



## MEMORANDUM

DATE: June 9, 2005

SUBJECT: Cost per Ton for NSPS for Stationary CI ICE

FROM: Tanya Parise, Alpha-Gamma Technologies, Inc.

TO: Sims Roy, EPA OAQPS ESD Combustion Group

---

The purpose of this memorandum is to estimate the cost per ton of pollutant removed for the proposed new source performance standards (NSPS) for stationary compression ignition (CI) internal combustion engines (ICE). This memorandum also presents the cost per ton of other control technologies EPA considered.

### Introduction

The proposed rule requires stationary CI engines to comply with standards that have been promulgated for nonroad CI engines. These standards consist of various tiered levels that increase in stringency. Although the proposed rule requires stationary CI engines to meet all tiers, EPA expects that stationary CI engines would generally emit the same levels as nonroad engines until Tier 4 is required, even in the absence of the rule. For the purpose of estimating reductions for stationary CI engines, the EPA does not take credit for reductions until Tier 4 is in effect. This means that the baseline level for estimating reductions is the tier level prior to Tier 4. The EPA expects that nitrogen oxides (NO<sub>x</sub>) adsorbers and catalyzed diesel particulate filters (CDPF) will be used to meet Tier 4 levels and are expected to reduce NO<sub>x</sub> and particulate matter (PM) emissions, respectively, by at least 90 percent.

### Control Cost

The methodology for estimating the cost of these control technologies is presented in the memorandum entitled "Control Costs for NO<sub>x</sub> adsorbers and CDPF for CI Engines," included in the docket (Docket ID No. OAR-2005-0029). The average annual cost of control for NO<sub>x</sub> adsorbers and CDPF were each estimated at \$1 per horsepower (HP). The combined annual cost of control was estimated at \$2/HP. To determine the annual control cost per engine, EPA multiplied the combined annual cost

of control by the average engine size for each HP range. The total annual cost of control per engine for each engine size range is presented in Table 1.

Table 1. Annual Cost of Control per Engine  
w/NO<sub>x</sub> Adsorbers and CDPF

| <b>HP Range</b> | <b>Average HP</b> | <b>Annual Control Cost (\$/HP)</b> | <b>Annual Control Cost per Engine (\$/yr)</b> |
|-----------------|-------------------|------------------------------------|-----------------------------------------------|
| 50-75           | 63                | 2                                  | 126                                           |
| 75-100          | 88                | 2                                  | 176                                           |
| 100-175         | 135               | 2                                  | 270                                           |
| 175-300         | 238               | 2                                  | 476                                           |
| 300-600         | 450               | 2                                  | 900                                           |
| 600-750         | 675               | 2                                  | 1,350                                         |
| 750-1,200       | 975               | 2                                  | 1,950                                         |
| 1,200-3,000     | 2,100             | 2                                  | 4,200                                         |
| >3,000          | 5,000             | 2                                  | 10,000                                        |

## Emission Reduction

The emission factors corresponding to the various tiers were obtained from Table A.2 of EPA's emission factors for nonroad CI engine modeling.<sup>1</sup> To determine the pollutant reduction per engine as a result of applying Tier 4 add-on control, EPA subtracted the Tier 4 level from the previous tier level. The resulting emission factors representing the reduction per engine for each size range are shown in Table 2.

Table 2. Emission Factors for NO<sub>x</sub> and PM

---

<sup>1</sup>US EPA. Exhaust and Crankcase Emission Factors for Nonroad Engine Modeling—Compression Ignition. EPA420-P-04-009. April 2004. NR-009c.

| HP Range    | Emission Factor (g/HP-hr) |         |           |               |          |           |
|-------------|---------------------------|---------|-----------|---------------|----------|-----------|
|             | NO <sub>x</sub>           |         |           | PM            |          |           |
|             | Previous Tier             | Tier 4* | Reduction | Previous Tier | Tier 4** | Reduction |
| 50-75***    | 3.0                       | 0.30    | 2.700     | 0.20          | 0.0184   | 0.1816    |
| 75-100      | 3.0                       | 0.276   | 2.724     | 0.30          | 0.0092   | 0.2908    |
| 100-175     | 2.5                       | 0.276   | 2.224     | 0.22          | 0.0092   | 0.2108    |
| 175-300     | 2.5                       | 0.276   | 2.224     | 0.15          | 0.0092   | 0.1408    |
| 300-600     | 2.5                       | 0.276   | 2.224     | 0.15          | 0.0092   | 0.1408    |
| 600-750     | 2.5                       | 0.276   | 2.224     | 0.15          | 0.0092   | 0.1408    |
| 750-1,200   | 2.392                     | 0.46    | 1.932     | 0.069         | 0.0184   | 0.0506    |
| 1,200-3,000 | 4.1                       | 0.46    | 3.640     | 0.069         | 0.0184   | 0.0506    |
| >3,000      | 4.1                       | 0.46    | 3.640     | 0.069         | 0.0184   | 0.0506    |

\*Tier 4 for NO<sub>x</sub> is based on the use NO<sub>x</sub> adsorbers.

