipe types. Further, ESPs come in both wet and dry configurations. This control is the use of Wet ESP Wire Plate Type. Unlike dry ESPs, resistivity of the collected material is not a major factor in performance. Because of the high humidity in a wet ESP, the resistivity of particles is lowered, eliminating the "back corona" condition. The frequent washing of the plates also limits particle buildup on the collectors. This control applies to copper alloy processing operations.	EPA1998a; EPA 1999a
Non-Ferrous Metals Processing - Copper	Wet Electrostatic Precipitator (ESP) - Wire Plate Type	99.5			This control measure is the same as the dry ESP for this source category with a control efficiency of 95%. It is expected that by 2020, the control efficiency for this sytem will increase to 99.5% for PM2.5.	EPA1998a; EPA 1999a
Non-Ferrous Metals Processing - Lead	Dry Electrostatic Precipitator (ESP) - Wire Plate Type	95	$156 per ton PM10		An electrostatic precipitator applies electrical forces to separate suspended particles from the flue gas stream. The suspended particles are given an electrical charge by passing through a high voltage DC corona region in which gaseous ions flow. There are two general types of ESP: wire/plate and wire/pipe types. Further, ESPs come in both wet and dry configurations. This control is the use of Dry ESP Wire Plate Type. In dry ESPs, the collectors are knocked by various mechanical means to dislodge the particulate, which slides downward into a hopper. This control applies to lead processing operations.	EPA 1998a; EPA 1999c
Non-Ferrous Metals Processing - Lead	Dry Electrostatic Precipitator (ESP) - Wire Plate Type	99.5			This control measure is the same as the dry ESP for this source category with a control efficiency of 95%. It is expected that by 2020, the control efficiency for this sytem will increase to 99.5% for PM2.5.	EPA 1998a; EPA 1999c
Non-Ferrous Metals Processing - Lead	Fabric Filter	99	$159-$186 per ton PM10		A fabric filter, or baghouse, consists of a number of fabric bags placed in parallel inside of an enclosure. Particulate matter is collected on the surface of the bags as the gas stream passes through them. The particulate is periodically removed from the bags and collected in hoppers located beneath the bags. A number of methods are employed to facilitate the removal of particulate from the bags, including shaking, reverse air flow, and pulse air flow. The only potential drawback to a fabric filter would be when used in conjunction with a high moisture flue gas stream or with extremely high temperatures. If moisture levels in the flue gas stream are too high then filter caking can occur. Cost-effectiveness varies depending on the type of filter (Reverse-Air Cleaned Type or Mech. Shaker Type) and is based on EPA's cost-estimating spreadsheet for fabric filters. This control applies to lead processing operations.	EPA 1998a; EPA 2000b; EPA 2000c
Non-Ferrous Metals Processing - Lead	Wet Electrostatic Precipitator (ESP) - Wire Plate Type	95	$313 per ton PM10		An electrostatic precipitator applies electrical forces to separate suspended particles from the flue gas stream. The suspended particles are given an electrical charge by passing through a high voltage DC corona region in which gaseous ions flow. There are two general types of ESP: wire/plate and wire/pipe types. Further, ESPs come in both wet and dry configurations. This control is the use of Wet ESP Wire Plate Type. Unlike dry ESPs, resistivity of the collected material is not a major factor in performance. Because of the high humidity in a wet ESP, the resistivity of particles is lowered, eliminating the "back corona" condition. The frequent washing of the plates also limits particle buildup on the collectors. This control applies to lead processing operations.	EPA1998a; EPA 1999a
Non-Ferrous Metals Processing - Lead	Wet Electrostatic Precipitator (ESP) - Wire Plate Type	99.5			This control measure is the same as the dry ESP for this source category with a control efficiency of 95%. It is expected that by 2020, the control efficiency for this sytem will increase to 99.5% for PM2.5.	EPA1998a; EPA 1999a
Non-Ferrous Metals Processing - Other	Dry Electrostatic Precipitator (ESP) - Wire Plate Type	95	$156 per ton PM10		An electrostatic precipitator applies electrical forces to separate suspended particles from the flue gas stream. The suspended particles are given an electrical charge by passing through a high voltage DC corona region in which gaseous ions flow. There are two general types of ESP: wire/plate and wire/pipe types. Further, ESPs come in both wet and dry configurations. This control is the use of Dry ESP Wire Plate Type. In dry ESPs, the collectors are knocked by various mechanical means to dislodge the particulate, which slides downward into a hopper. This control applies to miscellaneous non-ferrous metals processing operations, including molybdenum, titanium, gold, barium ore, lead battery, magnesium, nickel, electrode manufacture and metal heat treating operations.	EPA 1998a; EPA 1999c

Source Category	Emission Reduction Measure Name	Control Efficiency (%)*	Cost Effectiveness (2006$/ton)**	Other Pollutants Controlled	Description/Notes/Caveats	References
Non-Ferrous Metals Processing - Other	Dry Electrostatic Precipitator (ESP) - Wire Plate Type	99.5			This control measure is the same as the dry ESP for this source category with a control efficiency of 95%. It is expected that by 2020, the control efficiency for this sytem will increase to 99.5% for PM2.5.	EPA 1998a; EPA 1999c
Non-Ferrous Metals Processing - Other	Fabric Filter	99	$159-$186 per ton PM10		A fabric filter, or baghouse, consists of a number of fabric bags placed in parallel inside of an enclosure. Particulate matter is collected on the surface of the bags as the gas stream passes through them. The particulate is periodically removed from the bags and collected in hoppers located beneath the bags. A number of methods are employed to facilitate the removal of particulate from the bags, including shaking, reverse air flow, and pulse air flow. The only potential drawback to a fabric filter would be when used in conjunction with a high moisture flue gas stream or with extremely high temperatures. If moisture levels in the flue gas stream are too high then filter caking can occur. Cost-effectiveness varies depending on the type of filter (Reverse-Air Cleaned Type or Mech. Shaker Type) and is based on EPA's cost-estimating spreadsheet for fabric filters. This control applies to miscellaneous non-ferrous metals processing operations, including molybdenum, titanium, gold, barium ore, lead battery, magnesium, nickel, electrode manufacture and metal heat treating operations.	EPA 1998a; EPA 2000b; EPA 2000c
Non-Ferrous Metals Processing - Other	Wet Electrostatic Precipitator (ESP) - Wire Plate Type	95	$313 per ton PM10		An electrostatic precipitator applies electrical forces to separate suspended particles from the flue gas stream. The suspended particles are given an electrical charge by passing through a high voltage DC corona region in which gaseous ions flow. There are two general types of ESP: wire/plate and wire/pipe types. Further, ESPs come in both wet and dry configurations. This control is the use of Wet ESP Wire Plate Type. Unlike dry ESPs, resistivity of the collected material is not a major factor in performance. Because of the high humidity in a wet ESP, the resistivity of particles is lowered, eliminating the "back corona" condition. The frequent washing of the plates also limits particle buildup on the collectors. This control applies to miscellaneous non-ferrous metals processing operations, including molybdenum, titanium, gold, barium ore, lead battery, magnesium, nickel, electrode manufacture and metal heat treating operations.	EPA1998a; EPA 1999a
Non-Ferrous Metals Processing - Other	Wet Electrostatic Precipitator (ESP) - Wire Plate Type	99.5			This control measure is the same as the dry ESP for this source category with a control efficiency of 95%. It is expected that by 2020, the control efficiency for this sytem will increase to 99.5% for PM2.5.	EPA1998a; EPA 1999a
Non-Ferrous Metals Processing - Zinc	Dry Electrostatic Precipitator (ESP) - Wire Plate Type	95	$156 per ton PM10		An electrostatic precipitator applies electrical forces to separate suspended particles from the flue gas stream. The suspended particles are given an electrical charge by passing through a high voltage DC corona region in which gaseous ions flow. There are two general types of ESP: wire/plate and wire/pipe types. Further, ESPs come in both wet and dry configurations. This control is the use of Dry ESP Wire Plate Type. In dry ESPs, the collectors are knocked by various mechanical means to dislodge the particulate, which slides downward into a hopper. This control applies to zinc processing operations.	EPA 1998a; EPA 1999c
Non-Ferrous Metals Processing - Zinc	Dry Electrostatic Precipitator (ESP) - Wire Plate Type	99.5			This control measure is the same as the dry ESP for this source category with a control efficiency of 95%. It is expected that by 2020, the control efficiency for this sytem will increase to 99.5% for PM2.5.	EPA 1998a; EPA 1999c
Non-Ferrous Metals Processing - Zinc	Fabric Filter	99	$159-$186 per ton PM10		A fabric filter, or baghouse, consists of a number of fabric bags placed in parallel inside of an enclosure. Particulate matter is collected on the surface of the bags as the gas stream passes through them. The particulate is periodically removed from the bags and collected in hoppers located beneath the bags. A number of methods are employed to facilitate the removal of particulate from the bags, including shaking, reverse air flow, and pulse air flow. The only potential drawback to a fabric filter would be when used in conjunction with a high moisture flue gas stream or with extremely high temperatures. If moisture levels in the flue gas stream are too high then filter caking can occur. Cost-effectiveness varies depending on the type of filter (Reverse-Air Cleaned Type or Mech. Shaker Type) and is based on EPA's cost-estimating spreadsheet for fabric filters. This control applies to zinc processing operations.	EPA 1998a; EPA 2000b; EPA 2000c
Non-Ferrous Metals Processing - Zinc	Wet Electrostatic Precipitator (ESP) - Wire Plate Type	95	$313 per ton PM10		An electrostatic precipitator applies electrical forces to separate suspended particles from the flue gas stream. The suspended particles are given an electrical charge by passing through a high voltage DC corona region in which gaseous ions flow. There are two general types of ESP: wire/plate and wire/pipe types. Further, ESPs come in both wet and dry configurations. This control is the use of Wet ESP Wire Plate Type. Unlike dry ESPs, resistivity of the collected material is not a major factor in performance. Because of the high humidity in a wet ESP, the resistivity of particles is lowered, eliminating the "back corona" condition. The frequent washing of the plates also limits particle buildup on the collectors. This control applies to zinc processing operations.	EPA1998a; EPA 1999a
Non-Ferrous Metals Processing - Zinc	Wet Electrostatic Precipitator (ESP) - Wire Plate Type	99.5			This control measure is the same as the dry ESP for this source category with a control efficiency of 95%. It is expected that by 2020, the control efficiency for this sytem will increase to 99.5% for PM2.5.	EPA1998a; EPA 1999a
Open Burning	Substitution of chipping, shredding, and landfilling for open burning	50-100	$4,219	NOx	Development measure from PM NAAQS RIA. This measure requires residents to either landfill or chip and shred yard waste instead of burning it (this is related to open burning of land clearing debris for developments). This substitution can substantially reduce directly-emitted PM2.5. Landfill costs based upon limited cost information. Average landfill costs, and average debris/acre, may not well represent costs in some locations. Significant uncertainties exist in emissions factors for open burning.	EPA 2006a
Paved Roads	Limit the purchase of new street sweepers to PM10 efficient units	31	$37 per ton PM10		This control measure requires that all purchases of new or replacement street sweepers be limited to PM10-efficient units. Efficiency is incremental to the use of sweepers failing to qualify to certification standards and the cost-effectiveness is for purchasing and operating a certified unit instead of a non-certified unit. Efficiency and cost-effectiveness calculations are based on San Joaquin Valley Rule 8061.	San Joaquin Valley UAPCD 2003

