CHAPTER 12: Regulatory Alternatives

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Our proposed program represents a combination of engine and fuel standards and their associated timing that we believe to be superior to the alternatives considered given feasibility, cost, and environmental impact. In this chapter we present and discuss the alternative program options that we evaluated in order to make this determination. These alternatives are cast as twelve specific Program Options.

For each Option, we first present a full description of the level and timing of fuel and engine standards. We then present the emissions inventory impacts associated with each Option in comparison to our proposed program, as well as the monetized health and welfare benefits, costs, and cost-effectiveness. Finally, we present our assessment of the rationale, feasibility, and issues associated with each Option in light of the analyses we conducted.

12.1 Range of Options Considered

Our proposed emission control program consists of a two-step program to reduce the sulfur content of nonroad diesel fuel in conjunction with the NOx and PM engine standards. During the development of our program, we also considered a one-step fuel program wherein all sulfur reductions in the diesel fuel occur in a single step. Since the fuel provisions and timing dictate to a large extent the possible engine standards, we have structured this section to first discuss issues of variations in the fuel program. Thus, the Program Options are divided into One-Step and Two-Step options, to highlight the fuel sulfur program and its driving impact on the engine standards. Within each of these fuel program approaches, we considered several variations and combinations with engine standards.

This section provides only a description of what the program options are. Subsequent sections present the inventory impacts, benefits, costs, and cost-effectiveness. Finally, Section 12.6 summarizes the rationale for each option and our evaluation of the issues and feasibility associated with the options.

12.1.1 One-Step Options

One-step options are those in which the fuel sulfur standard is applied in a single step; there are no phase-ins or step changes. In all one-step options, the transient test cycle is required concurrently with the introduction of the transitional Tier 4 engine standards in any horsepower group.

Option 1a differs from Options 1 and 1b in terms of the engine standards and their associated timing. Because so much time was needed to produce benefits estimates, EPA decided early in the program development process to use this option as the basis of our benefits analysis (although EPA ultimately determined not to propose this option). Option 1b differs from Option 1 only in the timing of the fuel sulfur standard, and is intended to generate additional early sulfate PM reductions. As a result, we did not lower the certification fuel sulfur level to 15ppm in 2007 and 2008 when modeling this Option, since doing so would permit manufacturers to take advantage of the lower sulfur and thus reduce the PM reductions associated with their certified engines.

The one-step options are summarized in Table 12.1.1-1. Following this table is a summary of the existing Tier 1, Tier 2, and Tier 3 standards from 40 CFR §89.112 that form the baseline of our analyses. The specifics of the three one-step options are shown in the standard charts in Figures 12.1.1-2, 3, and 4. Only changes to the standards are shown in these three figures, i.e. if no new standard for a given pollutant is indicated, the previous standard applies.

Table 12.1.1-1
Summary of One-Step Options

Option	Summary Description
Option 1	• Fuel sulfur ≤ 15ppm in June 2008 for nonroad, ≤ 500ppm for locomotives and marine engines • <50 hp: PM stds only in 2009 • 25-75 hp: PM aftertreatment-based standards and EGR or equivalent NOx technology in 2013; no NOx aftertreatment • >75 hp: PM aftertreatment-based standards phasing in beginning in 2009; NOx aftertreatment-based standards phasing in beginning in 2011 *See Figure 12.1.1-2*
Option 1a	• Fuel sulfur ≤ 15ppm in June 2008 • PM aftertreatment-based standards introduced in 2009-10 • NOx aftertreatment-based standards introduced in 2011-12 *See Figure 12.1.1-3*
Option 1b	Same as Option 1a, except fuel sulfur standard required two years earlier *See Figure 12.1.1-4*

Figure 12.1.1-1
Existing Engine and Fuel Standards

<table>
<tr><th>hp group</th><th>2005</th><th>2006</th><th>2007</th><th>2008</th><th>2009</th><th>2010</th><th>2011</th><th>2012</th><th>2013</th><th>2014</th><th>2015</th></tr>
<tr><td colspan="12">Nonroad engine standards (g/bhp-hr)[α]</td></tr>
<tr><td>hp <25</td><td colspan="11">Tier 2: 5.6 NOx+NMHC, 0.6 PM</td></tr>
<tr><td>25 ≤ hp
hp < 50</td><td colspan="11">Tier 2: 5.6 NOx+NMHC, 0.4 PM</td></tr>
<tr><td>50 ≤ hp
hp < 75</td><td colspan="3" rowspan="2">Tier 2:
5.6 NOx+NMHC
0.3 PM</td><td colspan="8" rowspan="2">Tier 3:
3.5 NOx+NMHC
0.3 PM</td></tr>
<tr><td>75 ≤ hp
hp < 100</td></tr>
<tr><td>100 ≤ hp
hp < 175</td><td colspan="2">Tier 2:
4.9 NOx+NMHC
0.2 PM</td><td colspan="9">Tier 3:
3.0 NOx+NMHC
0.2 PM</td></tr>
<tr><td>175 ≤ hp
hp < 750</td><td>Tier 2:
4.8
NOx+NMHC
0.1 PM</td><td colspan="10">Tier 3:
3.0 NOx+NMHC
0.1 PM</td></tr>
<tr><td>hp ≥ 750</td><td>Tier 1:
6.9 NOx
0.4 PM</td><td colspan="10">Tier 2:
4.8 NOx+NMHC
0.1 PM</td></tr>
<tr><td colspan="12">Fuel sulfur standard (ppm)</td></tr>
<tr><td>Loco & marine</td><td colspan="11">Uncontrolled</td></tr>
<tr><td>Nonroad</td><td colspan="11">Uncontrolled</td></tr>
</table>

[α] Applies to model years.

Figure 12.1.1-2
Engine and Fuel Standards Under Option 1

<table>
<tr><th>hp group</th><th>2005</th><th>2006</th><th>2007</th><th>2008</th><th>2009</th><th>2010</th><th>2011</th><th>2012</th><th>2013</th><th>2014</th><th>2015</th></tr>
<tr><td colspan="12">Nonroad engine standards (g/bhp-hr)[α]</td></tr>
<tr><td>hp <25</td><td colspan="3">Tier 2</td><td colspan="8">0.30 PM</td></tr>
<tr><td>25 ≤ hp
hp < 50</td><td colspan="3">Tier 2</td><td colspan="5">0.22 PM</td><td colspan="3">0.02 PM, 3.3[γ] NOx</td></tr>
<tr><td>50 ≤ hp
hp < 75</td><td colspan="3">Tier 2</td><td colspan="5">Tier 3</td><td colspan="3">0.02 PM, 3.3[γ] NOx</td></tr>
<tr><td>75 ≤ hp
hp < 100</td><td colspan="3">Tier 2</td><td colspan="2">Tier 3</td><td colspan="2">50%: 0.01 PM</td><td colspan="2">0.01 PM
50%: 0.30 NOx</td><td colspan="2">0.30 NOx</td></tr>
<tr><td>100 ≤ hp
hp < 175</td><td colspan="2">Tier 2</td><td colspan="3">Tier 3</td><td colspan="2">50%: 0.01 PM</td><td colspan="2">0.01 PM
50%: 0.30 NOx</td><td colspan="2">0.30 NOx</td></tr>
<tr><td>175 ≤ hp
hp < 750</td><td>Tier 2</td><td colspan="3">Tier 3</td><td colspan="2">50%: 0.01 PM</td><td colspan="3">0.01 PM
50%: 0.30 NOx</td><td colspan="2">0.30 NOx</td></tr>
<tr><td>hp ≥ 750</td><td>Tier 1</td><td colspan="5">Tier 2</td><td colspan="3">50%: 0.01 PM, 0.30 NOx</td><td colspan="2">0.30 NOx</td></tr>
<tr><td colspan="12">Fuel sulfur standard (ppm)[β]</td></tr>
<tr><td>Loco & marine</td><td colspan="3">Uncontrolled</td><td colspan="8">500 ppm</td></tr>
<tr><td>Nonroad</td><td colspan="3">Uncontrolled</td><td colspan="8">15 ppm</td></tr>
</table>

[α] Applies to model years. If no standard is shown for a given pollutant, the previous standard applies.

[β] Applies to calender years. Begins in June.

[γ] Actual standard is 3.5g/bhp-hr NOx+NMHC, equivalent to the Tier 3 standard for 50-75hp. For modeling purposes, NOx portion of this standard is assumed to be 3.3g/bhp-hr.

Figure 12.1.1-3
Engine and Fuel Standards Under Option 1a

hp group	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Nonroad engine standards (g/bhp-hr)[α]											
hp <25											
25 ≤ hp hp < 50											
50 ≤ hp hp < 75		Tier 2									
75 ≤ hp hp < 100						0.01 PM			0.30 NOx		
100 ≤ hp hp < 175				Tier 3							
175 ≤ hp hp < 750											
hp ≥ 750	Tier 1		Tier 2								
Fuel sulfur standard (ppm)[β]											
Loco & marine	Uncontrolled							15 ppm			
Nonroad	Uncontrolled							15 ppm			

[α] Applies to model years. If no standard is shown for a given pollutant, the previous standard applies.

[β] Applies to calender years. Begins in June.

Figure 12.1.1-4
Engine and Fuel Standards Under Option 1b

hp group	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Nonroad engine standards (g/bhp-hr)[α]											
hp <25											
25 ≤ hp hp < 50											
50 ≤ hp hp < 75		Tier 2									
75 ≤ hp hp < 100						0.01 PM			0.30 NOx		
100 ≤ hp hp < 175				Tier 3							
175 ≤ hp hp < 750											
hp ≥ 750	Tier 1		Tier 2								
Fuel sulfur standard (ppm)[β]											
Loco & marine	Uncont rolled		15 ppm								
Nonroad	Uncont rolled		15 ppm								

[α] Applies to model years. If no standard is shown for a given pollutant, the previous standard applies.

[β] Applies to calender years. Begins in June.

12.1.2 Two-Step Options

Two-step options are those in which the fuel sulfur standard is set first at 500ppm for several years, and then is lowered further to 15ppm. The exact timing of the introduction of the 500ppm and the 15ppm standards varies among each of the two-step options. In addition, we considered a variety of engine standards and phase-ins. In the two-step options, the transient test cycle is required concurrently with the introduction of the transitional Tier 4 engine standards. The one exception is Option 5b, under which the existing steady-state test applies indefinitely for <75 hp engines.

Our proposed program forms the basis for all of the two-step program options. The two-step options are summarized in Table 12.1.2-1. Following this table is a summary of the existing Tier 1, Tier 2, and Tier 3 standards from 40 CFR §89.112 that form the baseline of our analyses. The specifics of the two-step options are shown in the standard charts in Figures 12.1.2-2 through 11.

As for the one-step standard charts, only changes to the standards are shown, i.e. if no new standard for a given pollutant is indicated, the previous standard applies.

Table 12.1.2-1
Summary of Two-Step Options

Option	Summary Description
Proposed program	• 500 ppm in 2007; 15 ppm in 2010 for nonroad engines only • >25 hp: PM aftertreatment-based standards introduced 2011-2013 • >75 hp: NOx aftertreatment-based standards introduced and phased-in 2011-2014 • <25 hp: PM standards in 2008 • 25-75 hp: PM standards in 2008 (optional for 50-75 hp) *See Figure 12.1.2-2*
Option 2a	Same as our proposed program, except: • Transitional sulfur standard of 500 ppm is introduced one year earlier *See Figure 12.1.2-3*
Option 2b	Same as our proposed program, except: • Final sulfur standard of 15 ppm is introduced one year earlier • Trap-based PM standards begin one year earlier for all engines *See Figure 12.1.2-4*
Option 2c	Same as our proposed program, except: • Final sulfur standard of 15 ppm is introduced one year earlier • Trap-based PM standards begin one year earlier for 175 - 750 hp engines *See Figure 12.1.2-5*
Option 2d	Same as our proposed program, except: • Final NOx standard for 25 - 75 hp engines is lowered to 0.30 g/bhp-hr • A phase-in for the NOx standard for this horsepower group is included *See Figure 12.1.2-6*
Option 2e	Same as our proposed program, except: • No new Tier 4 NOx standards. *See Figure 12.1.2-7*
Option 3	Same as our proposed program, except: • Above-ground mining equipment >750 hp remains at the Tier 2 standards *See Figure 12.1.2-8*
Option 4	Same as our proposed program, except: • 15 ppm final sulfur standard applies to fuel used by locomotives and marine engines in addition to all other nonroad engines *See Figure 12.1.2-9*
Option 5a	Same as our proposed program, except: • No new Tier 4 standards for <75 hp engines *See Figure 12.1.2-10*
Option 5b	Same as our proposed program, except: • No trap-based PM standards for <75 hp engines • No new Tier 4 NOx standards for <75 hp engines *See Figure 12.1.2-11*

Figure 12.1.2-1
Existing Engine and Fuel Standards

<table>
<tr><th>hp group</th><th>2005</th><th>2006</th><th>2007</th><th>2008</th><th>2009</th><th>2010</th><th>2011</th><th>2012</th><th>2013</th><th>2014</th><th>2015</th></tr>
<tr><td colspan="12">Nonroad engine standards (g/bhp-hr)[α]</td></tr>
<tr><td>hp <25</td><td colspan="11">Tier 2: 5.6 NOx+NMHC, 0.6 PM</td></tr>
<tr><td>25 ≤ hp
hp < 50</td><td colspan="11">Tier 2: 5.6 NOx+NMHC, 0.4 PM</td></tr>
<tr><td>50 ≤ hp
hp < 75</td><td colspan="3" rowspan="2">Tier 2:
5.6 NOx+NMHC
0.3 PM</td><td colspan="8" rowspan="2">Tier 3:
3.5 NOx+NMHC
0.3 PM</td></tr>
<tr><td>75 ≤ hp
hp < 100</td></tr>
<tr><td>100 ≤ hp
hp < 175</td><td colspan="2">Tier 2:
4.9 NOx+NMHC
0.2 PM</td><td colspan="9">Tier 3:
3.0 NOx+NMHC
0.2 PM</td></tr>
<tr><td>175 ≤ hp
hp < 750</td><td>Tier 2:
4.8
NOx+NMHC
0.1 PM</td><td colspan="10">Tier 3:
3.0 NOx+NMHC
0.1 PM</td></tr>
<tr><td>hp ≥ 750</td><td>Tier 1:
6.9 NOx
0.4 PM</td><td colspan="10">Tier 2:
4.8 NOx+NMHC
0.1 PM</td></tr>
<tr><td colspan="12">Fuel sulfur standard (ppm)</td></tr>
<tr><td>Loco & marine</td><td colspan="11">Uncontrolled</td></tr>
<tr><td>Nonroad</td><td colspan="11">Uncontrolled</td></tr>
</table>

[α] Applies to model years.

Figure 12.1.2-2
Engine and Fuel Standards under the Proposed Program

hp group	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Nonroad engine standards (g/bhp-hr)[α]											
hp <25							0.30 PM				
25 ≤ hp hp < 50						0.22 PM				0.02 PM, 3.3[ε] NOx	
50 ≤ hp hp < 75		Tier 2									
75 ≤ hp hp < 100											
100 ≤ hp hp < 175					Tier 3			100%[γ] : 0.01 PM 50%[γ] : 0.30 NOx		0.01 PM	
175 ≤ hp hp < 750										0.30 NOx	
hp ≥ 750	Tier 1	Tier 2					50%[δ] : 0.01 PM, 0.30 NOx				
Fuel sulfur standard (ppm)[β]											
Loco & marine	Uncontrolled						500 ppm				
Nonroad	Uncontrolled		500 ppm					15 ppm			

[α] Applies to model years. If no standard is shown for a given pollutant, the previous standard applies.

[β] Applies to calender years. Begins in June.

[γ] All engines must meet 0.01 PM, but only 50% of engines must meet the new NOx standard of 0.30. All engines must use the transient test cycle.

[δ] Only 50% of engines must meet both the new PM and NOx standards on the transient test cycle. Remaining engines meet Tier 2 standards on the steady-state test cycle.

[ε] Actual standard is 3.5g/bhp-hr NOx+NMHC, equivalent to the Tier 3 standard for 50-75hp. For modeling purposes, NOx portion of this standard is assumed to be 3.3g/bhp-hr.

Figure 12.1.2-3
Engine and Fuel Standards under Option 2a

<table>
<tr><th>hp group</th><th>2005</th><th>2006</th><th>2007</th><th>2008</th><th>2009</th><th>2010</th><th>2011</th><th>2012</th><th>2013</th><th>2014</th><th>2015</th></tr>
<tr><td colspan="12">Nonroad engine standards (g/bhp-hr)[α]</td></tr>
<tr><td>hp <25</td><td colspan="3" rowspan="4">Tier 2</td><td colspan="8">0.30 PM</td></tr>
<tr><td>25 ≤ hp
hp < 50</td><td colspan="5" rowspan="2">0.22 PM</td><td colspan="3" rowspan="2">0.02 PM, 3.3[ε] NOx</td></tr>
<tr><td>50 ≤ hp
hp < 75</td></tr>
<tr><td>75 ≤ hp
hp < 100</td><td colspan="4"></td><td colspan="2" rowspan="2">100%[γ] : 0.01 PM
50%[γ] : 0.30 NOx</td><td colspan="2" rowspan="4">0.01 PM

0.30 NOx</td></tr>
<tr><td>100 ≤ hp
hp < 175</td><td colspan="2"></td><td colspan="5">Tier 3</td></tr>
<tr><td>175 ≤ hp
hp < 750</td><td></td><td colspan="5"></td><td colspan="3"></td></tr>
<tr><td>hp ≥ 750</td><td>Tier 1</td><td colspan="5">Tier 2</td><td colspan="3">50%[δ] : 0.01 PM, 0.30 NOx</td></tr>
<tr><td colspan="12">Fuel sulfur standard (ppm)[β]</td></tr>
<tr><td>Loco & marine</td><td>Uncon-trolled</td><td colspan="10">500 ppm</td></tr>
<tr><td>Nonroad</td><td>Uncon-trolled</td><td colspan="4">500 ppm</td><td colspan="6">15 ppm</td></tr>
</table>

[α] Applies to model years. If no standard is shown for a given pollutant, the previous standard applies.
[β] Applies to calender years. Begins in June.
[γ] All engines must meet 0.01 PM, but only 50% of engines must meet the new NOx standard of 0.30. All engines must use the transient test cycle.
[δ] Only 50% of engines must meet both the new PM and NOx standards on the transient test cycle. Remaining engines meet Tier 2 standards on the steady-state test cycle.
[ε] Actual standard is 3.5g/bhp-hr NOx+NMHC, equivalent to the Tier 3 standard for 50-75hp. For modeling purposes, NOx portion of this standard is assumed to be 3.3g/bhp-hr.