\*\*Tier 4 for PM is based on the use of CDPF.

\*\*\*NO<sub>x</sub> add-on control is not required for this size range. Estimates shown are for information purposes only, assuming a hypothetical 90 percent reduction of NO<sub>x</sub> from the previous tier.

Using the emission reduction per engine shown in Table 2, the yearly emission reduction per engine for each HP range was calculated using the following equation:

$$\frac{\text{Reduction} \left( \frac{g}{\text{HP-hr}} \right) \times \text{Average HP} \times \frac{\text{hrs}}{\text{yr}} \times 0.0022046 \frac{\text{lb}}{g}}{2,000 \frac{\text{lb}}{\text{ton}}}$$

where:

Reduction = The reduction of NO<sub>x</sub> or PM per engine for each HP range, in g/HP-hr, from Table 2,  
Average HP = Average engine size for each HP range, from Table 1,  
hrs/yr = Average hours of operation (1,000 hrs/yr for prime engines; 37 hrs/yr for emergency engines),  
0.0022046 = Conversion factor, in lb/g, and  
2,000 = Conversion factor, in ton/lb.

Based on the above equation and the emission factors representing the reduction per

engine in Table 2, EPA estimated the reductions per engine per year presented in Table 3.

Table 3. Estimated Reduction of NO<sub>x</sub> and PM per Engine  
w/NO<sub>x</sub> Adsorbers and CDPF

| HP<br>Range | Reduction per Engine (tpy) |           |        |           |
|-------------|----------------------------|-----------|--------|-----------|
|             | NO <sub>x</sub>            |           | PM     |           |
|             | Prime                      | Emergency | Prime  | Emergency |
| 50-75*      | 0.188                      | 0.007     | 0.0126 | 0.0005    |
| 75-100      | 0.264                      | 0.010     | 0.0282 | 0.0010    |
| 100-175     | 0.331                      | 0.012     | 0.0314 | 0.0012    |
| 175-300     | 0.583                      | 0.022     | 0.0369 | 0.0014    |
| 300-600     | 1.103                      | 0.041     | 0.0698 | 0.0026    |
| 600-750     | 1.655                      | 0.061     | 0.1048 | 0.0039    |
| 750-1,200   | 2.076                      | 0.077     | 0.0544 | 0.0020    |
| 1,200-3,000 | 8.426                      | 0.312     | 0.1171 | 0.0043    |
| >3,000      | 20.062                     | 0.742     | 0.2789 | 0.0103    |

\*NO<sub>x</sub> add-on control is not required for this size range. Estimates shown are for information purposes only and are based on a hypothetical 90 percent reduction of NO<sub>x</sub> from the previous tier.

### Cost per ton

Based on the annual cost of control per engine shown in Table 1 and the reduction per engine shown in Table 3, EPA estimated the cost of control per ton of pollutant removed as shown in Table 4.

Table 4. Cost of Control per Ton of Pollutant Removed  
w/NO<sub>x</sub> Adsorbers and CDPF

| HP<br>Range | Cost per ton NO <sub>x</sub><br>Removed<br>(\$/ton) |           | Cost per ton PM<br>Removed<br>(\$/ton) |           | Cost per ton NO <sub>x</sub> +PM<br>Removed<br>(\$/ton) |           |
|-------------|-----------------------------------------------------|-----------|----------------------------------------|-----------|---------------------------------------------------------|-----------|
|             | Prime                                               | Emergency | Prime                                  | Emergency | Prime                                                   | Emergency |
| 50-75*      | 672                                                 | 18,162    | 4,996                                  | 135,015   | 630                                                     | 17,017    |
| 75-100      | 666                                                 | 18,002    | 6,239                                  | 168,630   | 602                                                     | 16,266    |
| 100-175     | 816                                                 | 22,049    | 8,607                                  | 232,626   | 745                                                     | 20,140    |
| 175-300     | 816                                                 | 22,049    | 12,886                                 | 348,278   | 767                                                     | 20,736    |

| HP Range    | Cost per ton NO <sub>x</sub> Removed (\$/ton) |           | Cost per ton PM Removed (\$/ton) |           | Cost per ton NO <sub>x</sub> +PM Removed (\$/ton) |           |
|-------------|-----------------------------------------------|-----------|----------------------------------|-----------|---------------------------------------------------|-----------|
|             | Prime                                         | Emergency | Prime                            | Emergency | Prime                                             | Emergency |
| 300-600     | 816                                           | 22,049    | 12,866                           | 348,278   | 767                                               | 20,736    |
| 600-750     | 816                                           | 22,049    | 12,866                           | 348,278   | 767                                               | 20,736    |
| 750-1,200   | 939                                           | 25,382    | 35,857                           | 969,121   | 915                                               | 24,734    |
| 1,200-3,000 | 498                                           | 13,472    | 35,857                           | 969,121   | 492                                               | 13,287    |
| >3,000      | 498                                           | 13,472    | 35,857                           | 969,121   | 492                                               | 13,287    |

\*NO<sub>x</sub> add-on control is not required for this size range. Estimates shown are for information purposes only and are based on a hypothetical 90 percent reduction of NO<sub>x</sub> from the previous tier.