Source Category	Emission Reduction Measure Name	Control Efficiency (%)*	Cost Effectiveness (2006$/ton)**	Other Pollutants Controlled	Description/Notes/Caveats	References
Paved Roads	Require 4 foot paved/stabilized shoulders	42-98	If required on all new paved roads: $15,677-$629,336 per ton PM10. If required on 50% of highest ADVT existing paved roads: $8,281-$12,837 per ton PM10.		This control measure requires that all new or modified paved roads be constructed with paved shoulders that vary in width between 4 and 8 feet depending on projected traffic levels,or the construction of paved or stabilized shoulders on existing paved roads with dirt shoulders (the 50% of road mileage that carried the most traffic). Efficiency and cost-effectiveness calculations are based on San Joaquin Valley Rule 8061.	San Joaquin Valley UAPCD 2003
Paved Roads	Require wind- and water-borne deposition to be removed within 24 hours of discovery	8	$3,238 per ton PM10		Under this control measure, counties and cities would be required to respond within 24 hours to any deposition of soil onto public paved roads carried by wind or water erosion. Efficiency and cost-effectiveness calculations are based on San Joaquin Valley Rule 8061.	San Joaquin Valley UAPCD 2003
Paved Roads	Street Sweeping	25 (PM10 mainly)	$1,216 per ton PM10		Vacuum sweeping is a road surface cleaning operation that removes loose material from the roadway, preventing it from becoming airborne particulate when vehicles travel over the road surface. This control measure requires municipalities to sweep streets at least once per month with PM10 efficient units. Cost-effectiveness calculations are based on San Joaquin Valley Rule 8061.	San Joaquin Valley UAPCD 2003; Pechan 2008
Residential Home Heating	Switch to Low Sulfur Fuel	80	$2,670	NOx, SO2, CO2	This measure will be a switch from high-sulfur (2,500 ppm sulfur content) to low-sulfur (500 ppm) home heating oil for residential users. SO2 co-control - 75%. NOx co-control - 10%. CO2 co-control - 1-2%.	NESCAUM 2005
Unpaved Roads	Chemical Stabilization / Dust Suppressant Application	40-80 (PM10 mainly)	$4,418 per ton PM		Chemical stabilization is a surface treatment option for unpaved roads (Dust Suppressant Application). Chemical suppressants used in road dust control may be either wetting or binding agents.The primary types of these suppressants are fresh or salt water in combination with a wetting agent; hygroscopic and deliquescent chemicals; organic binders; petroleum derived binders; and some waste products.	EPA 1986; WRAP 2006
Unpaved Roads	Limit maximum speed on unpaved roads to 25mph	1	$1,227 per ton PM10		Under this proposed measure, a maximum speed limit would be set for unpaved roads of 25 miles per hour. Implementation of this measure would require signing of unpaved roads and enforcement of the limit. Efficiency and cost-effectiveness calculations are based on San Joaquin Valley Rule 8061 and assumes that compliance with the speed limit will be no greater than 25%.	San Joaquin Valley UAPCD 2003
Unpaved Roads	Limit visible dust emissions to 20% opacity and require stabilized surfaces on unpaved parking areas receiving up to 100 trips per day	85	$5,941-$34,648 per ton PM10		Under this proposed control measure, unpaved parking areas would have to be sufficiently treated to prevent visible emissions greater than 20% opacity and to establish a surface that would comply with stability requirements specified in San Joaquin Valley Rule 8011.	San Joaquin Valley UAPCD 2003
Unpaved Roads	Pave unpaved roads and unpaved parking lots (in urban areas)	99	$2,454-$6,725 per ton PM10		Under this proposed measure, no new unpaved roads would be constructed. Also, existing public unpaved roads and parling areas in urban areas would be required to be paved. Baseline and controlled PM10 emissions were computed using the CARB statewide emissions factor for unpaved and paved roads. Cost-effectiveness calculations are based on San Joaquin Valley Rule 8061.	San Joaquin Valley UAPCD 2003
Unpaved Roads	Require paving, 4 inches gravel, or dust suppressant at special event parkings	84	$6,793-$67,932 per ton PM10		Under this proposed measure, watering of special event unpaved parking areas would not be deemed an acceptable control option, and one of several alternatives (paving, 4 inches of gravel, or dust suppressants) would be required. For the purposes of this analysis, the use of polymer emulsion dust suppressants was modeled. Efficiency and cost-effectiveness calculations are based on San Joaquin Valley Rule 8071 and assumes event parking involving more than 1,000 vehicles.	San Joaquin Valley UAPCD 2003
Utility Boilers	ESP (Electrostatic Precipitator)	96-99	$40-$591	Hg	An electrostatic precipitator applies electrical forces to separate suspended particles from the flue gas stream. The suspended particles are given an electrical charge by passing through a high voltage DC corona region in which gaseous ions flow. There are two general types of ESP: wire/plate and wire/pipe types. Further, ESPs come in both wet and dry configurations.	STAPPA/ALAPCO 2006
Utility Boilers	Fabric Filter	95-99.9	$42-$383		A fabric filter, or baghouse, consists of a number of fabric bags placed in parallel inside of an enclosure. Particulate matter is collected on the surface of the bags as the gas stream passes through them. The particulate is periodically removed from the bags and collected in hoppers located beneath the bags. A number of methods are employed to facilitate the removal of particulate from the bags, including shaking, reverse air flow, and pulse air flow. The only potential drawback to a fabric filter would be when used in conjunction with a high moisture flue gas stream or with extremely high temperatures. If moisture levels in the flue gas stream are too high then filter caking can occur.	STAPPA/ALAPCO 2006

Source Category	Emission Reduction Measure Name	Control Efficiency (%)*	Cost Effectiveness (2006$/ton)**	Other Pollutants Controlled	Description/Notes/Caveats	References
Utility Boilers	Wet Scrubber	70-99	$80-$2,726	SO2	The two most frequently utilized wet scrubbers for PM control are condensation scrubbers and venturi scrubbers. In a Venturi scrubber, water is injected into the flue gas stream at the Venturi throat to form droplets. Fly ash particles impact with the droplets to form a wet by-product which is then disposed of. The forceful contact resulting from the droplet dispersal (spray tower), contraction of the gas stream (Venturi) or counter current flow (collision), removes PM as well as SO2 from the flue gas. Condensation scrubbers are designed to control PM with a diameter of 0.25–1.0 μm. Venturi scrubbers are effective in controlling both PM10 and PM2.5.	STAPPA/ALAPCO 2006
Utility Boilers - Coal	Fuel switching away from coal: bituminous coal to natural gas	98		SO2, NOx	Fuel substitution involves replacing the current fuel with a fuel which emits less of a given pollutant when burned. For many older boilers, fuel switching is an especially attractive option because the capital investment is usually small when compared to that of control devices. This control measure involves switching from bituminous coal to natural gas.	EPA 1998a
Utility Boilers - Coal	Fuel switching away from coal: bituminous coal to residual oil	15		SO2, NOx	Fuel substitution involves replacing the current fuel with a fuel which emits less of a given pollutant when burned. For many older boilers, fuel switching is an especially attractive option because the capital investment is usually small when compared to that of control devices. This control measure involves switching from bituminous coal to residual oil.	EPA 1998a
Utility Boilers - Coal	Fuel switching away from coal: bituminous coal to subbituminous	21		SO2, NOx	Fuel substitution involves replacing the current fuel with a fuel which emits less of a given pollutant when burned. For many older boilers, fuel switching is an especially attractive option because the capital investment is usually small when compared to that of control devices. This control measure involves switching from bituminous coal to subbituminous.	EPA 1998a
Utility Boilers - Coal	Fuel switching away from coal: subbituminous coal to natural gas	97		SO2, NOx	Fuel substitution involves replacing the current fuel with a fuel which emits less of a given pollutant when burned. For many older boilers, fuel switching is an especially attractive option because the capital investment is usually small when compared to that of control devices. This control measure involves switching from subbituminous coal to natural gas.	EPA 1998a
Utility Boilers - Coal Fired	Coal Washing	45	$420 per ton SO2	SO2, Hg	Coal washing (or coal cleaning) is a pre-combustion process that improves the quality of coal by removing impurities and increasing its heat content. It decreases PM emissions as well as SO2 emissions. Coal washing can also be effective in removing mercury (Hg) from the coal and the utility plants emissions. This control is applicable to electricity generating sources powered by pulverized dry-bottom and bituminous/subbituminous coal.	ERG 2000; EPA 1997a; SIU 1997
Utility Boilers - Oil	Fuel switching away from oil: residual oil to natural gas	97		SO2, NOx	Fuel substitution involves replacing the current fuel with a fuel which emits less of a given pollutant when burned. For many older boilers, fuel switching is an especially attractive option because the capital investment is usually small when compared to that of control devices. This control measure involves switching from residual oil to natural gas.	EPA 1998a
Wood Pulp & Paper	Dry Electrostatic Precipitator (ESP) - Wire Plate Type	95	$156 per ton PM10		An electrostatic precipitator applies electrical forces to separate suspended particles from the flue gas stream. The suspended particles are given an electrical charge by passing through a high voltage DC corona region in which gaseous ions flow. There are two general types of ESP: wire/plate and wire/pipe types. Further, ESPs come in both wet and dry configurations. This control is the use of Dry ESP Wire Plate Type. In dry ESPs, the collectors are knocked by various mechanical means to dislodge the particulate, which slides downward into a hopper. This control applies to wood pulp and paper product operations including Evaporators, Recovery Furnaces, Lime Kiln, Calciners, or Liquor Oxidation Towers.	EPA 1998a; EPA 1999c
Wood Pulp & Paper	Dry Electrostatic Precipitator (ESP) - Wire Plate Type	99.5			This control measure is the same as the dry ESP for this source category with a control efficiency of 95%. It is expected that by 2020, the control efficiency for this sytem will increase to 99.5% for PM2.5.	EPA 1998a; EPA 1999c
Wood Pulp & Paper	Wet Electrostatic Precipitator (ESP) - Wire Plate Type	95	$313 per ton PM10		An electrostatic precipitator applies electrical forces to separate suspended particles from the flue gas stream. The suspended particles are given an electrical charge by passing through a high voltage DC corona region in which gaseous ions flow. There are two general types of ESP: wire/plate and wire/pipe types. Further, ESPs come in both wet and dry configurations. This control is the use of Wet ESP Wire Plate Type. Unlike dry ESPs, resistivity of the collected material is not a major factor in performance. Because of the high humidity in a wet ESP, the resistivity of particles is lowered, eliminating the "back corona" condition. The frequent washing of the plates also limits particle buildup on the collectors. This control applies to wood pulp and paper product operations including Evaporators, Recovery Furnaces, Lime Kiln, Calciners, or Liquor Oxidation Towers.	EPA1998a; EPA 1999a
Wood Pulp & Paper	Wet Electrostatic Precipitator (ESP) - Wire Plate Type	99.5			This control measure is the same as the dry ESP for this source category with a control efficiency of 95%. It is expected that by 2020, the control efficiency for this sytem will increase to 99.5% for PM2.5.	EPA1998a; EPA 1999a
Wood Combustion Appliances	Education Campaign	n/a	n/a	CO2, VOC's,CO CH4, Toxics, BC	Focus the Education Campaign on Best Burning Practices, such as those contained on the EPA Burn Wise web site: http://www.epa.gov/burnwise/burnwisekit.html.	http://epa.gov/burnwise/resources.html
Wood Stoves	Wood to Wood Replacement Program	60	$9,900 (2010$)	CO2, VOC's,CO CH4, Toxics	Implement a program and provide incentives to replace old uncertified wood stoves with new EPA-certified wood stoves. Control efficiency applies to an individual wood stove. Education on proper residentiall wood combustion (rwc) stove use (e.g., burn only dry wood) and maintenance is critical. See for more info: http://www.epa.gov/burnwise/burnwisekit.html.	http://epa.gov/burnwise/resources.html
Wood Stoves	Wood to Gas Replacement Program	100	$7,200 (2010$)	CO2, VOC's,CO CH4, Toxics, BC	Implement an incentive program to replace old, uncertified wood stoves with new gas stoves. Control efficiency (%) applies to an individual wood stove. Cost-effectiveness reflects converting from a wood stove to a gas stove. See for more info: http://www.epa.gov/burnwise/how-to-guide.html.	http://epa.gov/burnwise/resources.html