Figure 12.1.2-4
Engine and Fuel Standards under Option 2b

hp group	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Nonroad engine standards (g/bhp-hr)[α]											
hp <25				0.30 PM							
25 ≤ hp hp < 50				0.22 PM				0.02 PM	0.02 PM, 3.3[ε] NOx		
50 ≤ hp hp < 75	Tier 2										
75 ≤ hp hp < 100							0.01 PM				
100 ≤ hp hp < 175					Tier 3			50%[γ] : 0.30 NOx		0.01 PM	
175 ≤ hp hp < 750						0.01 PM				0.30 NOx	
hp ≥ 750	Tier 1	Tier 2				50%: 0.01 PM	50%[δ] : 0.01 PM, 0.30 NOx		100%: 0.01 PM		
Fuel sulfur standard (ppm)[β]											
Loco & marine	Uncontrolled		500 ppm								
Nonroad	Uncontrolled		500 ppm	15 ppm							

[α] Applies to model years. If no standard is shown for a given pollutant, the previous standard applies.

[β] Applies to calender years. Begins in June.

[γ] All engines must meet 0.01 PM, but only 50% of engines must meet the new NOx standard of 0.30. All engines must use the transient test cycle.

[δ] Only 50% of engines must meet both the new PM and NOx standards on the transient test cycle. Remaining engines meet Tier 2 standards on the steady-state test cycle.

[ε] Actual standard is 3.5g/bhp-hr NOx+NMHC, equivalent to the Tier 3 standard for 50-75hp. For modeling purposes, NOx portion of this standard is assumed to be 3.3g/bhp-hr.

Figure 12.1.2-5
Engine and Fuel Standards under Option 2c

<table>
<tr><th>hp group</th><th>2005</th><th>2006</th><th>2007</th><th>2008</th><th>2009</th><th>2010</th><th>2011</th><th>2012</th><th>2013</th><th>2014</th><th>2015</th></tr>
<tr><td colspan="12">Nonroad engine standards (g/bhp-hr)[α]</td></tr>
<tr><td>hp <25</td><td colspan="3" rowspan="4">Tier 2</td><td colspan="8">0.30 PM</td></tr>
<tr><td>25 ≤ hp
hp < 50</td><td colspan="5" rowspan="2">0.22 PM</td><td colspan="3" rowspan="2">0.02 PM, 3.3[ε] NOx</td></tr>
<tr><td>50 ≤ hp
hp < 75</td></tr>
<tr><td>75 ≤ hp
hp < 100</td><td colspan="4"></td><td colspan="2" rowspan="2">100%[γ] : 0.01 PM
50%[γ] : 0.30 NOx</td><td colspan="2" rowspan="4">0.01 PM
0.30 NOx</td></tr>
<tr><td>100 ≤ hp
hp < 175</td><td colspan="2"></td><td colspan="5">Tier 3</td></tr>
<tr><td>175 ≤ hp
hp < 750</td><td></td><td colspan="4"></td><td>0.01 PM</td><td colspan="3"></td></tr>
<tr><td>hp ≥ 750</td><td>Tier 1</td><td colspan="5">Tier 2</td><td colspan="3">50%[δ] : 0.01 PM, 0.30 NOx</td></tr>
<tr><td colspan="12">Fuel sulfur standard (ppm)[β]</td></tr>
<tr><td>Loco & marine</td><td colspan="2">Uncontrolled</td><td colspan="9">500 ppm</td></tr>
<tr><td>Nonroad</td><td colspan="2">Uncontrolled</td><td>500 ppm</td><td colspan="8">15 ppm</td></tr>
</table>

[α] Applies to model years. If no standard is shown for a given pollutant, the previous standard applies.

[β] Applies to calender years. Begins in June.

[γ] All engines must meet 0.01 PM, but only 50% of engines must meet the new NOx standard of 0.30. All engines must use the transient test cycle.

[δ] Only 50% of engines must meet both the new PM and NOx standards on the transient test cycle. Remaining engines meet Tier 2 standards on the steady-state test cycle.

[ε] Actual standard is 3.5g/bhp-hr NOx+NMHC, equivalent to the Tier 3 standard for 50-75hp. For modeling purposes, NOx portion of this standard is assumed to be 3.3g/bhp-hr.

Figure 12.1.2-6
Engine and Fuel Standards under Option 2d

<table>
<tr><th>hp group</th><th>2005</th><th>2006</th><th>2007</th><th>2008</th><th>2009</th><th>2010</th><th>2011</th><th>2012</th><th>2013</th><th>2014</th><th>2015</th><th>2016</th></tr>
<tr><td colspan="13">Nonroad engine standards (g/bhp-hr)[α]</td></tr>
<tr><td>hp <25</td><td colspan="3" rowspan="4">Tier 2</td><td colspan="9">0.30 PM</td></tr>
<tr><td>25 ≤ hp
hp < 50</td><td colspan="5" rowspan="2">0.22 PM</td><td colspan="3" rowspan="2">0.02 PM
50%: 0.30 NOx</td><td rowspan="2">0.30 NOx</td></tr>
<tr><td>50 ≤ hp
hp < 75</td></tr>
<tr><td>75 ≤ hp
hp < 100</td><td colspan="4"></td><td colspan="2"></td><td colspan="3" rowspan="4">0.01 PM
0.30 NOx</td></tr>
<tr><td>100 ≤ hp
hp < 175</td><td colspan="2"></td><td colspan="5">Tier 3</td><td colspan="2">100%[γ] : 0.01 PM
50%[γ] : 0.30 NOx</td></tr>
<tr><td>175 ≤ hp
hp < 750</td><td></td><td colspan="5"></td><td colspan="3"></td></tr>
<tr><td>hp ≥ 750</td><td>Tier 1</td><td colspan="5">Tier 2</td><td colspan="3">50%[δ] : 0.01 PM, 0.30 NOx</td></tr>
<tr><td colspan="13">Fuel sulfur standard (ppm)[β]</td></tr>
<tr><td>Loco & marine</td><td colspan="2">Uncontrolled</td><td colspan="10">500 ppm</td></tr>
<tr><td>Nonroad</td><td colspan="2">Uncontrolled</td><td colspan="3">500 ppm</td><td colspan="7">15 ppm</td></tr>
</table>

[α] Applies to model years. If no standard is shown for a given pollutant, the previous standard applies.

[β] Applies to calender years. Begins in June.

[γ] All engines must meet 0.01 PM, but only 50% of engines must meet the new NOx standard of 0.30. All engines must use the transient test cycle.

[δ] Only 50% of engines must meet both the new PM and NOx standards on the transient test cycle. Remaining engines meet Tier 2 standards on the steady-state test cycle.

Figure 12.1.2-7
Engine and Fuel Standards under Option 2e

<table>
<tr><td>hp group</td><td>2005</td><td>2006</td><td>2007</td><td>2008</td><td>2009</td><td>2010</td><td>2011</td><td>2012</td><td>2013</td><td>2014</td><td>2015</td></tr>
<tr><td colspan="12">Nonroad engine standards (g/bhp-hr)[α]</td></tr>
<tr><td>hp <25</td><td colspan="3"></td><td colspan="8">0.30 PM</td></tr>
<tr><td>25 ≤ hp
hp < 50</td><td colspan="3"></td><td colspan="5" rowspan="2">0.22 PM</td><td colspan="3" rowspan="2">0.02 PM</td></tr>
<tr><td>50 ≤ hp
hp < 75</td><td colspan="3">Tier 2</td></tr>
<tr><td>75 ≤ hp
hp < 100</td><td colspan="3"></td><td colspan="4"></td><td colspan="4"></td></tr>
<tr><td>100 ≤ hp
hp < 175</td><td colspan="2"></td><td colspan="5">Tier 3</td><td colspan="4">0.01 PM</td></tr>
<tr><td>175 ≤ hp
hp < 750</td><td></td><td colspan="5"></td><td colspan="5"></td></tr>
<tr><td>hp ≥ 750</td><td>Tier 1</td><td colspan="5">Tier 2</td><td colspan="3">50%[δ] : 0.01 PM</td><td colspan="2">0.01 PM</td></tr>
<tr><td colspan="12">Fuel sulfur standard (ppm)[β]</td></tr>
<tr><td>Loco & marine</td><td colspan="2">Uncontrolled</td><td colspan="9">500 ppm</td></tr>
<tr><td>Nonroad</td><td colspan="2">Uncontrolled</td><td colspan="3">500 ppm</td><td colspan="6">15 ppm</td></tr>
</table>

[α] Applies to model years. If no standard is shown for a given pollutant, the previous standard applies.

[β] Applies to calender years. Begins in June.

[δ] Only 50% of engines must meet the new PM standard on the transient test cycle. Remaining engines meet Tier 2 standards on the steady-state test cycle.

Figure 12.1.2-8
Engine and Fuel Standards under Option 3

hp group	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Nonroad engine standards (g/bhp-hr)[α]											
hp <25	Tier 2			0.30 PM							
25 ≤ hp hp < 50	Tier 2			0.22 PM					0.02 PM, 3.3[ε] NOx		
50 ≤ hp hp < 75	Tier 2			0.22 PM					0.02 PM, 3.3[ε] NOx		
75 ≤ hp hp < 100	Tier 2			Tier 3				100%[γ] : 0.01 PM 50%[γ] : 0.30 NOx		0.01 PM 0.30 NOx	
100 ≤ hp hp < 175	Tier 2		Tier 3					100%[γ] : 0.01 PM 50%[γ] : 0.30 NOx		0.01 PM 0.30 NOx	
175 ≤ hp hp < 750	Tier 2	Tier 3					100%[γ] : 0.01 PM 50%[γ] : 0.30 NOx			0.01 PM 0.30 NOx	
hp ≥ 750	Tier 1	Tier 2					50%[δ] : 0.01 PM, 0.30 NOx Mining equipment remains at Tier 2			0.01 PM 0.30 NOx Mining equipment at Tier 2	
Fuel sulfur standard (ppm)[β]											
Loco & marine	Uncontrolled		500 ppm								
Nonroad	Uncontrolled		500 ppm			15 ppm					

[α] Applies to model years. If no standard is shown for a given pollutant, the previous standard applies.

[β] Applies to calender years. Begins in June.

[γ] All engines must meet 0.01 PM, but only 50% of engines must meet the new NOx standard of 0.30. All engines must use the transient test cycle.

[δ] Only 50% of engines not used in mining equipment must meet both the new PM and NOx standards on the transient test cycle. Remaining engines meet Tier 2 standards on the steady-state test cycle.

[ε] Actual standard is 3.5g/bhp-hr NOx+NMHC, equivalent to the Tier 3 standard for 50-75hp. For modeling purposes, NOx portion of this standard is assumed to be 3.3g/bhp-hr.

Figure 12.1.2-9
Engine and Fuel Standards under Option 4

hp group	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Nonroad engine standards (g/bhp-hr)[α]											
hp <25						0.30 PM					
25 ≤ hp hp < 50						0.22 PM			0.02 PM, 3.3^{ϵ} NOx		
50 ≤ hp hp < 75		Tier 2									
75 ≤ hp hp < 100											
100 ≤ hp hp < 175					Tier 3			$100\%^{\gamma}$: 0.01 PM $50\%^{\gamma}$: 0.30 NOx		0.01 PM	
175 ≤ hp hp < 750										0.30 NOx	
hp ≥ 750	Tier 1	Tier 2					$50\%^{\delta}$: 0.01 PM, 0.30 NOx				
Fuel sulfur standard (ppm)[β]											
Loco & marine	Uncontrolled		500 ppm			15 ppm					
Nonroad	Uncontrolled		500 ppm			15 ppm					

[α] Applies to model years. If no standard is shown for a given pollutant, the previous standard applies.

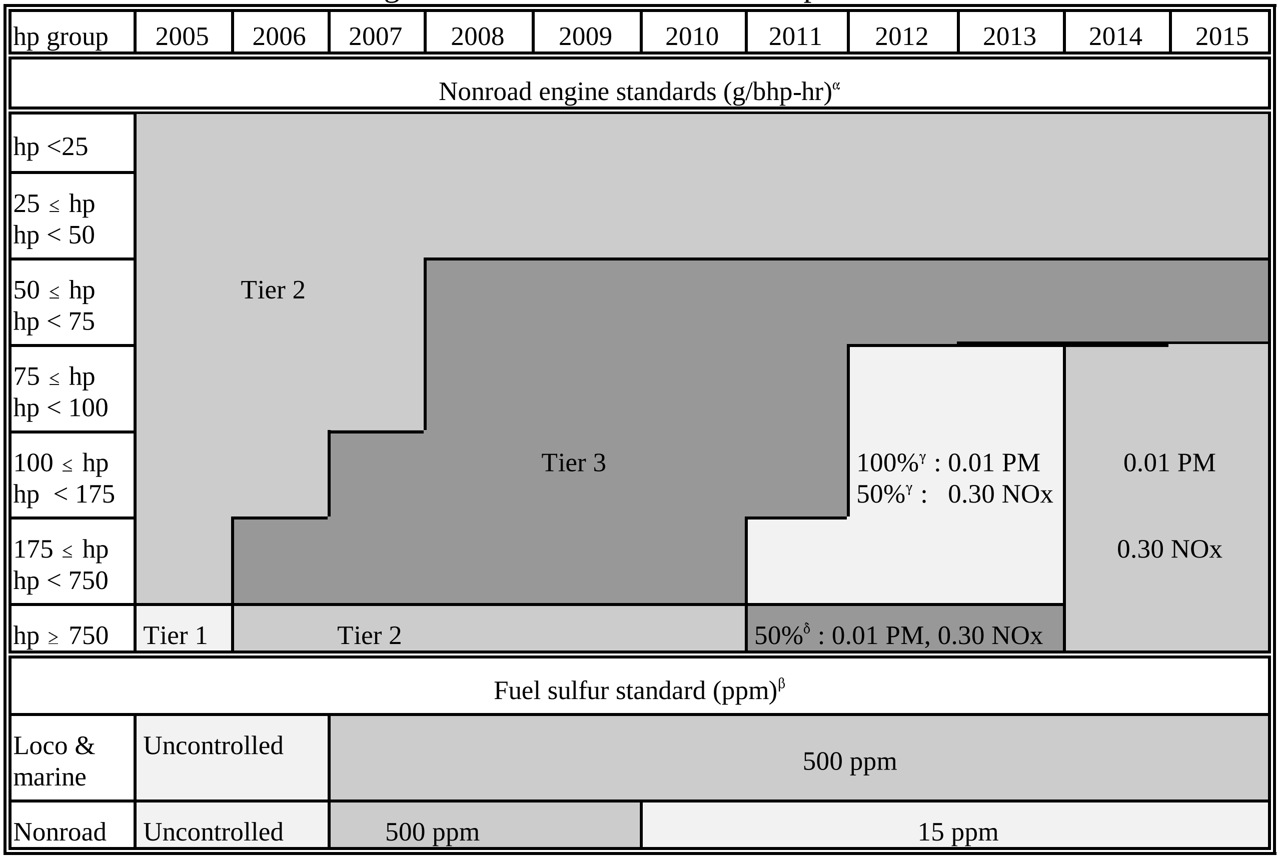
[β] Applies to calender years. Begins in June.

[γ] All engines must meet 0.01 PM, but only 50% of engines must meet the new NOx standard of 0.30. All engines must use the transient test cycle.

[δ] Only 50% of engines must meet both the new PM and NOx standards on the transient test cycle. Remaining engines meet Tier 2 standards on the steady-state test cycle.

[ϵ] Actual standard is 3.5g/bhp-hr NOx+NMHC, equivalent to the Tier 3 standard for 50-75hp. For modeling purposes, NOx portion of this standard is assumed to be 3.3g/bhp-hr.

Figure 12.1.2-10
Engine and Fuel Standards under Option 5a



α Applies to model years. If no standard is shown for a given pollutant, the previous standard applies.

β Applies to calender years. Begins in June.

γ All engines must meet 0.01 PM, but only 50% of engines must meet the new NOx standard of 0.30. All engines must use the transient test cycle.

δ Only 50% of engines must meet both the new PM and NOx standards on the transient test cycle. Remaining engines meet Tier 2 standards on the steady-state test cycle.

Figure 12.1.2-11
Engine and Fuel Standards under Option 5b

hp group	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Nonroad engine standards (g/bhp-hr)[α]											
hp <25	Tier 2			0.30 PM							
25 ≤ hp hp < 50	Tier 2			0.22 PM							
50 ≤ hp hp < 75	Tier 2			0.22 PM							
75 ≤ hp hp < 100	Tier 2			Tier 3				100%[γ] : 0.01 PM 50%[γ] : 0.30 NOx		0.01 PM 0.30 NOx	
100 ≤ hp hp < 175	Tier 2		Tier 3					100%[γ] : 0.01 PM 50%[γ] : 0.30 NOx		0.01 PM 0.30 NOx	
175 ≤ hp hp < 750	Tier 2	Tier 3					100%[γ] : 0.01 PM 50%[γ] : 0.30 NOx			0.01 PM 0.30 NOx	
hp ≥ 750	Tier 1	Tier 2					50%[δ] : 0.01 PM, 0.30 NOx			0.01 PM 0.30 NOx	
Fuel sulfur standard (ppm)[β]											
Loco & marine	Uncontrolled		500 ppm								
Nonroad	Uncontrolled		500 ppm			15 ppm					

[α] Applies to model years. If no standard is shown for a given pollutant, the previous standard applies.
[β] Applies to calender years. Begins in June.
[γ] All engines must meet 0.01 PM, but only 50% of engines must meet the new NOx standard of 0.30. All engines must use the transient test cycle.
[δ] Only 50% of engines must meet both the new PM and NOx standards on the transient test cycle. Remaining engines meet Tier 2 standards on the steady-state test cycle.

12.2 Emission Inventory Impacts Comparison

This section presents the nonroad inventory impacts of all the program options just set forth that we considered during development of our proposed program. The methodology and assumptions used to generate the inventories for all program options are the same as those described in Chapter 3 for the baseline (no new Tier 4 standards) and our proposed program. The primary differences between the assumptions made for our proposed program versus those made for the other program options are related to in-use fuel and certification fuel sulfur levels. These differences are described in Section 12.2.1 below.