The EPA also evaluated the cost per ton of using selective catalytic reduction (SCR). The NO<sub>x</sub> reduction using SCR is expected to be the same as NO<sub>x</sub> adsorber, i.e., about 90 percent, so the EPA used the NO<sub>x</sub> reduction shown in Table 3 to estimate the cost per ton with SCR. Based on information received from control technology vendors, EPA estimated SCR annual control costs of \$36/HP per engine. The resulting costs per ton of NO<sub>x</sub> removed for various stationary CI engine sizes are shown in Table 5.

Table 5. Cost of Control per Ton of NO<sub>x</sub> Removed w/SCR

| HP Range    | SCR Annual Control Cost per Engine (\$/yr) | NO <sub>x</sub> Reduction per Engine |           | Cost per ton NO <sub>x</sub> Removed (\$/ton) |           |
|-------------|--------------------------------------------|--------------------------------------|-----------|-----------------------------------------------|-----------|
|             |                                            | Prime                                | Emergency | Prime                                         | Emergency |
| 50-75       | 2,268                                      | 0.188                                | 0.007     | 12,096                                        | 326,917   |
| 75-100      | 3,168                                      | 0.264                                | 0.010     | 11,989                                        | 324,036   |
| 100-175     | 4,860                                      | 0.331                                | 0.012     | 14,685                                        | 396,886   |
| 175-300     | 8,568                                      | 0.583                                | 0.022     | 14,685                                        | 396,886   |
| 300-600     | 16,200                                     | 1.103                                | 0.041     | 14,685                                        | 396,886   |
| 600-750     | 24,300                                     | 1.655                                | 0.061     | 14,685                                        | 396,886   |
| 750-1,200   | 35,100                                     | 2.076                                | 0.077     | 16,904                                        | 456,871   |
| 1,200-3,000 | 75,600                                     | 8.426                                | 0.312     | 8,972                                         | 242,493   |

| HP Range | SCR Annual Control Cost per Engine (\$/yr) | NO <sub>x</sub> Reduction per Engine |           | Cost per ton NO <sub>x</sub> Removed (\$/ton) |           |
|----------|--------------------------------------------|--------------------------------------|-----------|-----------------------------------------------|-----------|
|          |                                            | Prime                                | Emergency | Prime                                         | Emergency |
| >3,000   | 180,000                                    | 20.062                               | 0.742     | 8,972                                         | 242,493   |

Finally, EPA evaluated the cost per ton of using oxidation catalyst. The technology can reduce PM emissions up to 30 percent from stationary CI engines. Based on information obtained from the Office of Transportation and Air Quality for oxidation catalysts, EPA developed oxidation control costs following the methodology discussed in the control cost memorandum referenced earlier in this memorandum. Using that methodology, EPA estimated an average annual cost of control for oxidation catalysts of \$0.30/HP per engine. Assuming oxidation catalysts will reduce PM emissions by 30 percent from stationary CI engines, EPA estimated the cost per ton of PM removed for various stationary CI engine sizes as shown in Table 6.

Table 6. Cost of Control per Ton of PM Removed  
w/Oxidation Catalyst

| HP Range    | Oxidation Catalyst Annual Control Cost per Engine (\$/yr) | PM Reduction per Engine |           | Cost per ton PM Removed (\$/ton) |           |
|-------------|-----------------------------------------------------------|-------------------------|-----------|----------------------------------|-----------|
|             |                                                           | Prime                   | Emergency | Prime                            | Emergency |
| 50-75       | 19                                                        | 0.004                   | 0.0002    | 4,536                            | 122,594   |
| 75-100      | 26                                                        | 0.009                   | 0.0003    | 3,024                            | 81,729    |
| 100-175     | 41                                                        | 0.010                   | 0.0004    | 4,124                            | 111,449   |
| 175-300     | 71                                                        | 0.012                   | 0.0004    | 6,048                            | 163,458   |
| 300-600     | 135                                                       | 0.022                   | 0.0008    | 6,048                            | 163,458   |
| 600-750     | 203                                                       | 0.033                   | 0.0012    | 6,048                            | 163,458   |
| 750-1,200   | 293                                                       | 0.022                   | 0.0008    | 13,148                           | 355,344   |
| 1,200-3,000 | 630                                                       | 0.048                   | 0.0018    | 13,148                           | 355,344   |
| >3,000      | 1,500                                                     | 0.114                   | 0.0042    | 13,148                           | 355,344   |