Point & NonPoint PM
Menu of Control Measures
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Source Category	Emission Reduction Measure Name	Control Efficiency (%)*	Cost Effectiveness (2006$/ton)**	Other Pollutants Controlled	Description/Notes/Caveats	References
Wood Stoves	Remove Old Wood Stoves for Money or "Bounty"	70	$5,300 (2012$)	CO2, VOC's,CO CH4, Toxics, BC	Implement an incentive program (usually voluntary) where cash (e.g., $250) is given in return for turning in a wood stove. Control efficiency (%) based on estimate provided by Washington State Department of Ecology of wood stoves turned in that were actually being used.	http://epa.gov/burnwise/resources.html

* when less than 99%, control efficiencies were rounded up to the closest whole number. They are for PM2.5, unless specified otherwise
** cost-effectiveness numbers are per ton PM2.5 reduced, unless specified otherwise

Source Category	Emission Reduction Measure Name	Control Efficiency (%)*	Cost Effectiveness (2006$/ton reduced)	Other Pollutants Controlled	Description/Notes/Caveats	References
By-Product Coke Manufacturing	Coke Oven Gas Desulfurization	90	Cost effectiveness is variable depending on stack flow rate.		This measure examines the impacts of improving the PM monitoring technique at units currently using an ESP, scrubber, or fabric filter. In this improved technique scenario, the monitoring technique is upgraded to a PM continuous emission monitor. This improved monitoring technique also results in an increase to the monitoring frequency because a PM CEMS can make a measurement every 7.5 minutes. The monitoring frequency increases from once per day to eight times per hour.	Pechan 2008
Cement Kilns	Absorbent Addition	60-80	$2,000-$7,400		A fabric filter, or baghouse, consists of a number of fabric bags placed in parallel inside of an enclosure. Particulate matter is collected on the surface of the bags as the gas stream passes through them. The particulate is periodically removed from the bags and collected in hoppers located beneath the bags. A number of methods are employed to facilitate the removal of particulate from the bags, including shaking, reverse air flow, and pulse air flow. The only potential drawback to a fabric filter would be when used in conjunction with a high moisture flue gas stream or with extremely high temperatures. If moisture levels in the flue gas stream are too high then filter caking can occur. Cost-effectiveness varies depending on the type of filter (Reverse-Air Cleaned Type, Mech. Shaker Type, Pulse Jet Type) and is based on EPA's cost-estimating spreadsheet for fabric filters.	LADCO 2006a
Cement Kilns	Advanced Flue Gas Desulfurization	95-99.5	$2,000-$4,000		This measure is to conduct improved monitoring for PM2.5 emissions at stationary sources. Improved monitoring in this case means increasing the monitoring frequency of electrostatic precipitators, scrubbers, and fabric filters from once per day to four times per hour, with no change in monitoring technique. The incremental costs included a one-time cost for development of the improved monitoring and recurring annual burden costs for incremental record keeping, reporting, and certification activities.	LADCO 2006a
Cement Kilns	Wet Gas Scrubber	90-99.9	$2,200-$7,000	HCl, Metals, NH3	Wet scrubbing techniques are used to control both particulate and SO2 emissions. Wet scrubbing processes used to control SO2 are generally termed flue-gas desulfurization (FGD) processes. FGD utilizes gas absorption technology, the selective transfer of materials from a gas to a contacting liquid, to remove SO2 in the waste gas. Caustic, crushed limestone, or lime are used as scrubbing agents. Wet scrubbers also significantly reduce the HCl, residual dust, metal and NH3 emissions. In 2008-2010, the SCAQMD conducted a BARCT assessment to capture advancement in SO2 control technology, identified the BARCT levels for seven source categories, determined the associated cost-effectiveness values, and amended the Regional Clean Air Incentives Market Program (RECLAIM) to reflect the BARCT levels. For cement kilns, the cost-effectiveness of achieving a SO2 Performance Standard of 5ppmv (or 0.04 lbs/ton clinker) is $26,800 (in 2010$). The control efficiency and cost effectiveness listed in this table are from the LADCO 2006 reference.	LADCO 2006a, SCAQMD 2012
Cement Kilns - Long Dry Process	Spray Dryer Absorber	90	$3,400-$5,700		Spray dryer absorption (SDA) systems spray lime slurry into an absorption tower where SO2 is absorbed by the slurry, forming CaSO3/CaSO4. The liquid-to-gas ratio is such that the water evaporates before the droplets reach the bottom of the tower. The dry solids are carried out with the gas and collected with a fabric filter or ESP. When used to specifically control SO2, the term dry flue-gas desulfurization (dry FGD) may also be used.	NESCAUM 2002
Cement Kilns - Long Dry Process	Wet Gas Scrubber	90	$3,400-$5,700	HCl, Metals, NH3	Wet scrubbing techniques are used to control both particulate and SO2 emissions. Wet scrubbing processes used to control SO2 are generally termed flue-gas desulfurization (FGD) processes. FGD utilizes gas absorption technology, the selective transfer of materials from a gas to a contacting liquid, to remove SO2 in the waste gas. Caustic, crushed limestone, or lime are used as scrubbing agents. Wet scrubbers also significantly reduce the HCl, residual dust, metal and NH3 emissions.	NESCAUM 2002
Cement Kilns - Preheater Process Kiln	Spray Dryer Absorber	90	$23,000-$57,000		Spray dryer absorption (SDA) systems spray lime slurry into an absorption tower where SO2 is absorbed by the slurry, forming CaSO3/CaSO4. The liquid-to-gas ratio is such that the water evaporates before the droplets reach the bottom of the tower. The dry solids are carried out with the gas and collected with a fabric filter or ESP. When used to specifically control SO2, the term dry flue-gas desulfurization (dry FGD) may also be used.	NESCAUM 2002
Cement Kilns - Preheater Process Kiln	Wet Gas Scrubber	90	$23,000-$57,000	HCl, Metals, NH3	Wet scrubbing techniques are used to control both particulate and SO2 emissions. Wet scrubbing processes used to control SO2 are generally termed flue-gas desulfurization (FGD) processes. FGD utilizes gas absorption technology, the selective transfer of materials from a gas to a contacting liquid, to remove SO2 in the waste gas. Caustic, crushed limestone, or lime are used as scrubbing agents. Wet scrubbers also significantly reduce the HCl, residual dust, metal and NH3 emissions.	NESCAUM 2002
Cement Kilns - Preheater/Precalciner Kiln	Spray Dryer Absorber	90	$23,000-$34,000		Spray dryer absorption (SDA) systems spray lime slurry into an absorption tower where SO2 is absorbed by the slurry, forming CaSO3/CaSO4. The liquid-to-gas ratio is such that the water evaporates before the droplets reach the bottom of the tower. The dry solids are carried out with the gas and collected with a fabric filter or ESP. When used to specifically control SO2, the term dry flue-gas desulfurization (dry FGD) may also be used.	This control is the use of low NOx burner (LNB) technology and selective non-catalytic
Cement Kilns - Preheater/Precalciner Kiln	Wet Gas Scrubber	90	$23,000-$34,000	HCl, Metals, NH3	Wet scrubbing techniques are used to control both particulate and SO2 emissions. Wet scrubbing processes used to control SO2 are generally termed flue-gas desulfurization (FGD) processes. FGD utilizes gas absorption technology, the selective transfer of materials from a gas to a contacting liquid, to remove SO2 in the waste gas. Caustic, crushed limestone, or lime are used as scrubbing agents. Wet scrubbers also significantly reduce the HCl, residual dust, metal and NH3 emissions.	NESCAUM 2002

Cement Kilns - Wet Process	Wet Gas Scrubber	90	$6,800-$9,100	HCl, Metals, NH3	Wet scrubbing techniques are used to control both particulate and SO2 emissions. Wet scrubbing processes used to control SO2 are generally termed flue-gas desulfurization (FGD) processes. FGD utilizes gas absorption technology, the selective transfer of materials from a gas to a contacting liquid, to remove SO2 in the waste gas. Caustic, crushed limestone, or lime are used as scrubbing agents. Wet scrubbers also significantly reduce the HCl, residual dust, metal and NH3 emissions.	NESCAUM 2002
ICI Boilers - Coal	Spray Dryer Absorber	90-95	Cost effectiveness varies by boiler size. - 100 MMBTU/hr: $1,555 - $7,521. - 250 MMBTU/hr: $1,448 - $3,922. - 750 MMBTU/hr: $1,389 - 2,228		Spray dryer absorption (SDA) systems spray lime slurry into an absorption tower where SO2 is absorbed by the slurry, forming CaSO3/CaSO4. The liquid-to-gas ratio is such that the water evaporates before the droplets reach the bottom of the tower. The dry solids are carried out with the gas and collected with a fabric filter or ESP. When used to specifically control SO2, the term dry flue-gas desulfurization (dry FGD) may also be used. Cost estimates are from the OTC / LADCO Workgroup (OTC / LADCO Control Cost Subgroup), for a 66% capacity factor at 8760 hour/year, and are based on a methodology similar to EPA's methodology provided in the EPA document "Alternative Control Techniques Document – NOx Emissions from Industrial/Commercial/Institutional (ICI) Boilers".	NESCAUM 2009, OTC/LADCO 2010
ICI Boilers - Coal	Wet Gas Scrubber	90-99	Cost effectiveness varies by boiler size. - 100 MMBTU/hr: $2,592 - $7,545. - 250 MMBTU/hr: $1,369 - $3,746. - 750 MMBTU/hr: $1,262 - 2,171	Hg	Wet scrubbing techniques are used to control both particulate and SO2 emissions. Wet scrubbing processes used to control SO2 are generally termed flue-gas desulfurization (FGD) processes. FGD utilizes gas absorption technology, the selective transfer of materials from a gas to a contacting liquid, to remove SO2 in the waste gas. Caustic, crushed limestone, or lime are used as scrubbing agents. Cost estimates are from the OTC / LADCO Workgroup (OTC / LADCO Control Cost Subgroup), for a 66% capacity factor at 8760 hour/year, and are based on a methodology similar to EPA's methodology provided in the EPA document "Alternative Control Techniques Document – NOx Emissions from Industrial/Commercial/Institutional (ICI) Boilers".	NESCAUM 2009, OTC/LADCO 2010
ICI Boilers - Coal--High Sulfur	In Duct Dry Sorbent Injection	40	$700-$1,400		As opposed to spray dryer absorption, in duct sorbent injection technology does not require a dedicated reactor and instead uses the existing boiler and duct system as the "reactor," and several configurations are possible based on the temperature window desired. DSI technologies include calcium (lime) and sodium (trona) reagents and are currently being tested or demonstrated within the ICI boiler sector.	EPA 2003a; NESCAUM 2009
ICI Boilers - Coal--Low Sulfur	In Duct Dry Sorbent Injection	40	$770-$1,700		As opposed to spray dryer absorption, in duct sorbent injection technology does not require a dedicated reactor and instead uses the existing boiler and duct system as the "reactor," and several configurations are possible based on the temperature window desired. DSI technologies include calcium (lime) and sodium (trona) reagents and are currently being tested or demonstrated within the ICI boiler sector.	EPA 2003a; NESCAUM 2009
ICI Boilers - Oil	Fuel Switching	75	$2,800	PM	This control transfers a home-heating oil fuel control to industrial boilers by substituting "red dye" distillate oil for high-sulfur fuel. Distillate has 500 ppm versus 2,500 to 3,000 ppm for high-sulfur diesel.The control applies to ICI external combustion boilers.	EPA 2007a
ICI Boilers - Residual Oil	Fuel switch from 3% sulfur residual oil to 0.2% sulfur distillate oil	94	$5,300	PM2.5	Fuel substitution involves replacing the current fuel with a fuel which emits less of a given pollutant when burned. For many older boilers, fuel switching is an especially attractive option because the capital investment is usually small when compared to that of control devices. This control measure involves switching from 3% sulfur residual oil to 0.2% sulfur distillate oil	NESCAUM 2009
ICI Boilers - Residual Oil	Fuel switch from 3% sulfur residual oil to 1% sulfur residual oil	67	$760	PM2.5	Fuel substitution involves replacing the current fuel with a fuel which emits less of a given pollutant when burned. For many older boilers, fuel switching is an especially attractive option because the capital investment is usually small when compared to that of control devices. This control measure involves switching from 3% to 1% sulfur content in residual fuel oil.	NESCAUM 2009
ICI Boilers - Residual Oil	Fuel switch from 1% sulfur residual oil to 0.5% sulfur residual oil	50	Cost effectiveness varies by boiler size; $1,858 - $3,717.	PM2.5	Fuel substitution involves replacing the current fuel with a fuel which emits less of a given pollutant when burned. For many older boilers, fuel switching is an especially attractive option because the capital investment is usually small when compared to that of control devices. This control measure involves switching from 1% sulfur residual oil to 0.5% sulfur residual oil. Cost estimates are from the OTC / LADCO Workgroup (OTC / LADCO Control Cost Subgroup), for a 66% capacity factor at 8760 hour/year, and are based on a methodology similar to EPA's methodology provided in the EPA document "Alternative Control Techniques Document – NOx Emissions from Industrial/Commercial/Institutional (ICI) Boilers". The estimated price differential between residual oil at 1.0% S and low sulfur residual oil at 0.5%S used in these cost estimates ranged from 7.5 to 15.0 cents per gallon	OTC/LADCO 2010
ICI Boilers - Distillate Oil	Fuel switch from 0.3% sulfur distillate oil to 0.05% sulfur distillate oil	84	Cost effectiveness varies by boiler size; $1,174 - $1,956.	PM2.5	Fuel substitution involves replacing the current fuel with a fuel which emits less of a given pollutant when burned. For many older boilers, fuel switching is an especially attractive option because the capital investment is usually small when compared to that of control devices. This control measure involves switching from 0.3% to 0.05 sulfur content in distillate fuel oil. Cost estimates are from the OTC / LADCO Workgroup (OTC / LADCO Control Cost Subgroup), for a 66% capacity factor at 8760 hour/year, and are based on a methodology similar to EPA's methodology provided in the EPA document "Alternative Control Techniques Document – NOx Emissions from Industrial/Commercial/Institutional (ICI) Boilers". The estimated price differential between distillate oil at 0.30% S and low sulfur distillate oil at 0.05%S used in these cost estimates ranged from 2.1 to 3.5 cents per gallon.	OTC/LADCO 2010
ICI Boilers - Residual Oil	Spray Dryer Absorber	90-95	$1,900-$5,400		Spray dryer absorption (SDA) systems spray lime slurry into an absorption tower where SO2 is absorbed by the slurry, forming CaSO3/CaSO4. The liquid-to-gas ratio is such that the water evaporates before the droplets reach the bottom of the tower. The dry solids are carried out with the gas and collected with a fabric filter or ESP. When used to specifically control SO2, the term dry flue-gas desulfurization (dry FGD) may also be used.	NESCAUM 2009