The inventories presented in this section represent all nonroad equipment categories, as well as locomotive and CI marine which are affected by the fuel standards, although not by the engine standards. We have not included any potential credits generated under ABT. The PM inventories include directly emitted sulfate PM (in the form of hydrated sulfuric acid) but do not include secondary sulfates produced from $_{SO2}$ in the atmosphere.

12.2.1 Assumptions Regarding Fuel Sulfur Content

Among the program options we considered, there are variations in the timing and level of the fuel sulfur standard. These variations impact both the in-use sulfur level and the certification sulfur level, which in turn affect the PM and $_{SO2}$ inventories estimated via the NONROAD model. This section presents our approach to in-use and certification fuel sulfur levels.

12.2.1.1 Certification Fuel

Fuel used to certify new nonroad engines should be representative of the fuel that those engines will use during their lifetime. Thus the specified maximum sulfur content of nonroad diesel certification fuel should change in concert with the in-use sulfur standard. For instance, our proposed program includes a 500ppm in-use sulfur standard that goes into effect in June of 2007, followed by a 15ppm sulfur standard that goes into effect in June of 2010. Nonroad engine manufacturers must therefore show that their engines can meet the standards when tested on fuel with a sulfur level as high as 500ppm during model years 2008 through 2010, and as high as 15ppm for model years 2011 and beyond.

For most program options, the certification fuel sulfur specification will change in the year following a change in the in-use fuel sulfur standard. However, we took a different approach for Options 1b and 2a. Both of these options are intended to show the impact that an earlier change from uncontrolled to controlled in-use sulfur levels will have on the PM inventories. In order to generate the full benefits of these options, our modeling does not include a concurrent change to certification fuel sulfur levels. In other words, we model an in-use reduction in sulfate PM and SO_2 emissions as a result of the in-use fuel having less sulfur than the certification fuel. If the certification fuel were set at a sulfur level equal to the in-use fuel sulfur level, there would be no in-use reduction in sulfate PM or SO_2 emissions.

A lower maximum sulfur specification for certification fuel makes it easier to comply with the PM standard, since, as shown in Chapter 4 of this draft RIA, lower fuel sulfur means less sulfate PM. Manufacturers could take advantage of this benefit of lower sulfur content in certification fuel by modifying their engines to reduce costs. However, if the change in certification fuel sulfur level does not exactly coincide with a change in the applicable engine emission standards, making modifications to an engine family simply to take advantage of the lower sulfur level of certification fuel may not be cost-effective. Therefore, we have made the assumption that engines within any horsepower group will only be modified to account for a lower certification fuel sulfur level when new engine standards become effective. In other words, for modeling purposes, all engines are assumed to be certified at the sulfur level that applied when the most recent set of emission standards became effective. This approach results in slightly larger in-use PM benefits, since there will be occasions when manufacturers are in effect meeting the PM standard using certification fuel with a higher-than-necessary sulfur level.

The assumed cert fuel sulfur levels were used to establish the proper zero-hour emission factors for new engines. For in-use inventory impacts of these new engines, the emission factors were further adjusted to account for the assumed in-use sulfur levels. Thus, for instance, engines certified on 2000ppm sulfur fuel and then operated on 500ppm fuel would realize a PM benefit relative to the PM certification standard.

The sulfur levels assumed for certification fuel for the purposes of establishing the zero-hour emission factors are given in Appendix 12A.

12.2.1.2 In-Use Fuel

Section 12.1 presented the sulfur standards that would apply to in-use nonroad fuel under each of the program options we evaluated. In order to calculate emission inventories using the NONROAD model, we estimated the likely in-use average sulfur level by calendar year for each of the options. These average sulfur values were a function of the level and timing of transitional and final standards, expected refiner compliance margins, and the amount of highway diesel fuel which is consumed by nonroad engines (so-called "spillover"). The various factors used in the calculations are listed in Table 12.2.1.2-1, based on the derivations and discussion presented in Section 7.1.4.2.

Table 12.2.1.2-1
Factors Used to Calculate In-use Sulfur Levels

Average in-use fuel sulfur level for any fuel designed to meet a standard of 500 ppm	340 ppm
Average in-use fuel sulfur level for fuel designed to meet California's diesel fuel specifications	120 ppm
Average in-use fuel sulfur level for any fuel designed to meet a standard of 15 ppm	11 ppm
Average in-use sulfur level for fuel intended to be used in nonroad engines, prior to sulfur control	3400 ppm
Nonroad spillover: Fraction of fuel consumed by nonroad engines which is actually designed to meet on-highway fuel sulfur standards	34.9%
Locomotive/marine spillover: Fraction of fuel consumed by locomotives and marine engines which is actually designed to meet on-highway fuel sulfur standards	32.4%

We first determined the average in-use sulfur level for highway fuel by calender year, using the factors in Table 12.2.1.2-1 and the phase-in schedule adopted in 2001 (66 FR 5002, January 18, 2001). Table 12.2.1.2-2 presents these sulfur levels.

Table 12.2.1.2-2
Average Sulfur Level for On-highway Fuel

Year	Average sulfur (ppm)	Explanation
≤ 2005	300	Nationwide average, including California, prior to introduction of 15ppm standard. Assumes 10% of nationwide highway diesel meets California's requirements.
2006	165	15ppm standard applies beginning in June. Only 80% of the pool meets the 15ppm standard.
2007	69	Only 80% of the pool meets the 15ppm standard.
2008	69	Only 80% of the pool meets the 15ppm standard.
2009	69	Only 80% of the pool meets the 15ppm standard.
≥ 2010	11	100% of the pool meets the 15ppm standard

We then determined the average in-use sulfur level for off-highway fuel. All of the program options we evaluated include one or more of the following types of transitions, for either nonroad fuel or locomotive and marine fuel:

- Transition from uncontrolled sulfur levels to a 500ppm standard
- Transition from a 500ppm sulfur standard to a 15ppm standard
- Transition from uncontrolled sulfur levels to a 15ppm standard

Every one of these transitions is assumed to occur in June, regardless of the calendar year in which the new standard applies. Using the average sulfur levels presented in Table 12.2.1.2-1, we generated in-use average sulfur levels for off-highway diesel fuel for the three types of transitions shown above. Table 12.2.1.2-3 presents the results.

Table 12.2.1.2-3
Average Sulfur Levels for Off-highway Fuel Sulfur Standard Transitions (ppm)

	Uncontrolled to 500ppm standard	500ppm standard to 15ppm standard	Uncontrolled to 15ppm standard
Prior to transition year	3400	340	3400
Transition year	1615	148	1423
After transition year	340	11	11

Finally, to calculate the in-use average sulfur levels under the various program options we evaluated, we combined the average sulfur levels for on-highway fuel from Table 12.2.1.2-2 with the average sulfur levels for off-highway fuel from Table 12.2.1.2-3. The spillover fractions given in Table 12.2.1.2-1 were used to properly weight the on-highway and off-highway average sulfur levels. The results for all program options are given in Tables 12.2.1.2-4 and 12.2.1.2-5, based on the fuel sulfur standards associated with each option as described in Section 12.1.

Table 12.2.1.2-4
In-use Average Sulfur Levels Used for Modeling Nonroad Engines (ppm)

	≤2005	2006	2007	2008	2009	2010	≥2011
Baseline	2318	2271	2237	2237	2237	2217	2217
Proposed program	2318	2271	1075	245	245	100	11
Option 1	2318	2271	2237	950	31	11	11
Option 1a	2318	2271	2237	950	31	11	11
Option 1b	2318	984	31	31	31	11	11
Option 2a	2318	1109	245	245	245	100	11
Option 2b	2318	2271	1075	245	120	11	11
Option 2c	2318	2271	1075	245	120	11	11
Option 2d	2318	2271	1075	245	245	100	11
Option 2e	2318	2271	1075	245	245	100	11
Option 3	2318	2271	1075	245	245	100	11
Option 4	2318	2271	1075	245	245	100	11
Option 5a	2318	2271	1075	245	245	100	11
Option 5b	2318	2271	1075	245	245	100	11

Table 12.2.1.2-5
In-use Average Sulfur Levels Used for Modeling Locomotive and Marine Engines (ppm)

	≤2005	2006	2007	2008	2009	2010	≥2011
Baseline	2396	2352	2321	2321	2321	2302	2302
Proposed program	2396	2352	1114	252	252	233	233
Option 1	2396	2352	2321	1114	252	233	233
Option 1a	2396	2352	2321	984	30	11	11
Option 1b	2396	1016	30	30	30	11	11
Option 2a	2396	1145	252	252	252	233	233
Option 2b	2396	2352	1114	252	252	233	233
Option 2c	2396	2352	1114	252	252	233	233
Option 2d	2396	2352	1114	252	252	233	233
Option 2e	2396	2352	1114	252	252	233	233
Option 3	2396	2352	1114	252	252	233	233
Option 4	2396	2352	1114	252	252	104	11
Option 5a	2396	2352	1114	252	252	233	233
Option 5b	2396	2352	1114	252	252	233	233

12.2.2 Emission Inventories for Alternative Program Options

This section presents the absolute inventories associated with our proposed program and each of the program options we evaluated, in short tons per year. All inventories represent only those off-highway engines affected by our proposed program or each of the alternative program options - no on-highway, biogenic, or other sources are included. We have presented graphical illustrations separately for nonroad and locomotive/marine, since we are proposing engine standards only for the former, and have investigated fuel sulfur standards for locomotives and marine engines as a way to generate additional PM and SO_2 reductions. In addition, there are no changes to NOx, NMHC, or CO for locomotive and marine under any Option, so we have not shown separate graphs for these pollutants. Inventory tables include nonroad, locomotive, and marine sources for PM and SO_2, and just nonroad sources for NOx, CO, and NMHC.

Graphic representations of inventories are shown for all years through 2030, and tabulated values are provided for selected years. All values are presented as 50-state annual tons, and the particulate matter values are PM10. Note that the emission reductions used for the calculation of health and welfare benefits were based on 48-state inventories and the relevant particulate matter was PM2.5 due to the fact that the air quality modeling on which these benefits were based requires the use of these alternative measures of inventory impacts.

12.2.2.1 NOx

This section presents the NOx inventories for nonroad engines affected by our proposed program and the alternative program options. In general, the options represent little or no change in the NOx standard levels and timing in comparison with our proposed program. Primary differences are exhibited for:

• Options 1a and 1b for which NOx aftertreatment is required for all engines
• Option 2d which adds NOx aftertreatment-based standards for 25-75hp
• Option 2e which assumes no new Tier 4 NOx standards
• Option 3 which exempts large above-ground mining equipment

Figure 12.2.2.1-1
50-State Inventories for nonroad NOx (tons)

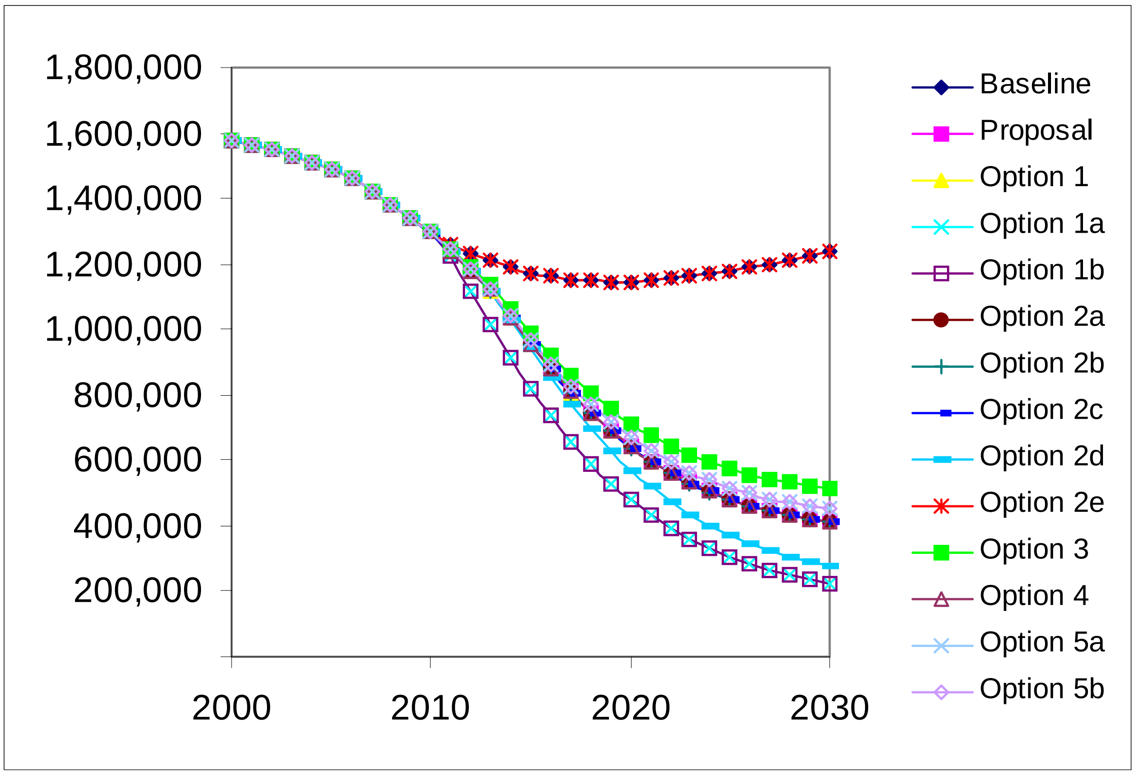


Table 12.2.2.1-1
50-State Inventories for NOx (tons)

	2010	2015	2020	2025	2030
Baseline	1,327,000	1,205,000	1,182,000	1,218,000	1,280,000
Proposed program	1,326,000	987,000	675,000	520,000	454,000
Option 1	1,325,000	986,000	675,000	520,000	454,000
Option 1a	1,327,000	853,000	514,000	343,000	265,000
Option 1b	1,327,000	853,000	514,000	343,000	265,000
Option 2a	1,326,000	987,000	675,000	520,000	454,000
Option 2b	1,325,000	984,000	674,000	519,000	453,000
Option 2c	1,324,000	985,000	674,000	519,000	453,000
Option 2d	1,326,000	974,000	605,000	411,000	320,000
Option 2e	1,327,000	1,205,000	1,182,000	1,218,000	1,280,000
Option 3	1,326,000	1,020,000	747,000	612,000	557,000
Option 4	1,326,000	987,000	675,000	520,000	454,000
Option 5a	1,327,000	1,000,000	703,000	555,000	495,000
Option 5b	1,327,000	1,000,000	703,000	555,000	495,000

12.2.2.2 PM

Particulate matter directly affected by our proposed program is included in these inventories. Although the majority of diesel exhaust PM is fine (<2.5 microns), we have included all PM up to 10 microns in our inventory estimates to most properly account for the full impacts of our proposed program. In terms of PM inventory impacts, differences between each of the alternative program options and our proposed program are exhibited for most of the program options.

Figure 12.2.2.2-1
50-State Inventories for nonroad PM (tons)

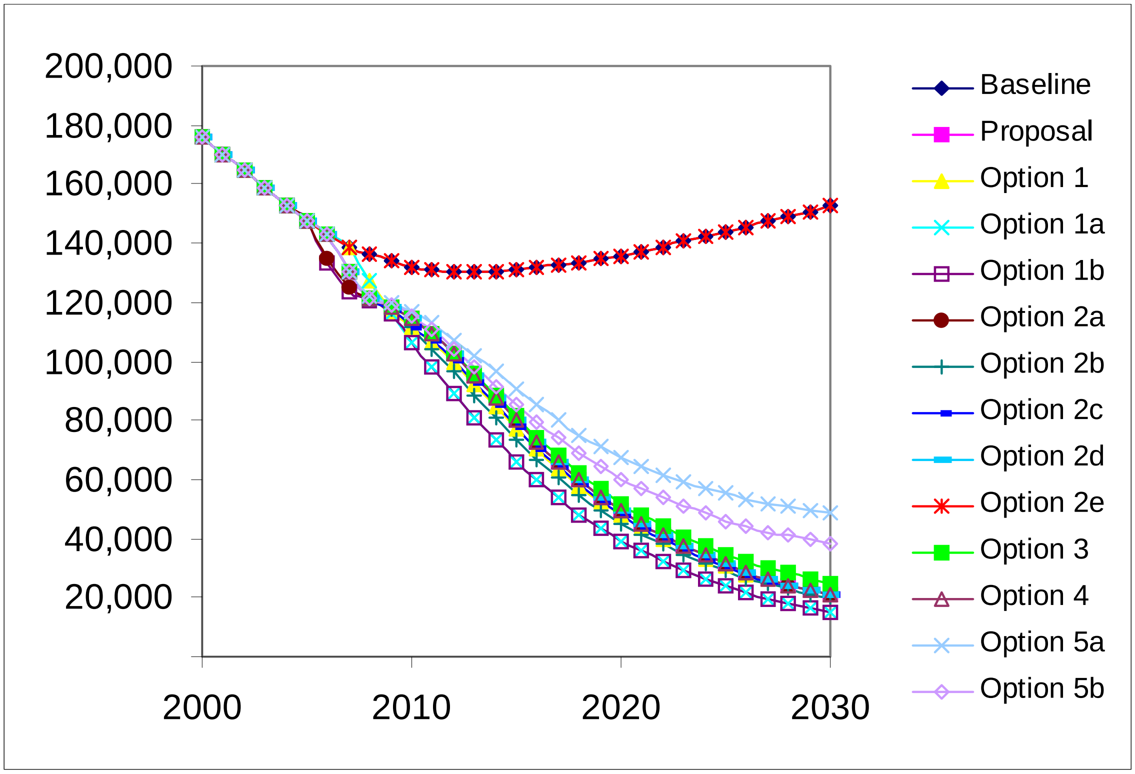


Figure 12.2.2.2-2
50-State Inventories for loco/marine PM (tons)