ICI Boilers - Residual Oil	Wet Gas Scrubber	90-99	$2,000-$5,400	Hg	Wet scrubbing techniques are used to control both particulate and SO2 emissions. Wet scrubbing processes used to control SO2 are generally termed flue-gas desulfurization (FGD) processes. FGD utilizes gas absorption technology, the selective transfer of materials from a gas to a contacting liquid, to remove SO2 in the waste gas. Caustic, crushed limestone, or lime are used as scrubbing agents.	NESCAUM 2009
Inorganic Chemical Manufacture Operations	Flue Gas Desulfurization	90	Cost effectiveness is variable depending on stack flow rate and concentration.		Flue Gas Desulfurization scrubbers can be either wet or dry systems. In wet systems, a liquid sorbent is sprayed into the flue gas in an absorber vessel. Limestone and lime-based reagents are most frequently used in scrubbers in the United States. Dry and semi-dry Flue Gas Desulfurization systems include spray dryers, and dry injection into a duct or a combustion zone.	Pechan 2008
In-process Fuel Use - Bituminous Coal	Flue Gas Desulfurization	90	Cost effectiveness is variable depending on stack flow rate and concentration.		Flue Gas Desulfurization scrubbers can be either wet or dry systems. In wet systems, a liquid sorbent is sprayed into the flue gas in an absorber vessel. Limestone and lime-based reagents are most frequently used in scrubbers in the United States. Dry and semi-dry Flue Gas Desulfurization systems include spray dryers, and dry injection into a duct or a combustion zone. This control applies to operations with in-process bituminous coal use. Emissions from these sources are classified under SCCs 39000288, 39000289, and 39000299.	EPA 1981; Pechan 1997
Mineral Products Industry	Flue Gas Desulfurization	90	Cost effectiveness is variable depending on stack flow rate and concentration.		Flue Gas Desulfurization scrubbers can be either wet or dry systems. In wet systems, a liquid sorbent is sprayed into the flue gas in an absorber vessel. Limestone and lime-based reagents are most frequently used in scrubbers in the United States. Dry and semi-dry Flue Gas Desulfurization systems include spray dryers, and dry injection into a duct or a combustion zone.	EPA 1981; Pechan 1997
Petroleum Refining--Catalytic Cracking	Catalyst Additives	35-50	$495-$872		DeSOx additives are typically metal oxide catalysts that convert SO2 to SO3 inside the catalyst regenerator. The SO3 is adsorbed to a sulfate and then recycled back to the reactor with the FCCU catalyst, where it is reduced in the reactor to H2S, which is controlled by the refinery's sulfur recovery plant.	MARAMA 2007
Petroleum Refining--Catalytic Cracking	Wet Gas Scrubber	95-99.9	$500-$3,000	PM2.5	Wet scrubbing techniques are used to control both particulate and SO2 emissions. Wet scrubbing processes used to control SO2 are generally termed flue-gas desulfurization (FGD) processes. FGD utilizes gas absorption technology, the selective transfer of materials from a gas to a contacting liquid, to remove SO2 in the waste gas. Caustic, crushed limestone, or lime are used as scrubbing agents. In 2008-2010, the SCAQMD conducted a BARCT assessment to capture advancement in SO2 control technology, identified the BARCT levels for seven source categories, determined the associated cost-effectiveness values, and amended the Regional Clean Air Incentives Market Program (RECLAIM) to reflect the BARCT levels. For Petroleum Refining--Catalytic Cracking, the cost-effectiveness of achieving a SO2 Performance Standard of 5ppmv is $21,200 (in 2010$). The control efficiency and cost effectiveness listed in this table are from the Mid-Atlantic Regional Air Management Association "Assessment of Control Technology Options For Petroleum Refineries in the Mid-Atlantic Region, Final Report".	MARAMA 2007, SCAQMD 2012
Coke Calciner	Wet Gas Scrubber	Achieve a performance level of 10ppmv SO2.	$22,563		In 2008-2010, the SCAQMD conducted a BARCT assessment to capture advancement in SO2 control technology, identified the BARCT levels for seven source categories, determined the associated cost-effectiveness values, and amended the Regional Clean Air Incentives Market Program (RECLAIM) to reflect the BARCT levels. For coke calciners, the cost-effectiveness of achieving a SO2 Performance Standard of 10ppmv is $23,036 (in 2010$).	SCAQMD 2012
Glass Melting Furnaces	Wet Gas Scrubber	95	$5,091		In 2008-2010, the SCAQMD conducted a BARCT assessment to capture advancement in SO2 control technology, identified the BARCT levels for seven source categories, determined the associated cost-effectiveness values, and amended the Regional Clean Air Incentives Market Program (RECLAIM) to reflect the BARCT levels. For Glass Melting Furnaces, the cost-effectiveness of achieving a SO2 Performance Standard of 5ppmv (95% efficiency) is $5,198 (in 2010$).	SCAQMD 2012
Petroleum Refining--Flares	BAAQMD Rule 12	65-86	$800-$1,600	PM2.5, CO, NOx	This control measure is the application of the requirement in BAAQMD Rule 12. Requirement include the development and implementation of flare minimization plan, continuous monitoring of knock-out drum water seal for leaks, determine and report the causes of each reportable flaring incident.	MARAMA 2007
Petroleum Refining--Flares	Flare Gas Recovery Unit		$0 (actually, cost savings).	PM2.5, CO, NOx	Emissions from flaring events are released due to oxidation of vent gases and incomplete combustion of fuel. Flare gas recovery units reduce emissions from flares by recycling the gases vented during emergency releases instead of combusting them in flare. The vent gases are collected in the flare header, compressed, cooled, and returned for re-use in the refinery as fuel gas or process feedstock.	MARAMA 2007
Petroleum Refining--Flares	SCAQMD Rule 1118	53	$4,500-$8,600	PM2.5, CO, NOx	This control measure is the application of the requirement in SCAQMD Rule 1118. Requirement include the prohibition of flaring except for emergencies, shutdowns and startups, turnarounds, and specific essential operational needs; establishes operational practices to minimize flaring events, sets annual SO2 performance targets, requires operation in a smokeless manner; increased inspections and monitoring.	MARAMA 2007
Petroleum Refining--Process Heaters	Flue Gas Desulfurization	90-99.9	$7,600-$45,000		Flue Gas Desulfurization scrubbers can be either wet or dry systems. In wet systems, a liquid sorbent is sprayed into the flue gas in an absorber vessel. Limestone and lime-based reagents are most frequently used in scrubbers in the United States. Dry and semi-dry Flue Gas Desulfurization systems include spray dryers, and dry injection into a duct or a combustion zone.	MARAMA 2007

Petroleum Refining--Sulfur Recovery Units	Increase Claus Unit Capacity & Tail Gas Scrubber Efficiency	Variable depending on current efficiency. Up to 97-99.9%.	$170-$450		Typical sulfur recovery configurations at petroleum refineries entail the use of the Claus sulfur recovery process followed by a tail gas clean-up unit (TGCU) to maximize removal of H_2S. Several process modifications are available to increase sulfur recovery from this process (they result in increased emissions of CO2 to the atmosphere). In 2008-2010, the SCAQMD conducted a BARCT assessment to capture advancement in SO2 control technology, identified the BARCT levels for seven source categories, determined the associated cost-effectiveness values, and amended the Regional Clean Air Incentives Market Program (RECLAIM) to reflect the BARCT levels. For Sulfur Recovery Units, the cost-effectiveness of achieving a SO2 Performance Standard of 5ppmv is $44,500 (in 2010$). The control efficiency and cost effectiveness listed in this table are from the Mid-Atlantic Regional Air Management Association "Assessment of Control Technology Options For Petroleum Refineries in the Mid-Atlantic Region, Final Report" (the control efficiency and cost-effectiveness ranges are for various technologies described in the reference.)	MARAMA 2007, SCAQMD 2012
Primary Lead Smelters - Sintering	Dual Absorption	99	Cost effectiveness is variable depending on stack flow rate.		The dual-absorption process for making sulfuric acid from waste gas containing SO2 is essentially the same as the single-contact process with the addition of an interpass absorption tower. The waste gas is cleaned and dried as in the single-contact process before entering the process. Upon leaving the second or third catalyst bed, the gas is cooled and introduced to a packed-bed, counter-current absorption tower where it contacts 98-99% sulfuric acid. After the absorbing tower, the gas is reheated and passed to the third or fourth catalyst bed, where approximately 97% of the remaining SO2 is converted to SO3 and passed to the final absorption tower for conversion to sulfuric acid as in the single-contact process.	Pechan 2008
Primary Metals Industry	Flue Gas Desulfurization	90	Cost effectiveness is variable depending on stack flow rate.		Flue Gas Desulfurization scrubbers can be either wet or dry systems. In wet systems, a liquid sorbent is sprayed into the flue gas in an absorber vessel. Limestone and lime-based reagents are most frequently used in scrubbers in the United States. Dry and semi-dry Flue Gas Desulfurization systems include spray dryers, and dry injection into a duct or a combustion zone.	EPA 2002a
Primary Zinc Smelters - Sintering	Dual Absorption	99	Cost effectiveness is variable depending on stack flow rate and concentration.		The dual-absorption process for making sulfuric acid from waste gas containing SO2 is essentially the same as the single-contact process with the addition of an interpass absorption tower. The waste gas is cleaned and dried as in the single-contact process before entering the process. Upon leaving the second or third catalyst bed, the gas is cooled and introduced to a packed-bed, counter-current absorption tower where it contacts 98-99% sulfuric acid. After the absorbing tower, the gas is reheated and passed to the third or fourth catalyst bed, where approximately 97% of the remaining SO2 is converted to SO3 and passed to the final absorption tower for conversion to sulfuric acid as in the single-contact process.	Pechan 2008
Process Heaters - Oil and Gas Production Industry	Flue Gas Desulfurization	90	Cost effectiveness is variable depending on stack flow rate.		Flue Gas Desulfurization scrubbers can be either wet or dry systems. In wet systems, a liquid sorbent is sprayed into the flue gas in an absorber vessel. Limestone and lime-based reagents are most frequently used in scrubbers in the United States. Dry and semi-dry Flue Gas Desulfurization systems include spray dryers, and dry injection into a duct or a combustion zone. This control applies to processes heaters involved in oil and gas production. Emissions from these sources are classified under SCCs beginning with 310004.	EPA 1981; Pechan 1997
Pulp and Paper - Acid Sulfite Pulping	Alkaline Scrubber	97			Acid sulfite pulping is used at a declining number of pulping operations, but it can emit large amounts of SO2 per ton of pulp. SO2 can be scrubbed out using an alkaline solution (with recovery of up to 97 percent).	STAPPA/ALAPCO 2006
Pulp and Paper - Acid Sulfite Pulping	Raise pH of Digester				Acid sulfite pulping is used at a declining number of pulping operations, but it can emit large amounts of SO2 per ton of pulp. Raising the pH of the digester before releasing excess gas reduces the amount of SO2 released.	STAPPA/ALAPCO 2006
Pulp and Paper - Recovery Furnaces	Reduce Sulfur Content of Black Liquor &/or Regulate Temperatures in the Furnace				Pulp facilities burn concentrated black liquor in recovery furnaces to produce energy and recover sodium and sulfur. Compared to the more traditional fuels burned in power boilers (i.e., natural gas, coal, wood and oil), the black liquor solids burned in the recovery furnace can have widely varying sulfur content. This results in variable SO2 emissions, making control difficult. Despite this difficulty, some facilities have successfully lowered SO2 emissions by reducing the sulfur content of the black liquor before combustion and by regulating temperatures in the furnace to minimize SO2 formation.	STAPPA/ALAPCO 2006
Pulp and Paper Industry - Sulfate Pulping	Flue Gas Desulfurization	90	Cost effectiveness is variable depending on stack flow rate.		Flue Gas Desulfurization scrubbers can be either wet or dry systems. In wet systems, a liquid sorbent is sprayed into the flue gas in an absorber vessel. Limestone and lime-based reagents are most frequently used in scrubbers in the United States. Dry and semi-dry Flue Gas Desulfurization systems include spray dryers, and dry injection into a duct or a combustion zone. This control applies to sulfate pulping processes involved in the pulp and paper industry. Emissions from these sources are classified under SCCs beginning with 307001.	EPA 2002a
Residential Fuel Combustion - Oil	Fuel switch from high sulfur to low sulfur home heating oil	75	$2,600	PM2.5, PM10, NOx	This measure will be a switch from high-sulfur (2,500 ppm sulfur content) to low-sulfur (500 ppm) home heating oil for residential users.	NESCAUM 2005
Steam Generating Unit - Coal/Oil	Flue Gas Desulfurization	90	Cost effectiveness is variable depending on stack flow rate.		Flue Gas Desulfurization scrubbers can be either wet or dry systems. In wet systems, a liquid sorbent is sprayed into the flue gas in an absorber vessel. Limestone and lime-based reagents are most frequently used in scrubbers in the United States. Dry and semi-dry Flue Gas Desulfurization systems include spray dryers, and dry injection into a duct or a combustion zone. This control applies to coal and oil-fired steam generating units.	EPA 2002a

Sulfur Recovery Plants - Elemental Sulfur	Process Modification	97-98	Cost effectiveness is variable depending on stack flow rate.		The Claus process is the most widely used method of producing sulfur from refinery H2S. The modified Claus process is based on producing elemental sulfur by first converting one-third of the H2S feed by precise combustion with air. The combustion products are then allowed to react thermally with the remaining two-thirds of the H2S feed in the presence of a suitable catalyst to form sulfur vapor. This control usually employs a high-energy liquid amine spray such as monoethanolamine (MEA), diethanolamine (DEA), methyldiethanolamine (MDEA), or diisopropylamine (DIPA) to increase the efficiency of the process to emit less SO2.	EPA 2002a; EPA 1983
Sulfuric Acid Plants	Flue Gas Desulfurization	90	Cost effectiveness is variable depending on stack flow rate.		Flue Gas Desulfurization scrubbers can be either wet or dry systems. In wet systems, a liquid sorbent is sprayed into the flue gas in an absorber vessel. Limestone and lime-based reagents are most frequently used in scrubbers in the United States. Dry and semi-dry Flue Gas Desulfurization systems include spray dryers, and dry injection into a duct or a combustion zone. In 2008-2010, the SCAQMD conducted a BARCT assessment to capture advancement in SO2 control technology, identified the BARCT levels for seven source categories, determined the associated cost-effectiveness values, and amended the Regional Clean Air Incentives Market Program (RECLAIM) to reflect the BARCT levels. For Sulfuric Acid Manufacturing , the cost-effectiveness of achieving a SO2 Performance Standard of 10ppmv (or 0.14 lbs/ton acid produced) is $3,400 (in 2010$). The control efficiency listed in this table is from the Pechan 2008 reference.	Pechan 2008, SCAQMD 2012
Sulfuric Acid Plants	Increase Absorption Efficiency from Existing to NSPS Level (99.7%)	75-95	Cost effectiveness is variable depending on stack flow rate.		This control is to increase adsorption efficiency from existing to NSPS level (99.7%), using technologies such as Dual Absorption. The dual-absorption process for making sulfuric acid from waste gas containing SO2 is essentially the same as the single-contact process with the addition of an interpass absorption tower. This control applies to sulfuric acid plants with contact absorption processes at 93% to 99% sulfur conversion efficiency. The control efficiency varies depending on the existing sulfur conversion.	Pechan 2008
Utility Boiler - Coal	Chemical Coal Cleaning	50-85			Uses chemical processes to remove pyrites (inorganic sulfur compounds) and organic sulfur in coal.	LADCO 2005a
Utility Boiler - Coal	Coal Washing	35	$420	Hg, PM	Coal washing (or coal cleaning) is a pre-combustion process that improves the quality of coal by removing impurities and increasing its heat content, thus reducing SO2 emissions. Coal washing can also be effective in removing mercury (Hg) from the coal and the utility plants emissions.	ERG 2000; EPA 1997a; SIU 1997
Utility Boiler - Coal	Fuel switching away from coal: bituminous coal to lignite	80	$160-$240	PM, NOx	Fuel substitution involves replacing the current fuel with a fuel which emits less of a given pollutant when burned. For many older boilers, fuel switching is an especially attractive option because the capital investment is usually small when compared to that of control devices. Cost effectiveness varies depending on the ranks of the old and new fuels and is estimated based on the emission factors.	LADCO 2005a; DOE 1994; Pechan 2008; EPA 1998a
Utility Boiler - Coal	Fuel switching away from coal: bituminous coal to natural gas	99.9		PM, NOx	Fuel substitution involves replacing the current fuel with a fuel which emits less of a given pollutant when burned. For many older boilers, fuel switching is an especially attractive option because the capital investment is usually small when compared to that of control devices. Cost effectiveness varies depending on the ranks of the old and new fuels and is estimated based on the emission factors.	LADCO 2005a; DOE 1994; Pechan 2008; EPA 1998a
Utility Boiler - Coal	Fuel switching away from coal: bituminous coal to No.2 oil	91		PM, NOx	Fuel substitution involves replacing the current fuel with a fuel which emits less of a given pollutant when burned. For many older boilers, fuel switching is an especially attractive option because the capital investment is usually small when compared to that of control devices. Cost effectiveness varies depending on the ranks of the old and new fuels and is estimated based on the emission factors.	LADCO 2005a; DOE 1994; Pechan 2008; EPA 1998a
Utility Boiler - Coal	Fuel switching away from coal: bituminous coal to No.4 oil	47		PM, NOx	Fuel substitution involves replacing the current fuel with a fuel which emits less of a given pollutant when burned. For many older boilers, fuel switching is an especially attractive option because the capital investment is usually small when compared to that of control devices. Cost effectiveness varies depending on the ranks of the old and new fuels and is estimated based on the emission factors.	LADCO 2005a; DOE 1994; Pechan 2008; EPA 1998a
Utility Boiler - Coal	Fuel switching away from coal: bituminous coal to subbituminous	73	$160-$240	PM, NOx	Fuel substitution involves replacing the current fuel with a fuel which emits less of a given pollutant when burned. For many older boilers, fuel switching is an especially attractive option because the capital investment is usually small when compared to that of control devices. Cost effectiveness varies depending on the ranks of the old and new fuels and is estimated based on the emission factors.	LADCO 2005a; DOE 1994; Pechan 2008; EPA 1998a
Utility Boiler - Coal	Fuel switching away from coal: subbituminous coal to lignite	27	$160-$240	PM, NOx	Fuel substitution involves replacing the current fuel with a fuel which emits less of a given pollutant when burned. For many older boilers, fuel switching is an especially attractive option because the capital investment is usually small when compared to that of control devices. Cost effectiveness varies depending on the ranks of the old and new fuels and is estimated based on the emission factors.	LADCO 2005a; DOE 1994; Pechan 2008; EPA 1998a
Utility Boiler - Coal	Fuel switching away from coal: subbituminous coal to natural gas	99.9		PM, NOx	Fuel substitution involves replacing the current fuel with a fuel which emits less of a given pollutant when burned. For many older boilers, fuel switching is an especially attractive option because the capital investment is usually small when compared to that of control devices. Cost effectiveness varies depending on the ranks of the old and new fuels and is estimated based on the emission factors.	LADCO 2005a; DOE 1994; Pechan 2008; EPA 1998a
Utility Boiler - Coal	Fuel switching away from coal: subbituminous coal to No.2 oil	70		PM, NOx	Fuel substitution involves replacing the current fuel with a fuel which emits less of a given pollutant when burned. For many older boilers, fuel switching is an especially attractive option because the capital investment is usually small when compared to that of control devices. Cost effectiveness varies depending on the ranks of the old and new fuels and is estimated based on the emission factors.	LADCO 2005a; DOE 1994; Pechan 2008; EPA 1998a
Utility Boiler - Coal	Fuel switching away from No.2 oil: No.2 oil to natural gas	99.7		PM, NOx	Fuel substitution involves replacing the current fuel with a fuel which emits less of a given pollutant when burned. For many older boilers, fuel switching is an especially attractive option because the capital investment is usually small when compared to that of control devices. Cost effectiveness varies depending on the ranks of the old and new fuels and is estimated based on the emission factors.	LADCO 2005a; DOE 1994; Pechan 2008; EPA 1998a