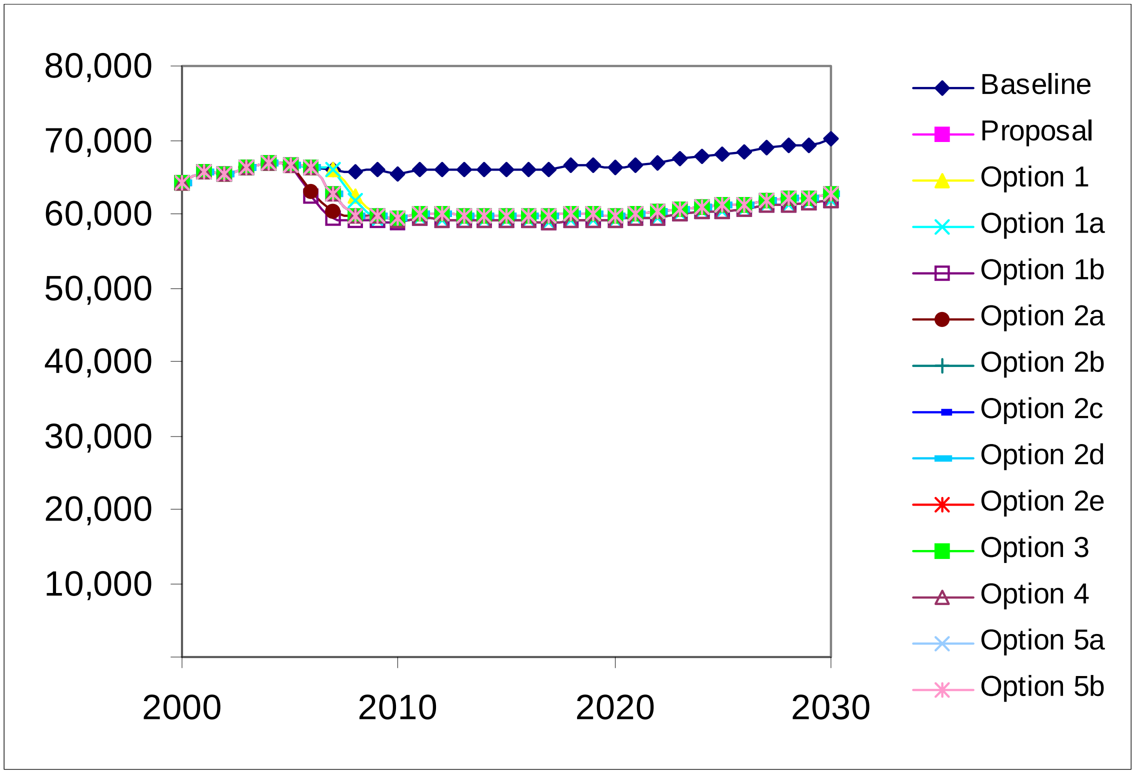


Table 12.2.2.2-1
50-State Inventories for total PM (tons)

	2010	2015	2020	2025	2030
Baseline	198,000	197,000	202,000	212,000	223,000
Proposed program	174,000	140,000	109,000	92,000	84,000
Option 1	171,000	137,000	108,000	92,000	83,000
Option 1a	165,000	125,000	98,000	84,000	77,000
Option 1b	165,000	125,000	98,000	84,000	77,000
Option 2a	174,000	140,000	109,000	92,000	84,000
Option 2b	171,000	133,000	105,000	90,000	83,000
Option 2c	171,000	137,000	108,000	92,000	83,000
Option 2d	174,000	140,000	109,000	92,000	84,000
Option 2e	174,000	140,000	109,000	92,000	84,000
Option 3	174,000	141,000	112,000	96,000	88,000
Option 4	173,000	139,000	108,000	92,000	83,000
Option 5a	177,000	150,000	127,000	116,000	111,000
Option 5b	175,000	145,000	120,000	107,000	101,000

12.2.2.3 NMHC

The new Tier 4 standards realize a significant reduction in NMHC emissions, including toxic hydrocarbons, due to the use of technologies such as oxidation catalysts and catalyzed diesel particulate filters. NMHC impacts exhibited by each alternative program option will largely mimic the PM impacts.

The NONROAD model provides total hydrocarbon emissions for both exhaust and crankcase emissions, though crankcase HC is typically only 1-2% of total HC. Methane and ethane are also included in total hydrocarbon output from NONROAD. However, our standards apply to non-methane hydrocarbons. Thus we have decided to convert total hydrocarbons from the NONROAD model into NMHC. To do this, total hydrocarbons is multiplied by 0.984[1], which subtracts out methane. Note that our air quality modeling requires volatile organic compounds (VOC) instead of total hydrocarbons, and many of the inventories with which we have compared the impacts of our proposed and alternative Tier 4 nonroad programs use VOCs. For these purposes, we converted total hydrocarbons from the NONROAD model into VOC by multiplying by 1.053, which subtracts out methane and ethane and simultaneously adds aldehydes.

Figure 12.2.2.3-1
50-State Inventories for nonroad NMHC (tons)

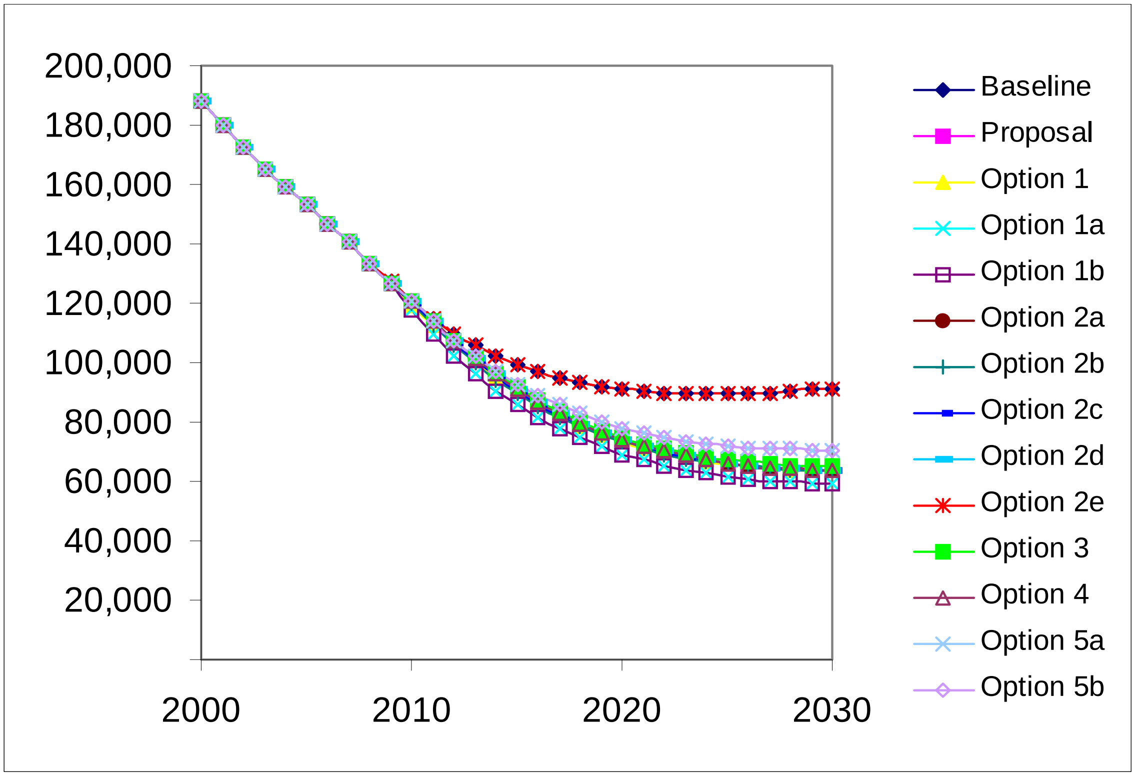


Table 12.2.2.3-1
50-State Inventories for NMHC (tons)

	2010	2015	2020	2025	2030
Baseline	122,000	100,000	92,000	91,000	93,000
Proposed program	122,000	92,000	75,000	68,000	65,000
Option 1	121,000	91,000	75,000	67,000	65,000
Option 1a	119,000	87,000	70,000	63,000	61,000
Option 1b	119,000	87,000	70,000	63,000	61,000
Option 2a	122,000	92,000	75,000	68,000	65,000
Option 2b	121,000	90,000	74,000	67,000	65,000
Option 2c	121,000	92,000	75,000	67,000	65,000
Option 2d	122,000	92,000	75,000	68,000	65,000
Option 2e	122,000	92,000	75,000	68,000	65,000
Option 3	122,000	93,000	76,000	69,000	66,000
Option 4	122,000	92,000	75,000	68,000	65,000
Option 5a	122,000	94,000	79,000	73,000	72,000
Option 5b	122,000	94,000	79,000	73,000	72,000

12.2.2.4 CO

The new Tier 4 standards realize a significant reduction in CO emissions due to the use of technologies such as oxidation catalysts and catalyzed diesel particulate filters. The minor adjustment we are proposing for CO standards is more of a bookeeping correction, as explained in the preamble. CO emissions are assumed to be reduced 90% for engines having a PM trap. Thus the CO impacts exhibited by each alternative program option will largely mimic the PM impacts.

Figure 12.2.2.4-1
50-State Inventories for nonroad CO (tons)

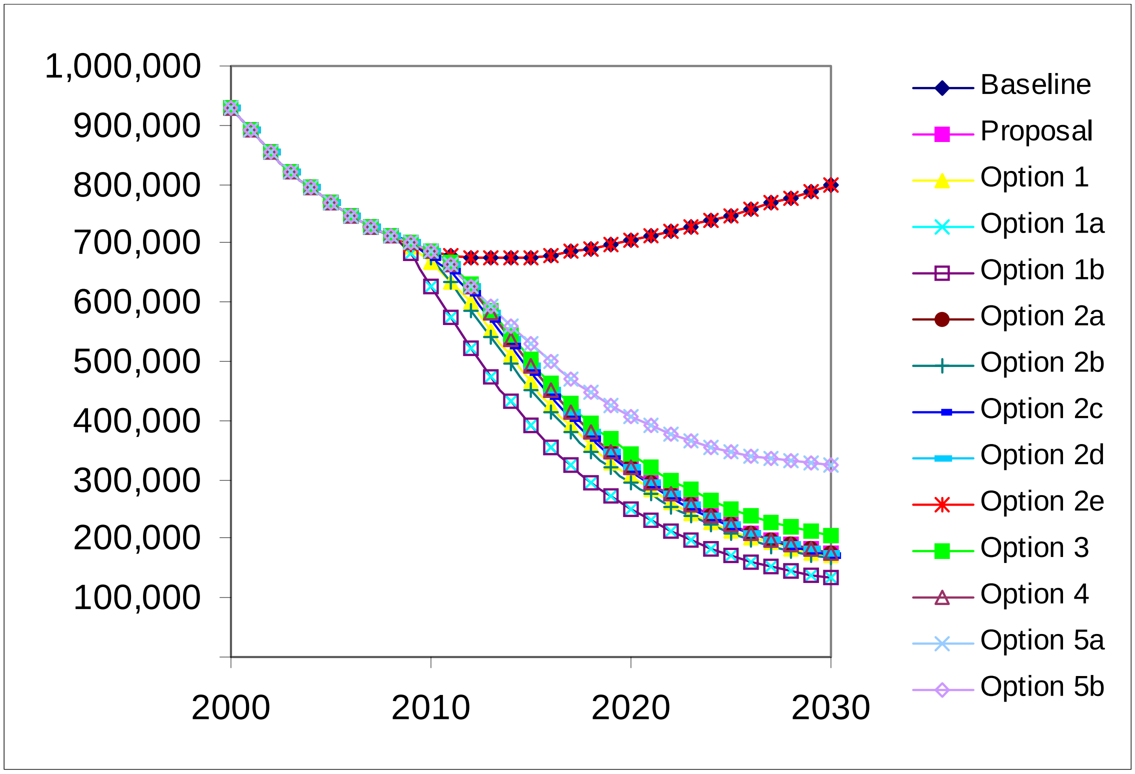


Table 12.2.2.4-1
50-State Inventories for CO (tons)

	2010	2015	2020	2025	2030
Baseline	693,000	682,000	709,000	754,000	805,000
Proposed program	693,000	498,000	326,000	230,000	181,000
Option 1	672,000	472,000	310,000	220,000	177,000
Option 1a	632,000	397,000	254,000	176,000	141,000
Option 1b	632,000	397,000	254,000	176,000	141,000
Option 2a	693,000	498,000	326,000	230,000	181,000
Option 2b	678,000	457,000	301,000	215,000	174,000
Option 2c	680,000	485,000	318,000	226,000	179,000
Option 2d	693,000	498,000	326,000	230,000	181,000
Option 2e	693,000	498,000	326,000	230,000	181,000
Option 3	693,000	508,000	348,000	258,000	212,000
Option 4	693,000	498,000	326,000	230,000	181,000
Option 5a	693,000	533,000	413,000	353,000	332,000
Option 5b	693,000	533,000	413,000	353,000	332,000

12.2.2.5 SO_2

Generally SO_2 emissions are proportional to fuel sulfur content. Thus differences in SO_2 inventories between our proposed program and the alternative program options are primarily a function of the differences in the assumed fuel programs. However, the assumed engine programs do play a small role, as the sulfur-to-SO_2 conversion rate decreases when aftertreatment-based standards are introduced, from a current conversion rate of approximately 98% to an ultimate conversion rate closer to 70%. Despite this engine-based impact of our proposed program on SO_2 emissions, we believe it is appropriate to associate all reductions in SO_2 with the costs of fuel sulfur reductions, as described in Chapter 8, since the 99% reduction in in-use nonroad fuel sulfur levels overwhelms any impact caused by changes in the sulfur-to-SO_2 conversion rate.

Figure 12.2.2.5-1
50-State Inventories for nonroad SO_2 (tons)

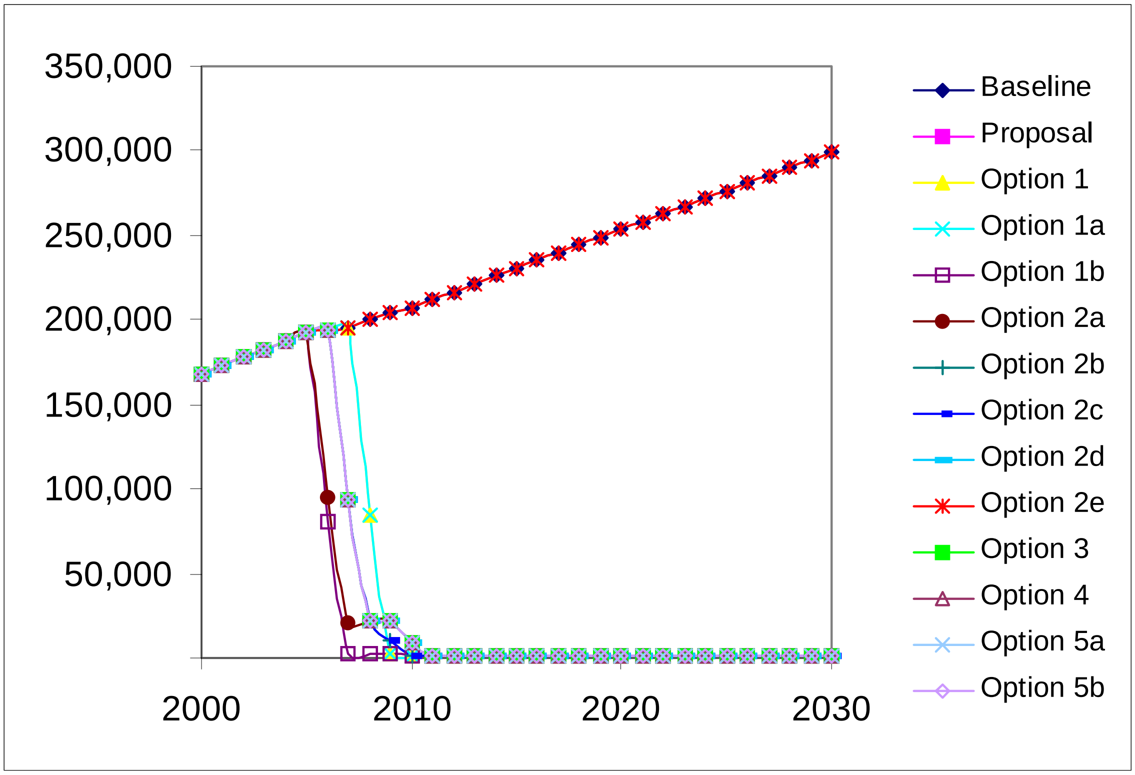


Figure 12.2.2.5-2
50-State Inventories for loco/marine SO_2 (tons)

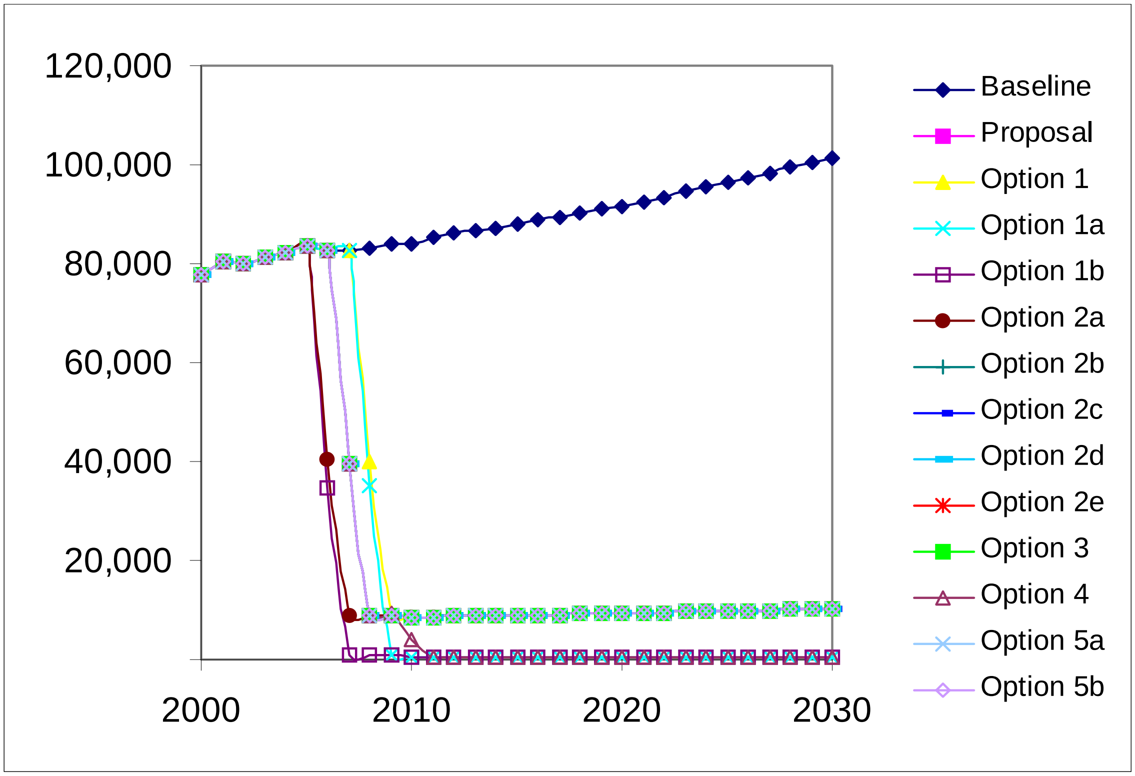


Table 12.2.2.5-1
50-State Inventories for total SO_2 (tons)

	2010	2015	2020	2025	2030
Baseline	291,000	318,000	345,000	373,000	401,000
Proposed program	18,000	10,000	10,000	11,000	11,000
Option 1	10,000	10,000	10,000	11,000	11,000
Option 1a	1,000	1,000	1,000	1,000	2,000
Option 1b	1,000	1,000	1,000	1,000	2,000
Option 2a	18,000	10,000	10,000	11,000	11,000
Option 2b	10,000	10,000	10,000	11,000	11,000
Option 2c	10,000	10,000	10,000	11,000	11,000
Option 2d	18,000	10,000	10,000	11,000	11,000
Option 2e	18,000	10,000	10,000	11,000	11,000
Option 3	18,000	10,000	10,000	11,000	11,000
Option 4	13,000	1,000	1,000	2,000	2,000
Option 5a	18,000	10,000	10,000	11,000	11,000
Option 5b	18,000	10,000	10,000	11,000	11,000

12.2.3 Cumulative Emission Reductions for Alternative Program Options

Inventory impacts of our proposed program and the alternative program options can be compared for individual calendar years or cumulatively over some timeframe. For the cumulative comparison, we have chosen to calculate the net present value of the annual emission reductions of each program, in comparison to the baseline, for all years through 2030. For this calculation we used a 3% discount rate to bring all tons into 2004. These net present value reductions are shown in Table 12.2.3-1. We also present the net present value of the differences between the emissions through 2030 for each alternative program option and our proposed program in Table 12.2.3-2.