Utility Boiler - Coal	Fuel switching away from No.4 oil: No.4 oil to natural gas	99.9		PM, NOx	Fuel substitution involves replacing the current fuel with a fuel which emits less of a given pollutant when burned. For many older boilers, fuel switching is an especially attractive option because the capital investment is usually small when compared to that of control devices. Cost effectiveness varies depending on the ranks of the old and new fuels and is estimated based on the emission factors.	LADCO 2005a; DOE 1994; Pechan 2008; EPA 1998a
Utility Boiler - Coal	Fuel switching away from No.4 oil: No.4 oil to No.2 oil	84		PM, NOx	Fuel substitution involves replacing the current fuel with a fuel which emits less of a given pollutant when burned. For many older boilers, fuel switching is an especially attractive option because the capital investment is usually small when compared to that of control devices. Cost effectiveness varies depending on the ranks of the old and new fuels and is estimated based on the emission factors.	LADCO 2005a; DOE 1994; Pechan 2008; EPA 1998a
Utility Boiler - Coal	Fuel switching away from No.6 oil: No.6 oil to natural gas	99.9		PM, NOx	Fuel substitution involves replacing the current fuel with a fuel which emits less of a given pollutant when burned. For many older boilers, fuel switching is an especially attractive option because the capital investment is usually small when compared to that of control devices. Cost effectiveness varies depending on the ranks of the old and new fuels and is estimated based on the emission factors.	LADCO 2005a; DOE 1994; Pechan 2008; EPA 1998a
Utility Boiler - Coal	Fuel switching away from No.6 oil: No.6 oil to No.2 oil	92		PM, NOx	Fuel substitution involves replacing the current fuel with a fuel which emits less of a given pollutant when burned. For many older boilers, fuel switching is an especially attractive option because the capital investment is usually small when compared to that of control devices. Cost effectiveness varies depending on the ranks of the old and new fuels and is estimated based on the emission factors.	LADCO 2005a; DOE 1994; Pechan 2008; EPA 1998a
Utility Boiler - Coal	Fuel switching away from No.6 oil: No.6 oil to No.4 oil	46		PM, NOx	Fuel substitution involves replacing the current fuel with a fuel which emits less of a given pollutant when burned. For many older boilers, fuel switching is an especially attractive option because the capital investment is usually small when compared to that of control devices. Cost effectiveness varies depending on the ranks of the old and new fuels and is estimated based on the emission factors.	LADCO 2005a; DOE 1994; Pechan 2008; EPA 1998a
Utility Boiler - Coal	Lime Spray Dryer System (LSD)	70-96	$160-$300		The LSD system utilizes a fine spray of slaked lime (Ca(OH)2) to absord SO2 in the scrubber resulting in the formation of calcium sulfate or calcium sulfite. The resulting calcium sulfate/sulfite is then removed, along with fly ash, in a fabric filter or ESP. LSD is one of the preferred technology worldwide. The cost per ton listed is for units larger than 200 megawatts. The cost per ton for smaller units is $517-$4,133 dollars per ton. Control efficiency ranges between 70%-96% with a median reduction of 90%; EPA used 90% for CAIR analysis.	LADCO 2005a
Utility Boiler - Coal	Limestone Forced Oxidation System (LSFO)	52-98	$200-$500		LSFO is a process based on wet limestone scrubbing which reduces scaling and eliminates need for landfilling of the waste product. It is one of the preferred technology worldwide. The cost per ton listed is for units larger than 400 megawatts. The cost per ton for smaller units is $517-$5,166 dollars per ton. Control efficiency ranges between 52%-98% with a median reduction of 90%; EPA used 95% for CAIR analysis.	LADCO 2005a
Utility Boiler - Coal	Magnesium Enhanced Lime System (MEL)	52-98	$200-$500		In the MEL process, slaked lime, containing calcium hydroxide [Ca(OH)2] and a portion of magnesium hydroxide [Mg(OH)2], is used to react with SO2. It is one of the preferred technology worldwide. The cost per ton listed is for units larger than 400 megawatts. The cost per ton for smaller units is $517-$5,166 dollars per ton. Control efficiency ranges between 52%-98% with a median reduction of 90%; EPA used 96% for CAIR analysis.	LADCO 2005a
Utility Boiler - Coal	Physical Coal Cleaning	10-40			Uses physical processes to remove pyrites (inorganic sulfur compounds) in coal.	LADCO 2005a
Utility Boiler - Coal	Repowering to IGCC	99	Cost effectiveness is variable depending on nameplate capacity: - capital cost = $1,027 per kW - fixed O&M cost = $33.37 per kW per year - variable O&M cost = $3.17 mills per kW	Hg, NOx	Repowering improves power plant efficiencies and implies significant waste reduction. Typical repowering entails steps in which the coal handling system and the boiler are replaced with new combustion turbines and a heat recovery boiler. The only significant part of the plant that is maintained is the original turbine generator. The IGCC is a repowering option that requires extensive gasification equipment to generate synthetic gas from coal in order to feed the gas turbines. IGCC plants offer the capability of removing the Hg from the compressed syngas prior to combustion where the gas volume treated is much less than the low pressure, post-combustion flow volume.	EPA 1998b

* when less than 99%, control efficiencies were rounded up to the closest whole number. Cost rounded to 2 significant figures.

Mobile Controls NOx
Menu of Control Measures
Updated 4/12/2012

Source Category	Emission Reduction Measure Name	Control Efficiency (%)	Cost Effectiveness (2006$/ton reduced)	Other pollutants controlled	Description/Notes/Caveats	References
Onroad Heavy Duty Diesel Vehicles (Class 6 and above)	Diesel Retrofit	NOx: 16-34% for Class 6&7;15-43% for Class 8 VOC: 35-59% for Class 6&7;32-68% for Class 8	- Class 8: $4,284-$12,157 per ton NOx - Class 6&7: $23,192-$62,873 per ton NOx	PM10, PM2.5, CO, VOC	This measure examines the impacts of improving the PM monitoring technique at units currently using an ESP, scrubber, or fabric filter. In this improved technique scenario, the monitoring technique is upgraded to a PM continuous emission monitor. This improved monitoring technique also results in an increase to the monitoring frequency because a PM CEMS can make a measurement every 7.5 minutes. The monitoring frequency increases from once per day to eight times per hour.	EPA 2011a
Onroad Heavy Duty Diesel Vehicles (Class 8)	Eliminate Long Duration Idling	Exhaust NOx: 10-33% Exhaust VOC: 21-60%	- Class 8: from a cost of $46,506 to savings of $16,001 per ton NOx - Class 6&7: from a cost of $68,323 to savings of $15,501 per ton NOx	PM10, PM2.5, CO, SO2, VOC, benzene, naphthalene, 1,3-butadiene, formaldehyde, acetaldehyde, acrolein	A fabric filter, or baghouse, consists of a number of fabric bags placed in parallel inside of an enclosure. Particulate matter is collected on the surface of the bags as the gas stream passes through them. The particulate is periodically removed from the bags and collected in hoppers located beneath the bags. A number of methods are employed to facilitate the removal of particulate from the bags, including shaking, reverse air flow, and pulse air flow. The only potential drawback to a fabric filter would be when used in conjunction with a high moisture flue gas stream or with extremely high temperatures. If moisture levels in the flue gas stream are too high then filter caking can occur. Cost-effectiveness varies depending on the type of filter (Reverse-Air Cleaned Type, Mech. Shaker Type, Pulse Jet Type) and is based on EPA's cost-estimating spreadsheet for fabric filters.	EPA 2011a
Onroad Light Duty Vehicles	Continuous Inspection and Maintenance	NOx: 1-3% (if biennial I/M in place). VOC: 1-5% (if biennial I/M in place).	$0	PM10, PM2.5, CO, Benzene, Ethanol, Naphtalene, Methanol, Formaldehyde	This measure is to conduct improved monitoring for PM2.5 emissions at stationary sources. Improved monitoring in this case means increasing the monitoring frequency of electrostatic precipitators, scrubbers, and fabric filters from once per day to four times per hour, with no change in monitoring technique. The incremental costs included a one-time cost for development of the improved monitoring and recurring annual burden costs for incremental record keeping, reporting, and certification activities.	EPA 2011a, I/M Workgroup 2008, EPA 1992a
Onroad Light Duty Gasoline Vehicles and Trucks	Travel Efficiency Strategies	NOx: 2-5%		VOC, CO, PM	These types of measures can achieve 2-5% reduction by 2020 if the "low cost" bundle of strategies from the "Moving Cooler" report is implemented either aggressively or to the maximum extent. The "Low Cost" bundle represents the best combination of strategies based on cost, likelihood of success, and accuracy of the research results. This bundle includes strategies like smart growth/transit, commuter strategies, system operations (e.g., eco-driving, ramp metering), pricing (e.g., parking taxes, congestion pricing, intercity tolls), speed limit restrictions, and multimodal freight strategies. Additionally EPA has released the Transportation Efficiency Assessment Method (TEAM) for assessing emissions reductions from travel efficiency strategies. For more information see references.	Cambridge 2009, EPA 2011d
Onroad and Nonroad Vehicles	Ozone Action Days - Education and promotion campaigns	Potential to reduce both NOx and VOC.	Low	VOC, PM10, PM2.5, CO	These controls encompass several sources of public awareness programs, whether employer-based, school-based, or public education based. For instance, in Arkansas, the Ozone Action Days program emphasis is on providing notification about the predicted high ozone episodes with suggestions for voluntary actions to protect public health, especially those populations identified as most at risk and ways in which individuals and groups can work to reduce the production of nitrogen oxides and volatile organic compounds released into our air. State and local agencies should consult the VMEP policy to determine how to include emissions reductions from these types of programs in a SIP.	ADEQ 2011, EPA 1997g
Nonroad Heavy Duty Diesel Equipment	Diesel Retrofits and Engine Rebuilds	NOx: 0-37% by equipment type VOC: 0-49% by equipment type	$4500 per ton NOx for most, $3,245-$5,164 per ton NOx for some construction equipment	PM10, PM2.5, CO, Benzene, Methanol, Formaldehyde	This measure achieves substantial NOx emission reductions from the use of selective catalytic reduction (SCR) technology and engine rebuilds for various types of nonroad equipment such as construction equipment, airport support equipment, and commercial generators. Can be combined with diesel particulate filters.	
Nonroad Aircraft Ground Support Equipment	Alternative Fuels - CNG/LPG	NOx: 25% for gas NOx: 65% for diesel NMHC: 50-70% for gas NMHC: 30% for diesel	Gas: $0 (savings) Diesel: $1,110-$3,325 per ton VOC/CO/NOx combined	CO	Conversion or replacement of conventionally-fueled GSE machines with LPG or CNG can provide significant emissions benefits. For gasoline-powered equipment, conventional engines are able to use alternative fuels by replacing the existing carburetor or fuel injection system with a new system capable of handling CNG/LPG. Existing fuel tanks are replaced with high pressure tanks for CNG or low pressure tanks for liquefied natural gas (LNG). Modifications are also made to the engine controls. Since diesel engines cannot be converted entirely to alternative fuels (as they do not have spark plugs) they are generally converted to dual fuel vehicles, which run 20 percent of the time on diesel and 80 percent of the time on alternative fuels.	Midwest RPO 2005, NESCAUM 2003b
Nonroad Aircraft Ground Support Equipment	Alternative Fuels - Electric	NOx: 100%	Varies depending on the GSE Gas: savings to $1,900 per ton NOx Diesel: savings to $5,800 per ton NOx	CO	In electric GSE, conventional engines are substituted with electric motors and fuel tanks are replaced with lead acid batteries. Electric aircraft tugs, potable water carts, baggage conveyor belts, and other machines are commercially available. The benefits of electric GSE include the elimination of onairport GSE emissions, noise, and the odor associated with gasoline or diesel machines. The costs associated with the use of electric equipment include installation of recharging units, incremental costs associated with the purchase of purpose-built electric GSE or conversion of conventional equipment, battery replacement, and mechanics and operator training.	Midwest RPO 2005, NESCAUM 2003b

Nonroad Commercial Marine - Ocean Going Vessels	Shore Based Electrical Power - Cold Ironing	NOx: 90%	$6,500-$18,000 ton of NOx + diesel PM reduced.	PM	Cost effectiveness is based on the 2006 ARB Emission Reduction Plan for Ports and Goods Movement and is based on a mix of strategies and approaches (it was calculated based on various ARB programs).	This control is the use of low NOx burner (LNB) technology and selective non-catalytic reduction (SNCR) to reduce NOx emissions. LNBs reduce the amount of NOx created from reaction between fuel nitrogen and oxygen by lowering the temperature of one combustion zone and reducing the amount of oxygen available in another. SNCR controls are post-combustion control technologies based on the chemical reduction of nitrogen oxides (NOx) into molecular nitrogen (N2) and water vapor (H2O). This control is applicable to process heaters fired with distillate, residual oil, and other unclassified
Nonroad Locomotives	Idling Reduction	Variable depending on technology and application		PM, VOC, SO2, CO, Toxics	Idle reduction technologies such as SmartStart and Diesel Driven Heating Systems can reduce idling up to 90 percent, depending on which technology is employed in which application. This can significantly reduce overall emissions as EPA estimates that idling accounts for about 60 percent of switch yard locomotive operating time and 12.5 percent of line-haul locomotive operating time. A specific control efficiency is not provided since EPA has recently adopted new more stringent emissions standards and mandated the application of idle-emission controls on newly manufactured and remanufactured locomotives. This control measure will thus be most efficient as a retrofit to older locomotives. The new EPA rule consists of a three-part emission control strategy: first, there are new standards for existing locomotives that take effect as soon as certified remanufacture systems are available. Second, the rule sets near-term emission standards, referred to as Tier 3 standards, for newly-built locomotive (phase-in starting in 2009). Third, the final long-term emissions standards, referred to as Tier 4, apply to newly-built locomotives (phase-in beginning in 2015). EPA estimates this final rule will result in PM reductions of about 90 percent and NOx reductions of about 80 percent from engines meeting these standards, compared to engines meeting the current standards. More information is available at: http://www.epa.gov/otaq/locomotives.htm and http://www.epa.gov/otaq/regs/nonroad/locomotv/420f08014.pdf	EPA 2005, EPA 1998h, EPA 2008e
Nonroad Locomotives	Upgrade Engines in Switcher Locomotives - Diesel-electric hybrid locomotives	NOx: 80%	$6,500-$18,000 ton of NOx + diesel PM reduced.	PM	Diesel-electric hybrid switch locomotives (e.g. Green Goats) are a proven technology that use the same basic concept as a gas-electric hybrid automobile – a battery pack powers the locomotive, while a small diesel engine runs as needed to keep the batteries charged. Hybrid switch locomotives have significantly reduced diesel PM and NOx emissions, idling time, and fuel use compared to conventional switchers. These can reduce PM and NOx emissions generated by a switcher locomotive by up to 80 percent. Cost effectiveness is based on the 2006 ARB Emission Reduction Plan for Ports and Goods Movement and is based on a mix of strategies and approaches (it was calculated based on various ARB programs).	ARB 2006

Mobile Controls VOC
Menu of Control Measures
Updated 4/12/2012

Source Category	Emission Reduction Measure Name	Control Efficiency (%)	Cost Effectiveness (2006$/ton reduced)	Other pollutants controlled	Description/Notes/Caveats	References
Federal Fuel Programs					This measure examines the impacts of improving the PM monitoring technique at units currently using an ESP, scrubber, or fabric filter. In this improved technique scenario, the monitoring technique is upgraded to a PM continuous emission monitor. This imp***roved monitoring technique also results in an increase to the monitoring frequency because a PM CEMS can make a measurement every 7.5 minutes. The monitoring frequency increases from once per day to eight times per hour.***	
Onroad and Nonroad Gasoline Vehicles	Opt into Reformulated Gasoline (RFG) standards	NOx: 2% (HC total ~ 0.1%)	$2,625 - $4,600 per ton NOx	Toxics	A fabric filter, or baghouse, consists of a number of fabric bags placed in parallel inside of an enclosure. Particulate matter is collected on the surface of the bags as the gas stream passes through them. The particulate is periodically removed from the bags and collected in hoppers located beneath the bags. A number of methods are employed to facilitate the removal of particulate from the bags, including shaking, reverse air flow, and pulse air flow. The only potential drawback to a fabric filter would be when used in conjunction with a high moisture flue gas stream or with extremely high temperatures. If moisture levels in the flue gas stream are too high then filter caking can occur. Cost-effectiveness varies depending on the type of filter (Reverse-Air Cleaned Type, Mech. Shaker Type, Pulse Jet Type) and is based on EPA's cost-estimating spreadsheet for fabric filters.	ARB 2007c
State Fuel Programs *					This measure is to conduct improved monitoring for PM2.5 emissions at stationary sources. Improved monitoring in this case means increasing the monitoring frequency of electrostatic precipitators, scrubbers, and fabric filters from once per day to four ti***mes per hour, with no change in monitoring technique.*** ***The incremental costs included a one-time cost for development of the improved monitoring and recurring annual burden costs for incremental record keeping, reporting, and certification activities.***	
Onroad Heavy Duty Vehicles	Alternative Fuel Programs	NOx: 0%-60% VOC: 0%-13%		PM, CO, SO2, CO2	These programs encompass a number of different programs, including alternative fuel refuse trucks programs, alternative fuel vehicle conversion, alternative fuel or hybrid school/transit bus programs, public sector clean fuel fleets, private sector clean fuel fleets, and alternative fuels tax credit programs. The control efficiencies listed are ranges for biodiesel, CNG, LPG, and E85. For heavy duty vehicles, LPG may actually increase VOC emissions by up to 78% compared to diesel.	EPA 2002f, NREL 2006, NREL 2003, ANL 1999
Onroad Gasoline Vehicles	Low RVP Gasoline	Exhaust VOC: 1-4%, varies by source type and season. Evaporative VOC: 1-13%, varies by source type and season.	$5,700	NOx, CO, SO2	Lower Reid Vapor Pressure (RVP) helps to reduce VOCs, which are a precursor to ozone formation. This control measure represents the use of gasoline with a RVP limit of 7.0 psi from May through September in counties with an ozone season RVP value greater than 7.0 psi. ***NOTE: Application limited by the Energy Policy Act and CAA section 211(c) requirements for a state waiver to require lower RVP fuels.*** This control measure was modeled with MOVES. Since efficiency and cost effectiveness of this control measure are based on MOVES runs, reductions associated with this control measures should NOT be applied to MOBILE6-based data.	EPA 2011a, EPA 2011b
Onroad and Nonroad Gasoline Vehicles	Petition EPA to remove the 1 psi allowance for 9-10% ethanol blends			NOx, CO for onroad. Refueling VOC for some nonroad source types.	The Energy Policy Act amended CAA section 211(h) to allow areas to petition EPA to remove the 1 psi allowance for 9-10% ethanol blends. ***NOTE: Such a petition requires documentation showing that the 1 psi allowance will increase emissions that contribute to air pollution.***	
Nonroad Gasoline Vehicles	Low RVP Gasoline	Evaporative VOC: 1-50%, varies by source type and season.	$5,700	Refueling VOC for some source types	Lower Reid Vapor Pressure (RVP) helps to reduce VOCs, which are a precursor to ozone formation. This control measure represents the use of gasoline with a RVP limit of 7.0 psi from May through September in counties with an ozone season RVP value greater than 7.0 psi. ***NOTE: Application limited by the Energy Policy Act and CAA section 211(c) requirements for a state waiver to require lower RVP fuels.***	EPA 2011b
Other Measures						

Onroad Light Duty Vehicles	Continuous Inspection and Maintenance	NOx: 7-18% (if no I/M program), or 1-3% (if biennial I/M in place). VOC: 4-25% (if no I/M program), or 1-5% (if biennial I/M in place).	$0	PM10, PM2.5, CO, Benzene, Ethanol, Naphtalene, Methanol, Formaldehyde	Continuous Inspection and Maintenance (I&M) uses onboard diagnostics and continuous cellular data transmission to provide more rapid identification of emission control failures. This technology can offer substantial emission reductions and major cost-savings for consumers. This control measure was modeled with MOVES. Since efficiency and cost effectiveness of this control measure are based on MOVES runs, reductions associated with this control measures should NOT be applied to MOBILE6-based data.	This control is the use of low NOx burner (LNB) technology and selective non-catalytic reduction (SNCR) to reduce NOx emissions. LNBs reduce the amount of NOx created from reaction between fuel nitrogen and oxygen by lowering the temperature of one combustion zone and reducing the amount of oxygen available in another. SNCR controls are post-combustion control technologies based on the chemical reduction of nitrogen oxides (NOx) into molecular nitrogen (N2) and water vapor (H2O). This control is applicable to process heaters fired with distillate, residual oil,
Onroad Light Duty Gasoline Vehicles and Trucks	Travel Efficiency Strategies	VOC: 2-5%		NOx, CO, PM	These types of measures can achieve 2-5% reduction by 2020 if the "low cost" bundle of strategies from the "Moving Cooler" report is implemented either aggressively or to the maximum extent. The "Low Cost" bundle represents the best combination of strategies based on cost, likelihood of success, and accuracy of the research results. This bundle includes strategies like smart growth/transit, commuter strategies, system operations (e.g., eco-driving, ramp metering), pricing (e.g., parking taxes, congestion pricing, intercity tolls), speed limit restrictions, and multimodal freight strategies. Additionally EPA has released the Transportation Efficiency Assessment Method (TEAM) for assessing emissions reductions from travel efficiency strategies. For more information see references.	Cambridge 2009, EPA 2011d
Onroad and Nonroad Vehicles	Ozone Action Days - Education and promotion campaigns	Potential to reduce both NOx and VOC.	Low	NOx, PM10, PM2.5, CO	These controls encompass several sources of public awareness programs, whether employer-based, school-based, or public education based. For instance, in Arkansas, the Ozone Action Days program emphasis is on providing notification about the predicted high ozone episodes with suggestions for voluntary actions to protect public health, especially those populations identified as most at risk and ways in which individuals and groups can work to reduce the production of nitrogen oxides and volatile organic compounds released into our air. State and local agencies should consult the VMEP policy to determine how to include emissions reductions from these types of programs in a SIP.	ADEQ 2011, EPA 1997g

* In SIPs, State Fuel programs have been identified by Congress as control measures of last resort and are subject to certain hurdles; notably, the requirement for a necessity determination that the measure is needed to meet a NAAQS and no other non-fuel programs exist and/or are practicable to implement. If such a necessity demonstration can be made, then there is a second hurdle of the fuel being listed on the boutique fuel list and in a SIP in the PADD in question. The CAA section 211(c) approval hurdles remove the option of many of these fuel programs for many areas.