Table 12.2.3-1
50-State Net Present Value Emission Reductions
In Comparison to Existing Standards Through 2030 (tons)

	NOx	PM	NMHC	CO	SO_2
Proposed program	5,407,000	1,126,000	184,000	4,149,000	4,952,000
Option 1	5,409,000	1,133,000	194,000	4,396,000	4,761,000
Option 1a	7,187,000	1,255,000	248,000	5,164,000	4,890,000
Option 1b	7,187,000	1,296,000	248,000	5,164,000	5,395,000
Option 2a	5,407,000	1,145,000	184,000	4,149,000	5,180,000
Option 2b	5,428,000	1,180,000	199,000	4,493,000	4,969,000
Option 2c	5,419,000	1,147,000	189,000	4,262,000	4,969,000
Option 2d	6,159,000	1,126,000	184,000	4,149,000	4,952,000
Option 2e	0	1,126,000	184,000	4,149,000	4,952,000
Option 3	4,665,000	1,097,000	175,000	3,924,000	4,952,000
Option 4	5,407,000	1,135,000	184,000	4,149,000	5,067,000
Option 5a	5,118,000	917,000	141,000	3,216,000	4,952,000
Option 5b	5,118,000	1,005,000	141,000	3,216,000	4,952,000

Table 12.2.3-2
50-State Net Present Value Emission Differences With Respect
To The Proposed Program, Through 2030 (tons)*

	NOx	PM	NMHC	CO	SO_2
Option 1	1,000	6,000	10,000	248,000	-191,000
Option 1a	1,780,000	129,000	63,000	1,015,000	-63,000
Option 1b	1,780,000	170,000	63,000	1,015,000	443,000
Option 2a	0	18,000	0	0	228,000
Option 2b	21,000	54,000	15,000	344,000	17,000
Option 2c	11,000	20,000	5,000	113,000	17,000
Option 2d	751,000	0	0	0	0
Option 2e	-5,407,000	0	0	0	0
Option 3	-742,000	-30,000	-9,000	-225,000	0
Option 4	0	9,000	0	0	114,000
Option 5a	-290,000	-209,000	-44,000	-933,000	0
Option 5b	-290,000	-121,000	-43,000	-933,000	0

*Positive values indicate that the Option produces greater environmental benefits, i.e. the Option results in a smaller cumulative absolute inventory

12.3 Benefits Comparison

We are able to estimate the benefits of various options using the benefit-transfer methodology developed in Chapter 9 for estimating the monetized benefits of the proposal. The specific methodology is described in Section 9.5 “Development of Intertemporal Scaling Factors and Calculation of Benefits Over Time” and will not be repeated here.

To use that methodology requires input of 48 state emission reductions for NOx, PM2.5 and SO_2 associated with each option. We cannot estimate 50 state benefits due to the fact that our air quality modeling work covers only 48 states, and we are unable to extrapolate those results to Alaska or Hawaii. PM2.5 is used for these calculations rather than PM10 because the underlying health effect studies rely on PM2.5 data.

The estimated 48 state emission reductions are given in Table 12.3-1, 12.3-2 and 12.3-3. Table 12.3-4 and Figure 12.3-1 present the estimated benefits for each of the options.

A key question for each of the options is how the benefits of that option compare with the benefits of our proposed program. Table 12.3-5 lists the difference in benefits between each of the options and the proposal. These differences are shown graphically in Figure 12.3-2.

Table 12.3-1A
48 State SO2 Emission Reductions for Program Options 1 - 2

Year	Option 1	Option 1a	Option 1b	Option 2a	Option 2b	Option 2c	Option 2d	Option 2e
2000	0	0	0	0	0	0	0	0
2001	0	0	0	0	0	0	0	0
2002	0	0	0	0	0	0	0	0
2003	0	0	0	0	0	0	0	0
2004	0	0	0	0	0	0	0	0
2005	0	0	0	0	0	0	0	0
2006	0	0	159,106	140,081	0	0	0	0
2007	0	0	271,364	245,048	142,948	142,948	142,948	142,948
2008	156,782	161,358	276,554	249,746	249,746	249,746	249,746	249,746
2009	273,998	281,907	281,907	254,544	265,904	265,860	254,543	254,543
2010	279,259	287,243	287,243	270,977	279,264	279,232	270,977	270,977
2011	285,014	293,130	293,130	285,003	285,025	285,014	285,003	285,003
2012	290,208	298,392	298,392	290,196	290,223	290,208	290,196	290,196
2013	295,325	303,562	303,562	295,312	295,340	295,323	295,312	295,312
2014	300,447	308,736	308,736	300,434	300,461	300,445	300,434	300,434
2015	305,653	314,001	314,001	305,639	305,665	305,650	305,639	305,639
2016	311,085	319,522	319,522	311,073	311,097	311,083	311,073	311,073
2017	316,310	324,813	324,813	316,299	316,319	316,307	316,299	316,299
2018	321,511	330,079	330,079	321,501	321,519	321,508	321,501	321,501
2019	326,735	335,371	335,371	326,725	326,741	326,732	326,725	326,725
2020	331,851	340,543	340,543	331,840	331,854	331,846	331,840	331,840
2021	337,241	346,020	346,020	337,231	337,243	337,236	337,231	337,231
2022	342,638	351,505	351,505	342,628	342,639	342,633	342,628	342,628
2023	348,041	356,998	356,998	348,032	348,042	348,037	348,032	348,032
2024	353,452	362,500	362,500	353,444	353,452	353,447	353,444	353,444
2025	358,871	368,010	368,010	358,863	358,870	358,866	358,863	358,863
2026	364,268	373,499	373,499	364,260	364,266	364,262	364,260	364,260
2027	369,673	378,998	378,998	369,665	369,670	369,667	369,665	369,665
2028	375,086	384,506	384,506	375,078	375,082	375,080	375,078	375,078
2029	380,509	390,025	390,025	380,500	380,504	380,502	380,500	380,500
2030	385,941	395,555	395,555	385,932	385,935	385,934	385,932	385,932

Table 12.3-1B
48 State SO2 Emission Reductions for Program Options 3 - 5

Year	**Option 3**	**Option 4**	**Option 5a**	**Option 5b**
2000	0	0	0	0
2001	0	0	0	0
2002	0	0	0	0
2003	0	0	0	0
2004	0	0	0	0
2005	0	0	0	0
2006	0	0	0	0
2007	142,948	142,948	142,948	142,948
2008	249,746	249,734	249,746	249,746
2009	254,543	254,532	254,544	254,544
2010	270,977	275,593	270,977	270,977
2011	285,001	293,072	285,003	285,003
2012	290,193	298,327	290,196	290,196
2013	295,308	303,496	295,307	295,307
2014	300,427	308,673	300,424	300,424
2015	305,630	313,942	305,624	305,624
2016	311,061	319,467	311,053	311,053
2017	316,284	324,764	316,274	316,274
2018	321,484	330,034	321,472	321,472
2019	326,706	335,330	326,693	326,693
2020	331,820	340,506	331,804	331,804
2021	337,209	345,986	337,192	337,192
2022	342,605	351,474	342,587	342,587
2023	348,008	356,969	347,988	347,988
2024	353,418	362,473	353,397	353,397
2025	358,837	367,985	358,814	358,814
2026	364,233	373,477	364,209	364,209
2027	369,637	378,977	369,612	369,612
2028	375,050	384,487	375,023	375,023
2029	380,472	390,007	380,444	380,444
2030	385,903	395,537	385,874	385,874

Table 12.3-2A
48 State NOx Emission Reductions for Program Options 1 - 2

Year	Option 1	Option 1a	Option 1b	Option 2a	Option 2b	Option 2c	Option 2d	Option 2e
2000	0	0	0	0	0	0	0	0
2001	0	0	0	0	0	0	0	0
2002	0	0	0	0	0	0	0	0
2003	0	0	0	0	0	0	0	0
2004	0	0	0	0	0	0	0	0
2005	0	0	0	0	0	0	0	0
2006	0	0	0	0	0	0	0	0
2007	0	0	0	0	0	0	0	0
2008	0	0	0	301	301	301	301	0
2009	503	1	1	619	619	619	619	0
2010	1,766	5	5	1,007	2,098	2,374	1,007	0
2011	21,522	36,934	36,934	20,574	23,185	21,936	20,574	0
2012	52,597	115,220	115,220	52,218	54,809	53,563	52,218	0
2013	87,976	194,212	194,212	87,616	89,885	88,943	91,884	0
2014	153,004	273,046	273,046	152,680	154,892	153,963	161,257	0
2015	217,852	350,521	350,521	217,575	219,688	218,816	230,428	0
2016	281,454	423,557	423,557	281,270	283,278	282,407	306,499	0
2017	342,819	492,722	492,722	342,740	344,625	343,732	379,886	0
2018	399,696	554,913	554,913	399,692	401,369	400,568	448,475	0
2019	453,617	611,895	611,895	453,643	455,139	454,456	513,588	0
2020	503,665	663,626	663,626	503,701	505,133	504,416	573,519	0
2021	548,065	711,839	711,839	548,149	549,447	548,807	626,977	0
2022	588,591	756,359	756,359	588,685	589,871	589,253	676,038	0
2023	626,255	796,861	796,861	626,368	627,461	626,879	721,538	0
2024	660,995	834,447	834,447	661,122	662,142	661,590	762,962	0
2025	693,689	869,952	869,952	693,857	694,803	694,254	801,885	0
2026	723,546	902,739	902,739	723,762	724,582	724,056	837,483	0
2027	750,977	932,592	932,592	751,182	751,889	751,441	870,213	0
2028	776,413	959,480	959,480	776,574	777,232	776,816	900,551	0
2029	800,222	985,095	985,095	800,392	800,997	800,611	928,871	0
2030	821,736	1,009,757	1,009,757	821,911	822,382	822,114	954,589	0

Table 12.3-2B
48 State NOx Emission Reductions for Program Options 3 - 5

Year	Option 3	Option 4	Option 5a	Option 5b
2000	(0)	0	0	0
2001	(0)	0	0	0
2002	(0)	0	0	0
2003	(0)	0	0	0
2004	(0)	0	0	0
2005	(0)	0	0	0
2006	(0)	0	0	0
2007	(0)	0	0	0
2008	301	301	0	0
2009	619	619	0	0
2010	1,007	1,007	0	0
2011	15,943	20,574	19,175	19,175
2012	42,959	52,218	50,418	50,418
2013	73,685	87,616	81,973	81,973
2014	129,199	152,680	143,208	143,208
2015	184,630	217,575	204,359	204,359
2016	239,010	281,270	264,494	264,494
2017	291,695	342,740	322,902	322,902
2018	341,250	399,692	377,053	377,053
2019	388,195	453,643	428,369	428,369
2020	431,864	503,701	476,010	476,010
2021	471,461	548,149	518,543	518,543
2022	507,554	588,685	557,366	557,366
2023	541,378	626,368	593,437	593,437
2024	572,629	661,122	626,712	626,712
2025	602,207	693,857	658,107	658,107
2026	629,553	723,762	686,773	686,773
2027	654,659	751,182	713,101	713,101
2028	677,917	776,574	737,449	737,449
2029	699,765	800,392	760,270	760,270
2030	719,378	821,911	780,876	780,876

Table 12.3-3A
48 State PM2.5 Emission Reductions for Program Options 1 - 2

Year	Option 1	Option 1a	Option 1b	Option 2a	Option 2b	Option 2c	Option 2d	Option 2e
2000	0	0	0	0	0	0	0	0
2001	0	0	0	0	0	0	0	0
2002	0	0	0	0	0	0	0	0
2003	0	0	0	0	0	0	0	0
2004	0	0	0	0	0	0	0	0
2005	0	0	0	0	0	0	0	0
2006	0	0	11,805	10,394	0	0	0	0
2007	0	0	20,131	18,179	10,605	10,605	10,605	10,605
2008	11,630	11,969	20,513	19,061	19,061	19,061	19,061	19,061
2009	21,397	22,791	22,791	19,998	20,841	20,841	19,998	19,998
2010	24,225	29,437	29,437	21,864	24,363	24,236	21,864	21,864
2011	28,235	36,451	36,451	25,496	30,085	27,341	25,496	25,496
2012	33,664	43,747	43,747	31,233	36,723	33,151	31,233	31,233
2013	40,514	51,222	51,222	37,975	43,772	39,955	37,975	37,975
2014	47,663	58,464	58,464	45,139	51,005	47,128	45,139	45,139
2015	54,920	65,596	65,596	52,476	58,165	54,470	52,476	52,476
2016	62,027	72,326	72,326	59,682	65,096	61,539	59,682	59,682
2017	68,710	78,595	78,595	66,680	71,631	68,290	66,680	66,680
2018	75,009	84,351	84,351	73,288	77,749	74,714	73,288	73,288
2019	80,989	89,834	89,834	79,475	83,475	80,819	79,475	79,475
2020	86,591	94,962	94,962	85,254	88,803	86,448	85,254	85,254
2021	91,784	99,794	99,794	90,651	93,826	91,767	90,651	90,651
2022	96,713	104,398	104,398	95,702	98,536	96,669	95,702	95,702
2023	101,364	108,827	108,827	100,450	103,049	101,334	100,450	100,450
2024	105,799	113,021	113,021	104,977	107,373	105,794	104,977	104,977
2025	109,990	116,925	116,925	109,325	111,463	110,012	109,325	109,325
2026	113,855	120,414	120,414	113,414	115,223	113,904	113,414	113,414
2027	117,486	123,752	123,752	117,166	118,599	117,593	117,166	117,166
2028	120,883	126,976	126,976	120,557	121,819	120,955	120,557	120,557
2029	124,049	129,945	129,945	123,788	124,929	124,147	123,788	123,788
2030	127,107	132,829	132,829	126,910	127,826	127,239	126,910	126,910

Table 12.3-3B
48 State PM2.5 Emission Reductions for Program Options 3 - 5

Year	Option 3	Option 4	Option 5a	Option 5b
2000	0	0	0	0
2001	0	0	0	0
2002	0	0	0	0
2003	0	0	0	0
2004	0	0	0	0
2005	0	0	0	0
2006	0	0	0	0
2007	10,605	10,605	10,605	10,605
2008	19,003	19,060	18,240	18,796
2009	19,880	19,997	18,304	19,452
2010	21,685	22,206	19,211	21,003
2011	25,129	26,093	21,803	24,246
2012	30,676	31,835	26,572	29,607
2013	37,288	38,581	31,635	35,247
2014	44,181	45,748	37,094	41,268
2015	51,234	53,091	42,743	47,449
2016	58,148	60,303	48,364	53,523
2017	64,854	67,307	53,903	59,490
2018	71,216	73,919	59,112	65,101
2019	77,163	80,112	63,953	70,323
2020	82,718	85,896	68,458	75,189
2021	87,946	91,299	72,715	79,790
2022	92,842	96,357	76,700	84,096
2023	97,454	101,111	80,439	88,144
2024	101,858	105,645	84,033	92,020
2025	106,094	110,000	87,502	95,753
2026	110,095	114,096	90,771	99,270
2027	113,770	117,856	93,774	102,499
2028	117,089	121,254	96,444	105,389
2029	120,253	124,492	99,006	108,164
2030	123,309	127,621	101,490	110,855

Table 12.3-4A

Monitized Benefit Estimates for Program Options 1 - 2 (Millions of year 2000 dollars)