Source Category	Emission Reduction Measure Name	Control Efficiency (%)	Cost Effectiveness (2006$/ton reduced)	Other pollutants controlled	Description/Notes/Caveats	References
Onroad Heavy Duty Diesel Vehicles (Class 8)	Eliminate Long Duration Idling	Exhaust PM2.5: 2%-5% Exhaust SO2: 1%-4%	- Class 8: from a cost of $46,506 to savings of $16,001 per ton NOx - Class 6&7: from a cost of $68,323 to savings of $15,501 per ton NOx	NOx, VOC, CO, SO2, benzene, naphthalene, 1,3-butadiene, formaldehyde, acetaldehyde, acrolein	This measure examines the impacts of improving the PM monitoring technique at units currently using an ESP, scrubber, or fabric filter. In this improved technique scenario, the monitoring technique is upgraded to a PM continuous emission monitor. This improved monitoring technique also results in an increase to the monitoring frequency because a PM CEMS can make a measurement every 7.5 minutes. The monitoring frequency increases from once per day to eight times per hour.	EPA 2011a
Onroad Heavy Duty Diesel Vehicles (Class 8)	Intermodal - shift of transportation of goods from truck to rail transport.	PM: 1% SO2: 1% NH3: 1%	$0	NOx, VOC	A fabric filter, or baghouse, consists of a number of fabric bags placed in parallel inside of an enclosure. Particulate matter is collected on the surface of the bags as the gas stream passes through them. The particulate is periodically removed from the bags and collected in hoppers located beneath the bags. A number of methods are employed to facilitate the removal of particulate from the bags, including shaking, reverse air flow, and pulse air flow. The only potential drawback to a fabric filter would be when used in conjunction with a high moisture flue gas stream or with extremely high temperatures. If moisture levels in the flue gas stream are too high then filter caking can occur. Cost-effectiveness varies depending on the type of filter (Reverse-Air Cleaned Type, Mech. Shaker Type, Pulse Jet Type) and is based on EPA's cost-estimating spreadsheet for fabric filters.	EPA 2006d
Onroad Heavy Duty Diesel Vehicles (Class 6 and above)	Diesel Retrofit	PM: 53-56% for Class 6&7; 52-61% for Class 8	- Class 8: $4,284-$12,157 per ton NOx - Class 6&7: $23,192-$62,873 per ton NOx	NOx, VOC, CO	This measure is to conduct improved monitoring for PM2.5 emissions at stationary sources. Improved monitoring in this case means increasing the monitoring frequency of electrostatic precipitators, scrubbers, and fabric filters from once per day to four times per hour, with no change in monitoring technique. The incremental costs included a one-time cost for development of the improved monitoring and recurring annual burden costs for incremental record keeping, reporting, and certification activities.	EPA 2011a
Onroad Heavy Duty Diesel Vehicles (Class 5 and above)	Truck Replacement	PM: 90%-98%	$17,267-$35,475	NOx, VOC	Applies to 1990-2006 model years. This control measure involves replacing older trucks with model year 2007 and later heavy-duty highway trucks. The new stringent emission standards (for MY 2007+) impose a limit of 0.01g/bhp-hr PM, while previous regulations imposed limits of 0.1g/bhp-hr PM, 0.25g/bhp-hr PM, and 0.6g/bhp-hr PM for model years 1994, 1991, and 1990 respectively. Replacing a 1990 truck would yield a 98% reduction, while replacing a 2006 truck would yield a 90% reduction.	EPA 2006d
Onroad Heavy Duty Diesel Vehicles	Alternative Fuel Programs	PM: 11%-99% SO2: 19%-71%	No cost-effectiveness available	NOx, VOC, CO, SO2, CO2	These programs encompass a number of different programs, including alternative fuel refuse trucks programs, alternative fuel vehicle conversion, alternative fuel or hybrid school/transit bus programs, public sector clean fuel fleets, private sector clean fuel fleets, and alternative fuels tax credit programs. The control efficiencies listed are ranges for biodiesel, CNG, LPG, and E85. For heavy duty vehicles, LPG may actually increase VOC emissions by up to 78% compared to diesel.	EPA 2002f, NREL 2006, NREL 2003, ANL 1999
Onroad Light Duty Gasoline Vehicles	Alternative Fuel Programs	PM: 34%-80% SO2: 19%-77%	No cost-effectiveness available	NOx, VOC, CO, SO2, CO2	These programs encompass a number of different programs, including alternative fuel vehicle conversion, public sector clean fuel fleets, private sector clean fuel fleets, and alternative fuels tax credit programs. The control efficiencies listed are ranges for CNG and E85.	EPA 2002f, NREL 2006, JAWMA 2009, ANL 1999
Onroad Light Duty Gasoline Vehicles and Trucks	Travel Efficiency Strategies	VOC: 2-5%		NOx, CO, VOC	These types of measures can achieve 2-5% reduction by 2020 if the "low cost" bundle of strategies from the "Moving Cooler" report is implemented either aggressively or to the maximum extent. The "Low Cost" bundle represents the best combination of strategies based on cost, likelihood of success, and accuracy of the research results. This bundle includes strategies like smart growth/transit, commuter strategies, system operations (e.g., eco-driving, ramp metering), pricing (e.g., parking taxes, congestion pricing, intercity tolls), speed limit restrictions, and multimodal freight strategies. Additionally EPA has released the Transportation Efficiency Assessment Method (TEAM) for assessing emissions reductions from travel efficiency strategies. For more information see references.	Cambridge 2009, EPA 2011d
Nonroad Commercial Marine - Ocean Going Vessels	Shore Based Electrical Power - Cold Ironing	PM: 90%	$6,500-$18,000 ton of NOx + diesel PM reduced.	NOx	Cost effectiveness is based on the 2066 ARB Emission Reduction Plan for Ports and Goods Movement and is based on a mix of strategies and approaches (it was calculated based on various ARB programs).	ARB 2006
Nonroad Locomotives	Idling Reduction	Variable depending on technology and application		PM, VOC, SO2, CO, Toxics	Idle reduction technologies such as SmartStart and Diesel Driven Heating Systems can reduce idling up to 90 percent, depending on which technology is employed in which application. This can significantly reduce overall emissions as EPA estimates that idling accounts for about 60 percent of switch yard locomotive operating time and 12.5 percent of line-haul locomotive operating time. A specific control efficiency is not provided since EPA has recently adopted new more stringent emissions standards and mandated the application of idle-emission controls on newly manufactured and remanufactured locomotives. This control measure will thus be most efficient as a retrofit to older locomotives. The new EPA rule consists of a three-part emission control strategy: first, there are new standards for existing locomotives that take effect as soon as certified remanufacture systems are available. Second, the rule sets near-term emission standards, referred to as Tier 3 standards, for newly-built locomotive (phase-in starting in 2009). Third, the final long-term emissions standards, referred to as Tier 4, apply to newly-built locomotives (phase-in beginning in 2015). EPA estimates this final rule will result in PM reductions of about 90 percent and NOx reductions of about 80 percent from engines meeting these standards, compared to engines meeting the current standards. More information is available at: http://www.epa.gov/otaq/locomotives.htm and http://www.epa.gov/otaq/regs/nonroad/locomotv/420f08014.pdf	This control is the use of low NOx burner (LNB) technology and selective non-catalytic reduction (SNCR) to reduce NOx emissions. LNBs reduce the amount of NOx created from reaction between fuel nitrogen and oxygen by lowering the temperature of one combustion zone and

Nonroad Locomotives	Upgrade Engines in Switcher Locomotives - Diesel-electric hybrid locomotives	PM: 80%	$6,500-$18,000 ton of NOx + diesel PM reduced.	NOx	Diesel-electric hybrid switch locomotives (e.g. Green Goats) are a proven technology that use the same basic concept as a gas-electric hybrid automobile – a battery pack powers the locomotive, while a small diesel engine runs as needed to keep the batteries charged. Hybrid switch locomotives have significantly reduced diesel PM and NOx emissions, idling time, and fuel use compared to conventional switchers. These can reduce PM and NOx emissions generated by a switcher locomotive by up to 80 percent. Cost effectiveness is based on the 2066 ARB Emission Reduction Plan for Ports and Goods Movement and is based on a mix of strategies and approaches (it was calculated based on various ARB programs).	ARB 2006
Nonroad Diesel Industrial	ARB Cargo Handling Equipment Rule - Application of Best Available Control Technology	PM: 25%-85%	$6,500-$18,000	NOx	The range of control efficiency values represents Level 1, 2 and 3, which are three benchmarks that control systems can be verified to. Cost effectiveness is based on the 2006 ARB Emission Reduction Plan for Ports and Goods Movement and is based on a mix of strategies and approaches (it was calculated based on various ARB programs).	ARB 2006
Nonroad Heavy Duty Diesel	Diesel Retrofit - DOC/DPF/Rebuild	PM: 20%-90%	$18,100 - $33,900	NOx, VOC, CO	This measure achieves substantial PM emission reductions from the use of diesel particulate filter technology or engine rebuilds for various types of nonroad equipment such as construction equipment, airport support equipment, and commercial generators. PM cost effectiveness values apply for all retrofit measures combined (DOC, DPF, and rebuild).	EPA 2006l, EPA 2006m

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Statement of Reasonably Available Control Technology Principles

OZONE
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Connecticut

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Vermont

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J. Wick Havens
Interim Executive
Director

444 N. Capitol St. NW
Suite 322
Washington, DC 20001
(202) 508-3840
FAX (202) 508-3841
Email: ozone@otcair.org

The Ozone Transport Commission (OTC) is a multi-state organization created under the Clean Air Act (CAA) to advise the U.S. Environmental Protection Agency (EPA) on practical and cost effective solutions to the environmental and public health problem of ground-level ozone transport that negatively affects the Ozone Transport Region (OTR).

Ozone has been shown to cause respiratory illnesses, exacerbate or trigger asthma related episodes, increase respiratory-related emergency room and hospital admissions and compromise the immune system leading to increased incidents of other respiratory illnesses, including pneumonia and bronchitis, and to cause premature death.

In 2014, each OTC state is required under Section 184 of the Clean Air Act to perform a review of the state's control requirements to ensure that all major sources of NOx and VOC are subject to a RACT (or Reasonably Available Control Technology) level of control under the 2008 national ambient air quality standard (NAAQS) for ozone. OTC's Stationary and Area Sources Committee has conducted extensive analysis of largest contributing sources inside and outside of the region published in a whitepaper. EPA has defined RACT as the lowest emission limitation that a particular source is capable of meeting by the application of control technology that is reasonably available considering technological and economic feasibility. Over time, RACT changes to reflect advances in technology, becoming more stringent as the NAAQS are revised and lowered. In order to protect the public adequately from the adverse health effects associated with ozone and ensure consistency, the OTC recommends the following minimum principles for RACT to assist in attainment and maintenance of the ozone NAAQS:

1. Consistent with EPA guidance, levels of control, and emissions rates, that are achieved in practice by existing similar sources are technologically and economically feasible, considering capacity, fuel, equipment design, control technology, age and site limitations, and therefore represent RACT. Thus, requirements in place in other states for certain sources provide a benchmark for RACT for that source category.

2. Sources that have purchased and installed pollution control technology must run those technologies year round and ensure that, during the ozone season, daily emissions are minimized.

3. For electricity generating units:

    a. Compliance with the Cross-State Air Pollution Rule or the Clean Air

Interstate Rule cannot substitute for RACT.

b. Peaking units need to be assessed with due consideration given to total daily emissions from the category of sources and the economics of meeting peak demands.

4. The averaging time for a RACT-based emission limitation should be as short as practicably consistent with the ozone standard and characteristic operation of the source category.

Therefore, the OTC member states strongly believe that the implementation of the aforementioned RACT core principles will strengthen emissions limitations, lower overall emissions, and thereby derive air quality and public health benefits.

Abstained: New Hampshire ,Pennsylvania, Virginia

Adopted by the Commission on June 11, 2014

Robert M. Summers, OTC Chair
Secretary, Maryland Department of Environmental Protection