Year	Option 1	Option 1a	Option 1b	Option 2a	Option 2b	Option 2c	Option 2d	Option 2e
2000	$0	$0	$0	$0	$0	$0	$0	$0
2001	$0	$0	$0	$0	$0	$0	$0	$0
2002	$0	$0	$0	$0	$0	$0	$0	$0
2003	$0	$0	$0	$0	$0	$0	$0	$0
2004	$0	$0	$0	$0	$0	$0	$0	$0
2005	$0	$0	$0	$0	$0	$0	$0	$0
2006	$0	$0	$5,094	$4,497	$0	$0	$0	$0
2007	$0	$0	$8,935	$8,088	$4,701	$4,701	$4,701	$4,701
2008	$5,274	$5,425	$9,327	$8,564	$8,564	$8,564	$8,564	$8,563
2009	$9,719	$10,269	$10,269	$9,072	$9,456	$9,455	$9,072	$9,068
2010	$10,814	$12,159	$12,159	$10,015	$10,848	$10,820	$10,015	$10,009
2011	$13,300	$15,665	$15,665	$12,490	$13,786	$12,973	$12,490	$12,358
2012	$15,437	$18,777	$18,777	$14,794	$16,257	$15,308	$14,794	$14,441
2013	$18,260	$22,185	$22,185	$17,570	$19,156	$18,115	$17,600	$16,847
2014	$21,551	$25,736	$25,736	$20,845	$22,496	$21,409	$20,909	$19,604
2015	$25,056	$29,444	$29,444	$24,253	$26,000	$24,934	$24,454	$22,545
2016	$28,683	$33,182	$33,182	$27,891	$29,601	$28,547	$28,199	$25,474
2017	$32,398	$36,994	$36,994	$31,683	$33,297	$32,279	$32,104	$28,617
2018	$36,113	$40,742	$40,742	$35,478	$36,980	$36,029	$36,020	$31,752
2019	$39,932	$44,592	$44,592	$39,348	$40,741	$39,885	$40,019	$34,831
2020	$43,770	$48,453	$48,453	$43,231	$44,511	$43,731	$44,028	$38,007
2021	$47,512	$52,376	$52,376	$47,131	$48,315	$47,514	$48,055	$41,202
2022	$51,384	$56,343	$56,343	$51,034	$52,129	$51,376	$52,090	$44,294
2023	$55,290	$60,370	$60,370	$54,966	$55,903	$55,287	$56,155	$47,497
2024	$59,231	$64,426	$64,426	$58,933	$59,819	$59,237	$60,251	$50,725
2025	$62,916	$68,185	$68,185	$62,670	$63,477	$62,931	$64,013	$53,644
2026	$66,547	$71,759	$71,759	$66,382	$67,079	$66,572	$67,851	$56,637
2027	$70,056	$75,436	$75,436	$69,935	$70,498	$70,103	$71,630	$59,469
2028	$73,641	$79,121	$79,121	$73,515	$74,021	$73,675	$75,338	$62,322
2029	$77,201	$82,678	$82,678	$77,099	$77,565	$77,246	$78,950	$65,070
2030	$80,669	$86,372	$86,372	$80,591	$80,971	$80,728	$82,670	$67,929
NPV 2004	$550,024	$608,730	$625,176	$557,176	$565,879	$556,177	$559,522	$485,616
Delta from Proposal	$186	$58,892	$75,338	$7,338	$16,040	$6,339	$9,683	($64,222)

Table 12.3-4B
Monitized Benefit Estimates for Program Options 3 - 5
(millions of year 2000 dollars)

Year	Option 3	Option 4	Option 5a	Option 5b
2000	$0	$0	$0	$0
2001	$0	$0	$0	$0
2002	$0	$0	$0	$0
2003	$0	$0	$0	$0
2004	$0	$0	$0	$0
2005	$0	$0	$0	$0
2006	$0	$0	$0	$0
2007	$4,701	$4,701	$4,701	$4,701
2008	$8,551	$8,564	$8,378	$8,503
2009	$9,045	$9,071	$8,680	$8,943
2010	$9,973	$10,275	$9,390	$9,808
2011	$12,366	$12,800	$11,533	$12,161
2012	$14,585	$15,116	$13,555	$14,354
2013	$17,285	$17,905	$15,713	$16,691
2014	$20,303	$21,194	$18,434	$19,596
2015	$23,639	$24,717	$21,362	$22,710
2016	$27,091	$28,371	$24,422	$25,940
2017	$30,688	$32,179	$27,544	$29,335
2018	$34,303	$35,991	$30,766	$32,727
2019	$37,986	$39,879	$34,048	$36,183
2020	$41,682	$43,780	$37,340	$39,650
2021	$45,416	$47,599	$40,671	$43,057
2022	$49,156	$51,523	$44,011	$46,572
2023	$52,928	$55,476	$47,278	$50,116
2024	$56,638	$59,465	$50,689	$53,699
2025	$60,229	$63,222	$53,913	$57,080
2026	$63,807	$66,953	$57,123	$60,343
2027	$67,329	$70,527	$60,190	$63,659
2028	$70,679	$74,128	$63,286	$66,903
2029	$74,133	$77,733	$66,296	$70,063
2030	$77,493	$81,347	$69,418	$73,334
NPV 2004	$531,782	$556,114	$479,478	$507,053
Delta from Proposal	($18,056)	$6,276	($70,360)	($42,785)

Figure 12.3-1A
Monitized Benefit Estimates for Program Options 1 - 2 (millions of year 2000 dollars)

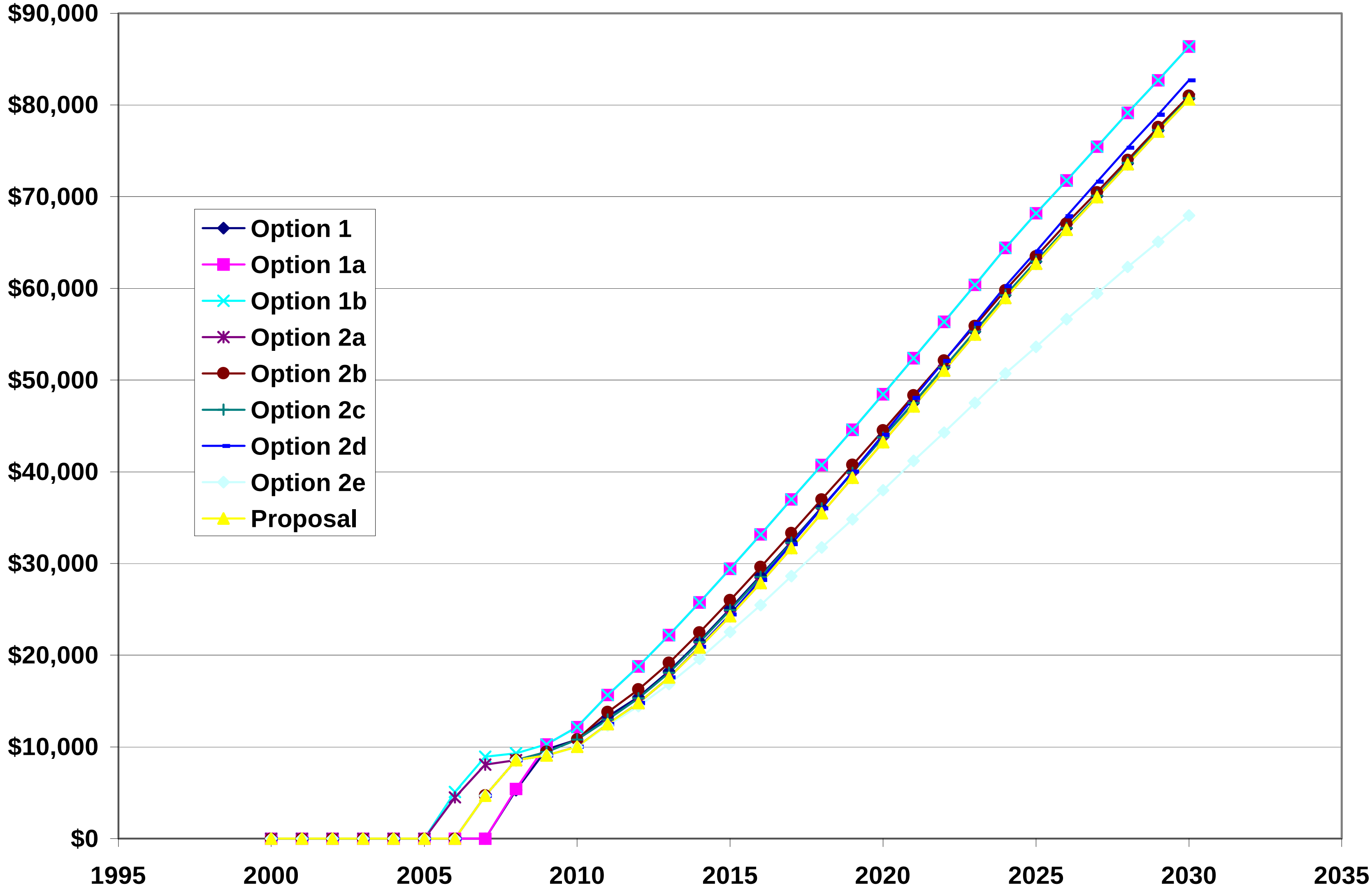


Figure 12.3-1B
Monitized Benefit Estimates for Program Options 3 - 5 (millions of year 2000 dollars)

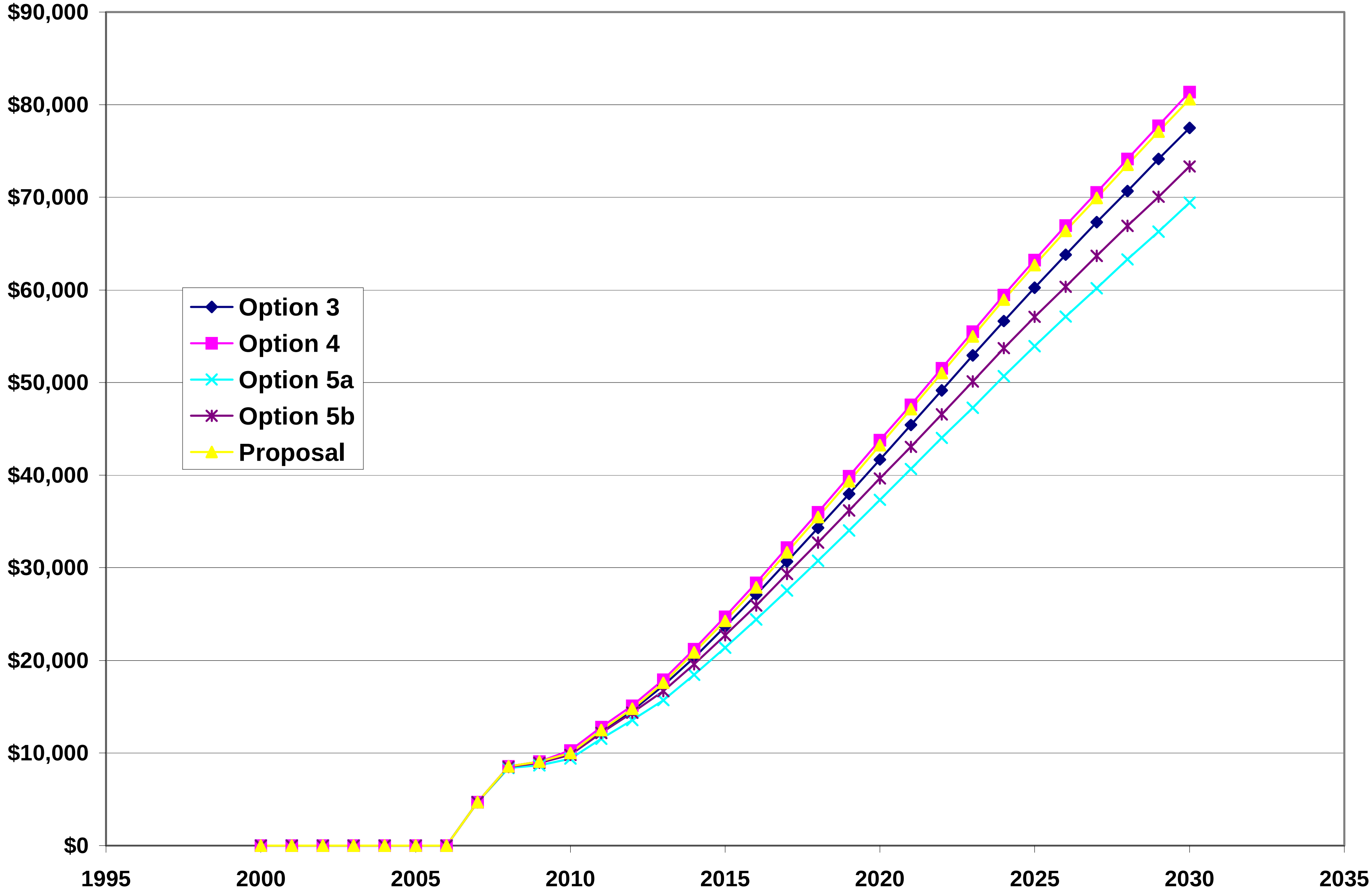


Table 12.3-5A

Benefit Increases for Options 1 - 2 Compared to Proposal (millions of year 2000 dollars)

Year	Option 1	Option 1a	Option 1b	Option 2a	Option 2b	Option 2c	Option 2d	Option 2e
2000	$0	$0	$0	$0	$0	$0	$0	$0
2001	$0	$0	$0	$0	$0	$0	$0	$0
2002	$0	$0	$0	$0	$0	$0	$0	$0
2003	$0	$0	$0	$0	$0	$0	$0	$0
2004	$0	$0	$0	$0	$0	$0	$0	$0
2005	$0	$0	$0	$0	$0	$0	$0	$0
2006	$0	$0	$5,094	$4,497	$0	$0	$0	$0
2007	-$4,701.5	-$4,701.5	$4,234	$3,387	$0	$0	$0	$0
2008	-$3,290	-$3,139	$763	$0	$0	$0	$0	-$2
2009	$647	$1,197	$1,197	$0	$385	$384	$0	-$3
2010	$799	$2,144	$2,144	$0	$833	$805	$0	-$6
2011	$809	$3,175	$3,175	$0	$1,295	$483	$0	-$133
2012	$642	$3,983	$3,983	$0	$1,463	$514	$0	-$353
2013	$690	$4,615	$4,615	$0	$1,586	$545	$30	-$723
2014	$706	$4,891	$4,891	$0	$1,651	$564	$64	-$1,241
2015	$802	$5,190	$5,190	$0	$1,746	$681	$201	-$1,708
2016	$792	$5,291	$5,291	$0	$1,710	$656	$308	-$2,417
2017	$715	$5,311	$5,311	$0	$1,615	$596	$421	-$3,065
2018	$635	$5,264	$5,264	$0	$1,502	$551	$542	-$3,726
2019	$584	$5,244	$5,244	$0	$1,393	$537	$670	-$4,517
2020	$539	$5,221	$5,221	$0	$1,280	$499	$796	-$5,224
2021	$382	$5,245	$5,245	$0	$1,185	$383	$924	-$5,929
2022	$349	$5,309	$5,309	$0	$1,095	$341	$1,056	-$6,741
2023	$324	$5,404	$5,404	$0	$936	$320	$1,189	-$7,469
2024	$298	$5,493	$5,493	$0	$885	$303	$1,318	-$8,208
2025	$245	$5,515	$5,515	$0	$807	$261	$1,343	-$9,026
2026	$165	$5,377	$5,377	$0	$696	$190	$1,468	-$9,745
2027	$121	$5,500	$5,500	$0	$563	$168	$1,695	-$10,467
2028	$126	$5,606	$5,606	$0	$505	$160	$1,823	-$11,193
2029	$102	$5,579	$5,579	$0	$466	$147	$1,851	-$12,029
2030	$78	$5,781	$5,781	$0	$381	$137	$2,079	-$12,662
NPV 2004	**$186**	**$58,892**	**$75,338**	**$7,338**	**$16,040**	**$6,339**	**$9,683**	**($64,222)**

Table 12.3-5B
Benefit Increases for Options 3 - 5 Compared to Proposal
(millions of year 2000 dollars)

Year	Option 3	Option 4	Option 5a	Option 5b
2000	$0	$0	$0	$0
2001	$0	$0	$0	$0
2002	$0	$0	$0	$0
2003	$0	$0	$0	$0
2004	$0	$0	$0	$0
2005	$0	$0	$0	$0
2006	$0	$0	$0	$0
2007	$0.0	$0.0	$0	$0
2008	-$13	$0	-$186	-$61
2009	-$27	$0	-$391	-$129
2010	-$42	$260	-$625	-$207
2011	-$124	$309	-$957	-$330
2012	-$209	$322	-$1,239	-$440
2013	-$285	$335	-$1,856	-$879
2014	-$542	$349	-$2,411	-$1,249
2015	-$615	$464	-$2,892	-$1,544
2016	-$800	$480	-$3,468	-$1,951
2017	-$995	$497	-$4,139	-$2,348
2018	-$1,175	$513	-$4,712	-$2,751
2019	-$1,362	$531	-$5,301	-$3,165
2020	-$1,550	$549	-$5,891	-$3,581
2021	-$1,714	$469	-$6,459	-$4,073
2022	-$1,879	$489	-$7,023	-$4,462
2023	-$2,038	$510	-$7,688	-$4,850
2024	-$2,296	$532	-$8,244	-$5,234
2025	-$2,441	$551	-$8,757	-$5,590
2026	-$2,575	$571	-$9,259	-$6,039
2027	-$2,606	$592	-$9,745	-$6,276
2028	-$2,836	$613	-$10,230	-$6,612
2029	-$2,966	$634	-$10,803	-$7,036
2030	-$3,098	$756	-$11,173	-$7,257
NPV 2004	**($18,056)**	**$6,276**	**($70,360)**	**($42,785)**

Figure 12.3-2A
Benefit Increases for Options 1 - 2 Compared to Proposal (millions of year 2000 dollars)

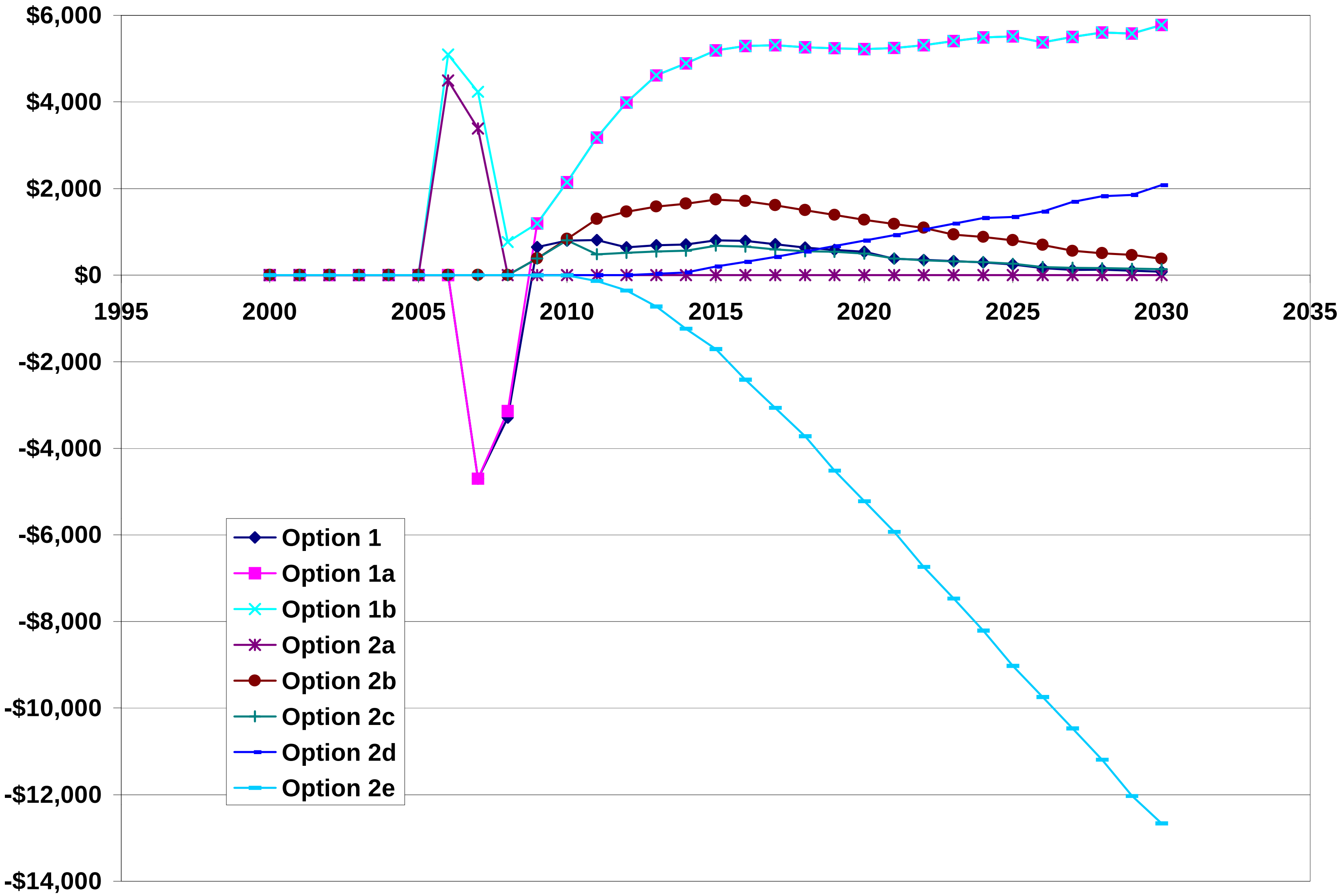
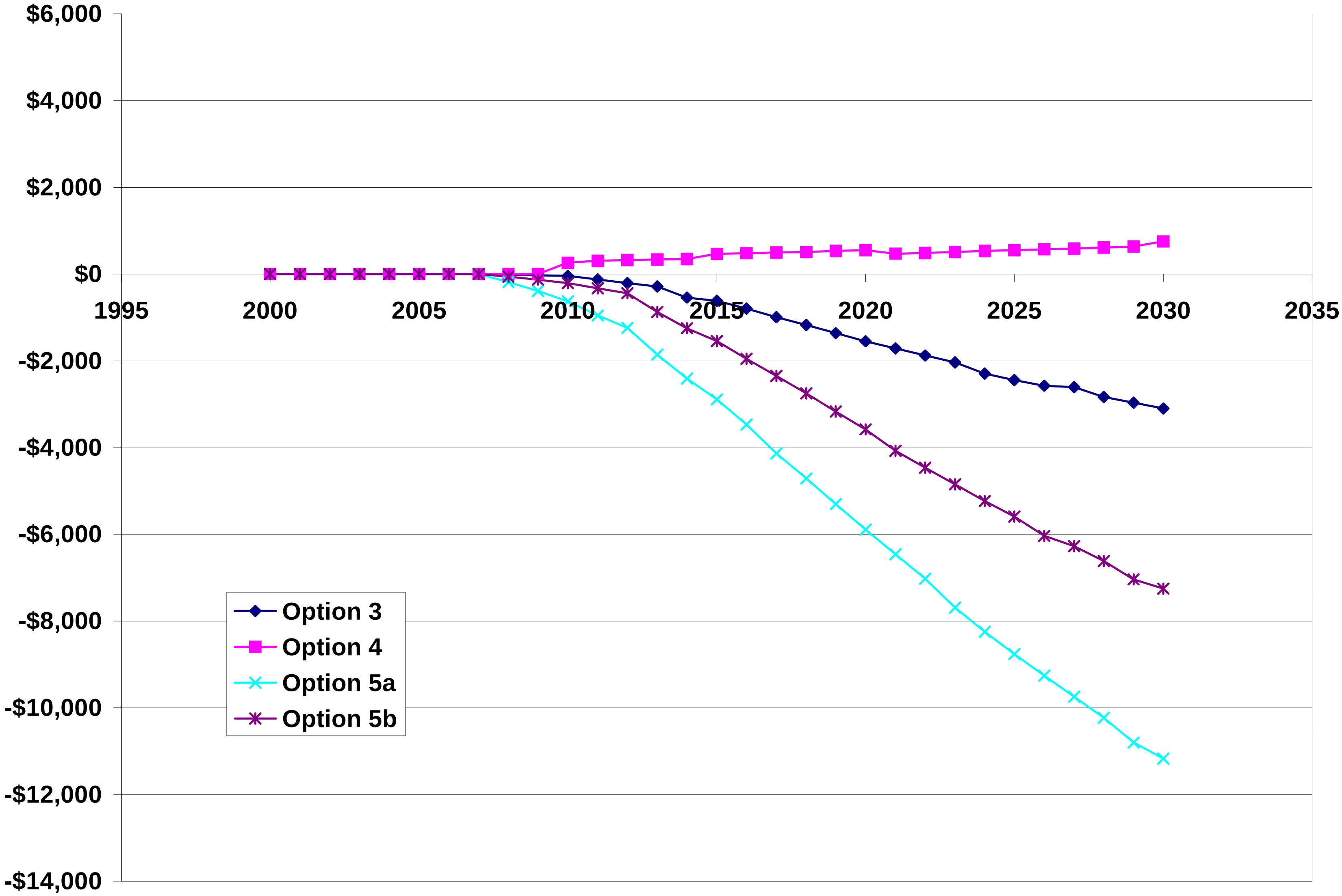


Figure 12.3-2B
Benefit Increases for Options 3 - 5 Compared to Proposal (millions of year 2000 dollars)



12.4 Cost Analysis for Alternative Options

This section describes the cost methodology and the estimates used to evaluate the alternative options. The section describes our estimates for both the fuel impacts and the engine/equipment impacts of the various options, if applicable.

The presentation of information on fuel costs is summarized in a series of tables showing the impact on a cost-per-gallon basis for the appropriate fuel alternative, as well as an estimate of the aggregate fuel cost impact for each alternative option. However, the detailed fuel cost analysis used to derive the cost-per-gallon estimates is contained in Chapter 7 of this draft RIA. The presentation of information on engine/equipment costs are detailed in the related sections below.

The engine and equipment cost estimates for the alternative options relies heavily on the methodology, and in some cases the estimates, used for the proposal. Our discussion of the cost estimates for the alternative options will focus on those inputs or methods which are different from the input or method used for the proposal. To the extent the cost estimates are based on the data used for the proposal, we have not repeated the analysis behind the estimate here, rather, the reader can refer to Chapter 6 of this draft RIA for the engine/equipment cost estimates for the proposal.

As noted in Chapter 3.1.5, there are differences in the fuel quantities used for costs and the fuel quantities used for emissions inventories resulting rom differences in methods. Please see Chapter 3.1.5 for additional discussion of these differences.

12.4.1 One Step Options

12.4.1.1 Option 1

This option is described in Figure 12.1.1-1 in Section 12.1 of this draft RIA. Option 1 requires 15ppm sulfur fuel in 2008 for nonroad engines only and 500 ppm sulfur fuel in 2008 for locomotive and marine engines, which allows early introduction of PM filter technology for some engines.

12.4.1.1.1 Fuel Costs for Option 1

The total fuel costs from Chapter 7 of the draft RIA comprising the refining and distribution and additive costs for Option 1 are summarized in the following tables.

Table 12.4.1.1.1-1
Per-Gallon Fuel Costs for Option 1 (cents per gallon)

Option	Specification	Year	Refining Costs (¢/gal)	Distribution & Additive Costs (¢/gal)	Total Costs (¢/gal)
One Step	15 ppm NR	2008 +	4.8	0.4	5.2
	500 ppm L & M	2008-2011	2.2	0.4	2.6
	500 ppm L & M	2012	2.2	0.2	2.4

Table 12.4.1.1.1-2
Net Operating Costs for Option 1 Incremental To The Proposal (millions)
(Net present values through 2030 at 3% discount rate)

Specification	Gallons	Fuel costs*	Net maintenance costs	Change in net operating costs
15 ppm fuel	11,530	$1,020	$250	$720
500 ppm fuel	-21,770	-$550		

* Note that the incremental fuel costs presented here are calculated as: [proposal $/gal] multiplied by [proposal gallons] minus the [option $/gal] multiplied by [option gallons]. This is not mathematically equivalent to the difference in gallons multiplied by the difference in $/gal.

These fuel costs and other related operating costs (i.e., maintenance savings) result in an increase in the net-present value of Option 1 of approximately $720 million as compared to the proposal through 2030.

12.4.1.1.2 Engine & Equipment Costs for Option 1

Engine Fixed Costs

As discussed in Section 12.6.2.1.1 of this draft RIA, Option 1 presents a number of unique challenges for engine manufacturers as compared to the proposal. These include up to two years of overlap with the nonroad Tier 3 development time frame and two fewer years of learning for the highway to nonroad technology transfer as compared to our proposal. These changes impact the engine engineering costs are described below. Because of these unique challenges, Option 1 has the potential to result in limited product offerings for certain segments of the nonroad engine and equipment market. This potential exists primarily because of the overlapping development time frames between Tier 3 and Tier 4. To the extent that engine and equipment manufacturers engineering staff and resources (e.g., sufficient laboratory test cells) are unable to cover both development programs, companies may need to decide to shift resources from one program to the other, with the result being limited product availability for either Tier 3 or possibly for Tier 4. Our cost analysis for Option 1 presented below assumes companies do have these resources. However, to the extent some companies do not have the necessary resources, our cost analysis does not attempt to estimate the cost impacts of limited product offerings.

Option 1 has significant overlap with Tier 3 engine development. Nonroad engine manufacturers typically require 3 to 4 years of development in advance of a major new emission standard or new engine product launch. This period allows for sufficient time for engine development as well as providing adequate time for equipment manufacturers to redesign equipment to accommodate the new technology engines. For the 175-750 hp category, a 2009 implementation could require engine development beginning as early as calender year 2005, which is also the final year of development before the Tier 3 implementation in 2006. There is also overlap with Option 1's 2010 implementation for the 100-175 hp category, which has a 2007 Tier 3 implementation. Finally, there would be two years of overlap under Option 1 for the 75-100 hp engines, which have a 2008 Tier 3 start date.

To estimate the cost impacts of these overlapping development programs, we have estimated that manufacturers would have sufficient staff to address the work load issues associated with product development of concurrent engine programs (i.e., development of Tier 3 and Tier 4 engines). This of course assumes that manufacturers have the additional staff to perform the concurrent engine development programs as well as the testing resources (e.g., laboratory capacity). It is possible that some manufactures do not have the personnel resources and/or the laboratory resources to cover both Tier 3 and Tier 4 engine development, and this cost analysis does not attempt to estimate what the impacts of such a short-fall would be. Based on our experience and discussions with engine manufacturers we have estimated that a typical product development group consists of 21 workers (9 engineers, 12 technicians). Our annual cost estimate for each team, including test cell time, is $3 million per year.[2] Therefore, for each year of potential overlap between the Tier 3 program and the Tier 4 program under Option 1 we have estimated an additional cost of $3 million per engine platform. Consistent with our estimation of the number of engine platforms in each power category used for the proposal, this would add approximately $290 million dollars to Option 1 as compared to the proposal.

The second impact on engine engineering costs of Option 1 is the reduced amount of time for nonroad engine companies to learn from the 2007 highway heavy-duty diesel experience with aftertreatment systems. There are a number of ways in which nonroad companies can learn from the extensive research and development effort being expended to achieve the 2007 highway standards. These include:

- nonroad engine companies can purchase 2007 highway products and reverse engineer how the products work;
- nonroad engine companies can learn from information available in the public literature regarding 2007 highway technologies (such as SAE papers and other technical publications);
- nonroad engine companies can learn by collaboration with technology vendors such as exhaust aftertreatment companies who are developing PM filters and NOx aftertreatment systems with on-highway companies;
- nonroad engine manufacturers can work with 3rd party engineering laboratories such as AVL, FEV, Ricardo, or Southwest Research Institute who through their work with

industry and governments will acquire significant expertise with diesel aftertreatment; and,

- nonroad engine companies can hire engineers and scientists away from highway companies who have already gone through the engine design experience.

In order to reduce costs for nonroad companies, they must have access to these various learning channels early enough in time to impact their R&D programs. For our proposal, which provides at least 4 years after the 2007 program before the first nonroad engines must use advanced aftertreatment systems, we have estimated this learning can reduce the R&D costs for nonroad companies by 30 percent compared to what they would incur if there was no 2007 highway program and the companies were required to develop the aftertreatment technologies without any learning from outside sources, and for nonroad companies who also are developing engines to comply with the 2007 highway standards we have estimated the learning time available with our proposal will reduce their R&D costs by 90 percent. We project based on our engineering judgement that as the time frame for learning is reduced below 4 years, the potential R&D cost reductions will decrease substantially, as shown in Table 12.4.1.1.2-1 below.

Table 12.4.1.1.2-1
Impact of Tier 4 Implementation of Engine Research and Development Costs

Company Type	Estimated Reduction in Tier 4 Engine R&D Costs as a Function of the First Year of Implementation for Nonroad Advanced Aftertreatment			
	2011 implementation	2010 implementation	2009 implementation	2008 implementation
Nonroad & Highway Companies	90 %	63%	14%	0%
Nonroad only companies	30 %	21%	5%	0%

Option 1 reduces the availability to learn from the highway program by two years for the 175 - 750 hp category. Based on the estimates provided in the table 12.4.1.1.2-1, this would reduce the learning for highway companies from 90 percent down to 14 percent, and for the nonroad only engine companies from 30 percent down to 5 percent. For the 75 - 175 hp category, Option 1 reduces the highway learning by one year. Based on the estimates provided in Table 12.4.1.1.2-1, this will reduce the learning for highway companies to 63 percent and for nonroad only companies to 21 percent. Consistent with the engine research and development costs estimated for the proposal and described in detail in Chapter 6 of this RIA, these adjustments increase the R&D expenditure of Option 1 by approximately $120 million dollars.

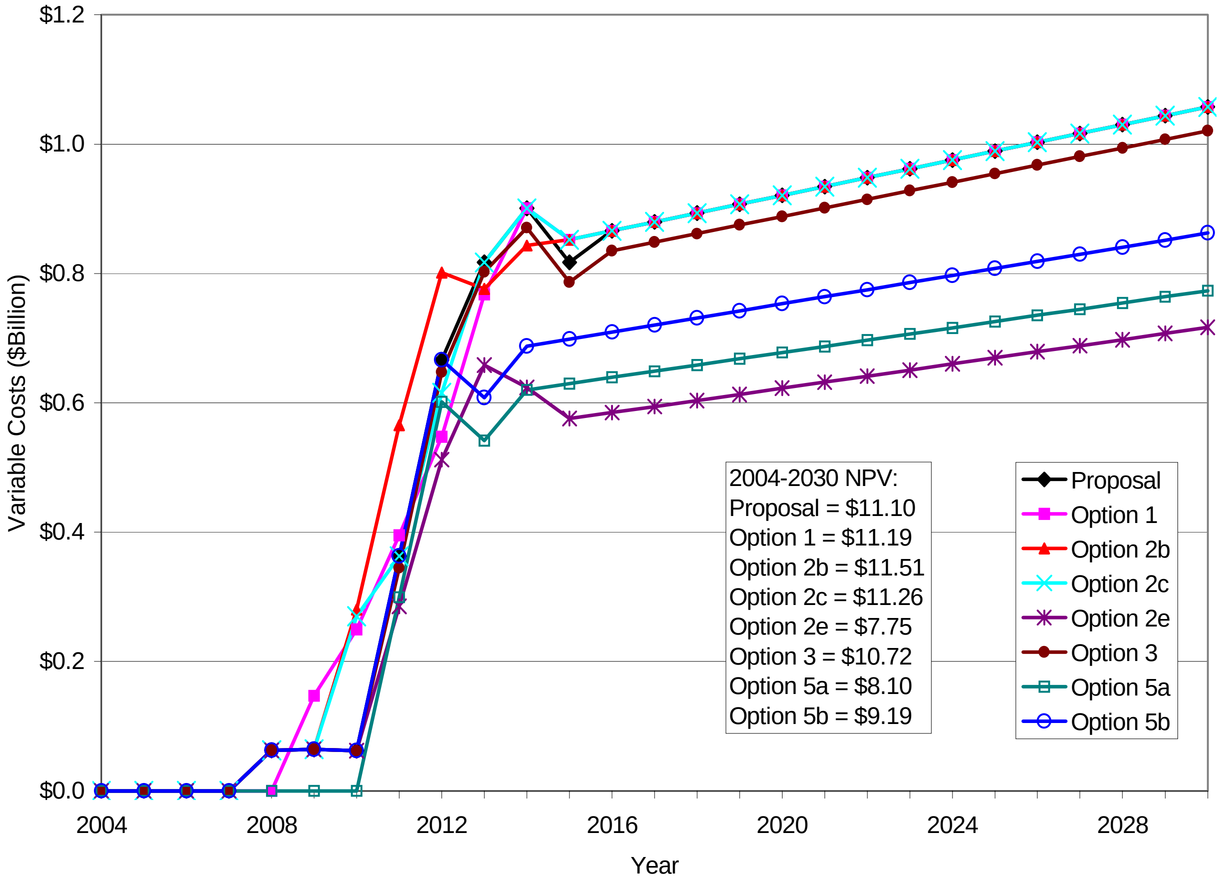
Engine Variable Costs

This option relies on the same engine hardware cost estimates as for the proposal, which are described in Chapter 6 of this draft RIA. Where appropriate, we have shifted the engine variable hardware costs in time to match the implementation dates of Option 1. Specifically:

- for the <50 hp category, the hardware costs described in Chapter 6 have been delayed by 1 year;
- for the 50-75 hp category, the 2008 transitional standard hardware has been eliminated;
- for the 75-175 hp category and the 175 - 750 hp category, the PM filter system hardware has been pulled forward by two years for 50 percent of the engines; and,
- for the >750 hp category, the hardware cost are the same as in the proposal.

The NPV of the engine variable costs through 2030 is approximately $90 million more than in the proposal. These costs are higher than the proposal because the elimination of the transitional PM standards for the 50-75 hp engines, combined with a 1 year delay in the standards for the < 50 hp engines does not off-set the increased hardware costs associated with the one year pull-ahead of PM filters for the 75 - 750 hp engines. The annual engine variable costs are shown in Figure Figure 12.4.1.1.2-1, along with the annual engine variable costs for the proposal and the other alternative options.

Figure 12.4.1.1.2-1. Engine Variable Costs for the Proposal and Alternative Options



Equipment Fixed Costs

Chapter 6 of this draft RIA presents a detailed discussion of our methodology for estimating equipment fixed costs, which is dominated by our estimates for equipment redesign costs. In this sub-section we will discuss the impact of Option 1 on the equipment fixed costs for each of the engine power categories.

For the <50 hp engine category there is a one year delay in the standards to 2009. We have not adjusted the costs to redesign the < 50 hp engines, but we have shifted the costs back by one year in time.

For the 50-75 hp engine category, Option 1 eliminates the 2008 transitional PM standards, and we have eliminated the equipment redesign costs associated with the proposed 2008 transitional standard.

For the 75 - 175 hp engine category, Option 1 pulls ahead the proposed 0.01 g/bhp-hr PM standard ahead by two years to 2010 for 50 percent of the engines. This is followed by 50 percent of the engines meeting the proposed PM and NOx standard in 2012, and finally 50 percent of the engines must meet the final NOx standard. Therefore, we have estimated Option 1 will require a major equipment redesign for 50 percent of the engines 3 times (2010, 2012 and 2014), or a total of 1.5 redesigns for the power category. In effect, this is one-quarter more redesigns than expected under the proposal which increases redesign costs by approximately $470 million.

Equipment Variable Costs

We have estimated the impacts on equipment variable costs in the same manner as done for engine variable costs by eliminated costs where appropriate and shifting them up a year or two or back a year or two where appropriate. These changes increase the NPV through 2030 by approximately $20 million relative to the equipment variable costs expected under the proposal.

Total Engine/Equipment Cost

Based on the estimates provided above, we have estimated the Option 1 will result in an increase in the net-present value of the engine and equipment costs through 2030 of approximately $990 million dollars.

12.4.1.2 Option 1a

Option 1a is described in Figure 12.1.1-2 in Section 12.1 of this draft RIA. Option 1a requires 15ppm sulfur fuel in 2008 for nonroad, locomotive and marine engines. The engine standards, which are also described in Chapter 12.1, consist of a 2 year introduction for a 0.01 g/bhp-hr PM standard for all nonroad engines by power category beginning in 2009, and a two year introduction of a 0.30 g/bhp-hr NOx standard for all nonroad engines by power category beginning in 2011.

As discussed in Section 12.6.2.1.2, we do not believe this very aggressive standards program is technically feasible for either the fuel program or the engine program, and therefore we have not provided a cost estimate for Option 1a.

12.4.1.3 Option 1b

Option 1b is described in Figure 12.1.1-3 in Section 12.1 of this draft RIA. Option 1b has the same engine standards as Option 1a; however, the fuel program consists of 15ppm for nonroad, locomotive and marine engines beginning in 2006. Option 1b is identical to Option 1a with respect to the engine standards program, and the fuel program is implemented two years earlier in 2006. As discussed in Section 12.6.2.1.3, we do not believe this very aggressive standards program is technically feasible for either the fuel program or the engine program, and therefore we have not provided a cost estimate for Option 1b.

12.4.2 Two Step Options

12.4.2.1 The Proposal

Our fuel and engine standards proposal is summarized in Figure 12.1.2-1 in Section 12.1 of this draft RIA. The cost estimation for the proposal is detailed in Chapters 6 (engine & equipment program) and 7 (fuel program) of this draft RIA, and will not be repeated here.

12.4.2.2 Option 2a

Option 2a is described in Figure 12.1.2-2 in Section 12.1 of this draft RIA. Option 2a requires the same engine program as our proposal; however, the first-step of the two step fuel program (500 ppm sulfur fuel for nonroad, locomotive and marine engines) is implemented one year earlier than in our proposal (2006 rather than 2007).

As discussed in Section 12.6.2.2.2, we do not believe this aggressive fuel program is technically feasible and therefore we have not provided a cost estimate for Option 2a.

12.4.2.3 Option 2b

This option is described in Figure 12.1.2-3 in Section 12.1 of this draft RIA. Option 2b is similar to the fuel program for the proposal, except the 15 ppm sulfur nonroad fuel is pulled ahead one year to 2009. The engine standards program under Option 2b is similar to the proposal, except that the PM filter based standards for the >25 hp engines is pulled forward by one year, however the NOx program and the 2008 PM standards for the <75 hp engines are the same as the proposal.

12.4.2.3.1 Fuel Costs for Option 2b

The total fuel costs from Chapter 7 of the Draft RIA comprising the refining and distribution and additive costs for Option 2b are summarized in the following tables.

Table 12.4.2.3.1-1
Total Fuel Costs for Option 2b (cents per gallon)

Option	Specification	Year	Refining Costs (¢/gal)	Distribution & Additive Costs (¢/gal)	Total Costs (¢/gal)
Nonroad goes to 15 ppm in 2009	500 ppm NR, L & M	2007-2008	2.2	0.3	2.5
	500 ppm L & M	2009-2012	2.2	0.4	2.6
	15 ppm NR (total incl 2007)	2009+	4.6	0.4	5.0
	500 ppm L & M	2013+	2.2	0.2	2.4

Table 12.4.2.3.1-2
Net Operating Costs for Option 2b Incremental To The Proposal (millions)
(Net present values through 2030 at 3% discount rate)

Specification	Gallons	Fuel costs*	Net maintenance costs	Total operating costs
15 ppm fuel	4,270	$430	$250	$540
500 ppm fuel	-5,180	-$130		

* Note that the incremental fuel costs presented here are calculated as: [proposal $/gal] multiplied by [proposal gallons] minus the [option $/gal] multiplied by [option gallons]. This is not mathematically equivalent to the difference in gallons multiplied by the difference in $/gal.

These fuel costs and other related operating costs (e.g., maintenance savings, fuel consumption impacts) result in an increase in the net-present value of Option 2b of approximately $540 million as compared to the proposal through 2030.

12.4.2.3.2 Engine and Equipment Costs for Option 2b

Engine Fixed Costs

As discussed in Section 12.6.2.2.3, Option 2b presents a number of unique challenges for engine manufacturers as compared to the proposal. These include up to one year of overlap with the nonroad Tier 3 development time frame for one power category, and one less year for learning for the highway to nonroad technology transfer as compared to our proposal. In addition, Option 2b presents a significant challenge for engine manufacturers during the implementation of the standards for NOx and PM in the 2010-2013 time frame which is not present in our proposal. Specifically, engines >25 hp will have a series of introductions with new PM standards one year and new NOx standards the next year. We have estimated a cost impact for each of these engine engineering impacts as compared to our proposal, as described below. Because of these unique challenges, Option 2b has the potential to result in limited product offerings for certain segments of the nonroad engine and equipment market. This potential exists primarily from the rapid change in PM and NOx standards for the same engine power categories in the 2010-2013 time frame, as well as the overlapping development time frames between Tier 3 and Tier 4. To the extent that engine and equipment manufacturers engineering staff and resources (e.g., sufficient laboratory test cells) are not sufficient to address the workload issues associated with these engineering requirements, companies may need to decide to focus their resources on certain products at the expense of others, with the result being limited product availability for Tier 3 as well as for Tier 4. Our cost analysis for Option 2b presented below assumes companies do have these resources. However, to the extent some companies do not have the necessary resources, our cost analysis does not attempt to estimate the cost impacts of limited product offerings.

Option 2b has up to one year of engine design overlap with Tier 3 engine development, specifically for engines in the 75 - 100 hp range. For these engines, Tier 3 is implemented in 2008, and Option 2b's one year pull-ahead of PM standards would begin in 2011. As discussed in Section 12.4.1.1.2 (Engine & Equipment Costs for Option 1), nonroad engine manufacturers typically require 3 to 4 years of development in advance of a major new emission standard or new engine product launch. As discussed in Section 12.4.1.1.2, we have estimated this potential overlap in Tier 3 and Tier 4 engine development could cost on the order of $3 million per engine platform. Consistent with our estimation of the number of engine platforms in each power category used for the proposal, this adds approximately $30 million dollars to Option 2b as compared to the proposal.

The second impact on engine engineering costs of Option 2b is the reduced amount of time for nonroad engine companies to learn from the 2007 highway heavy-duty diesel experience with aftertreatment systems. Compared to our proposal, Option 2b reduces this time frame by one year because of the pull-ahead of the PM filter based standards. As discussed in Section 12.4.1.1.2 and using the estimates provided in Table 12.4.1.1.2-1, Option 2b will reduce the engine research and development cost savings due to learning for highway companies from 90 to 63 percent and for nonroad only companies from 70 to 21 percent. Consistent with the engine research and development costs estimated for the proposal and described in detail in Chapter 6 of this RIA, these adjustments increase the R&D expenditure of Option 2b by approximately $40 million dollars.

The third impact of Option 2b on the engine engineering costs is the rapid change of PM and NOx standards in two years for both the 75-175 hp and 175-750 hp categories. Option 2b implements a 0.01 g/bhp-hr PM standard in 2010 for 100 percent of the engines, and the following year 50 percent of the engines must meet a 0.30 g/bhp-hr NOx standard, therefore ½ of the engines will require a redesign in 2009 and 2010. This will present a significant engine calibration challenge for engine manufacturers. Under Option 2b, we are projecting that in order to comply with the requirement to produce 50 percent of the engines to a new standard the next year, companies would need to expend considerable engineering resources (staff and test cell time) to develop the new calibrations. We have estimated that each engine platform would require a team of 3 engineers and 4 technicians plus laboratory test cell resources working for one year to develop the additional calibrations which Option 2b would require (implementation of Tier 4 NOx standards 1 year after Tier 4 PM standards for ½ of the engines). We estimate the cost of this team for one year at $1 million.[3] Consistent with our estimation of the number of engine platforms in each power category used for the proposal, this engineering effort ($1 million per engine platform for ½ of the platforms in the 75-750 hp categories) adds approximately $30 million dollars to Option 2b as compared to the proposal.

Engine Variable Costs

Option 2b relies on the same engine hardware cost estimates as for the proposal, which are described in Chapter 6 of this draft RIA. Where appropriate, we have shifted the engine variable hardware costs in time to match the implementation dates of Option 2b. Specifically:

- for the >25 hp engines, 75-175 hp category and the 175 - 750 hp category, the PM filter system hardware has been pulled forward by one year
- for the >750 hp category, the PM filter system has been pulled forward by one year for 50 percent of the engines.

The NPV of the engine variable costs through 2030 is approximately $410 million more than the proposal. The annual engine variable costs are shown in Figure 12.4.1.1.2-1.

Equipment Fixed Costs

Chapter 6 of this draft RIA presents a detailed discussion of our methodology for estimating equipment fixed costs, which is dominated by our estimates for equipment redesign costs. In this sub-section we will discuss the impact of Option 2b on the equipment fixed costs for each of the engine power categories.

For the <25 hp engine category, Option 2b is the same as the proposal, so there are no differences for equipment redesign costs.

For the 25-50 hp engines, Option 2b would require a redesign in 2012 for PM filters , followed by a minor equipment update the next year to accommodate the 3.5 g/bhp-hr NOx standard. We have estimated the 2012 equipment redesign costs as being equivalent to the redesign costs of the proposal's 2013 program. We have estimated the cost of Option 2b's 2013 NOx standard impact as being ½ of the redesign costs of the proposal's 2013 costs.

For the 50-75 hp engines, Option 2b requires equipment redesign one year earlier than in the proposal. However, we estimate the equipment redesign effort is identical to the proposal, and we have estimated the costs to be the same as the proposal.

For the 75 - 175 hp engine category, Option 2b pulls ahead the proposed 0.01 g/bhp-hr PM standard ahead by one year to 2011. This is followed by 50 percent of the engines meeting the proposed NOx standard in 2012, and finally 50 percent of the engines must meet the final NOx standard in 2014. Therefore, we have estimated Option 2b will require a major equipment redesign for all of the equipment in 2011, followed by a minor redesign effort in 2012 for 50 percent of the equipment and in 2014 for 50 percent of the equipment. We have estimated that each of these minor redesign efforts will cost ½ of the major redesign costs estimated for the proposal.

For the 175 - 750 hp engine category, Option 2b pulls ahead the proposed 0.01 g/bhp-hr PM standard ahead by one year to 2010. This is followed by 50 percent of the engines meeting the proposed NOx standard in 2011, and finally 50 percent of the engines must meet the final NOx standard in 2014. Therefore, we have estimated Option 2b will require a major equipment redesign for all of the equipment in 2010, followed by a minor redesign effort in 2011 for 50 percent of the equipment and in 2014 for 50 percent of the equipment. We have estimated that each of these minor redesign efforts will cost ½ of the major redesign costs estimated for the proposal.

For the > 750 hp category, Option 2b pulls ahead the proposed 0.01 g/bhp-hr PM standard ahead by one year to 2010 for 50 percent of the engines. This is followed by 50 percent of the engines meeting the proposed NOx standard in 2011, and finally all of the engines must meet the final PM and NOx standard in 2014. We have estimated that the equipment which goes through a major redesigned to accommodate the new PM standard engines in 2010 will not redesign again until 2014, when they would go through a minor equipment redesign related to the NOx standard. The other half of the equipment fleet would go through a major redesign in 2011 to accommodate the NOx standard, and this same equipment would also go through a minor redesign in 2014 to meet the final PM standard. Consistent with the discussion above, we have estimated the costs of the major redesign to be equivalent to the redesign estimates for the proposal, and we have estimated that a minor redesign costs ½ of the proposal's major redesign estimates.

The combined result of the changes listed above for the equipment fixed costs result in an increase for Option 2b as compared to our proposal of approximately $130 million.

Equipment Variable Costs

We have estimated the impacts on equipment variable costs in the same manner as done for engine variable costs by eliminated costs where appropriate and shifting them up a year or two or back a year or two where appropriate. These changes increase the NPV through 2030 by $10 million relative to the equipment variable costs expected under the proposal.

Total Engine/Equipment Cost

Based on the estimations provided above, we have estimated the Option 2b will result in an increase in the net-present value of the engine and equipment costs through 2030 of approximately $640 million dollars.

12.4.2.4 Option 2c

This option is described in Figure 12.1.2-4 in Section 12.1 of this draft RIA. Option 2c is almost identical to Option 2b which is described in section 12.4.2.3 above, with the exception that the one year pull ahead of the PM standard is only for the 175-750 hp engine category (Option 2b pulls ahead the PM filter based standard for all engines >25 hp by one year). As with Option 2b, this will require 15 ppm sulfur nonroad fuel in 2009, one year earlier than in the proposal.

12.4.2.4.1 Fuel Costs for Option 2c

The total fuel costs from Chapter 7 of the Draft RIA comprising the refining and distribution and additive costs for Option 2c are summarized in the following tables. These tables are the same as in Option 2b.

Table 12.4.2.4.1-1
Total Fuel Costs for Option 2c (cents per gallon)

Option	Specification	Year	Refining Costs (¢/gal)	Distribution & Additive Costs (¢/gal)	Total Costs (¢/gal)
Nonroad goes to 15 ppm in 2009	500 ppm NR, L & M	2007-2008	2.2	0.3	2.5
	500 ppm L & M	2009-2012	2.2	0.4	2.5
	15 ppm NR (total incl 2007)	2009+	4.6	0.4	5.0
	500 ppm L & M	2013+	2.2	0.2	2.4

Table 12.4.2.4.1-2
Net Operating Costs for Option 2c Incremental To The Proposal (millions)
(Net present values through 2030 at 3% discount rate)

Specification	Gallons	Fuel costs*	Net maintenance costs	Total operating costs
15 ppm fuel	4,270	$430	$240	$530
500 ppm fuel	-5,180	-$130		

* Note that the incremental fuel costs presented here are calculated as: [proposal $/gal] multiplied by [proposal gallons] minus the [option $/gal] multiplied by [option gallons]. This is not mathematically equivalent to the difference in gallons multiplied by the difference in $/gal.

These fuel costs and other related operating costs (e.g., maintenance savings, fuel consumption impacts) result in an increase in the net-present value of Option 2c of approximately $530 million as compared to the proposal through 2030.

12.4.2.4.2 Engine and Equipment Costs for Option 2c

Engine Fixed Costs

As discussed in Section 12.6.2.2.4, Option 2c represents a number of unique challenges for engine and manufacturers as compared to the proposal (these challenges are very similar to those for Option 2b, but only for those engines and equipment in the 175-750 hp category). As discussed in Section 12.4.2.3.2 (Option 2b), to the extent that engine and equipment manufacturers engineering staff and resources are not sufficient to address the workload issues associated with these engineering requirements, companies may need to decide to focus their resources on certain products at the expense of others, with the result being limited product availability for Tier 3 as well as for Tier 4. Our cost analysis for Option 2c presented below assumes companies do have these resources. However, to the extent some companies do not have the necessary resources, our cost analysis does not attempt to estimate the cost impacts of limited product offerings.

Option 2c reduces the amount of time for nonroad engine companies to learn from the 2007 highway heavy-duty diesel experience with aftertreatment systems. Compared to our proposal, Option 2c reduces this time frame by one year because of the pull-ahead of the PM filter based standards for the 175-750 hp engine category. As discussed in Section 12.4.1.1.2 and using the estimates provided in Table 12.4.1.1.2-1, Option 2c will reduce the engine research and development cost savings due to learning for highway companies from 90 to 63 percent and for nonroad only companies from 70 to 21 percent. Consistent with the engine research and development costs estimated for the proposal and described in detail in Chapter 6 of this RIA, these adjustments increase the R&D expenditure of Option 2c by approximately $40 million dollars.

As discussed under Option 2b, Option 2c also increases the engine engineering costs relative to the proposal due to the rapid change of PM and NOx standards in two years. For the 175-750 hp category, Option 2c implements a 0.01 g/bhp-hr PM standard in 2010 for 100 percent of the engines, and the following year 50 percent of the engines must meet a 0.30 g/bhp-hr NOx standard, therefore ½ of the engines will require a redesign in 2009 and 2010. This will present a significant engine calibration challenge for engine manufactures. Under Option 2c, we are projecting that in order to comply with the requirement to produce 50 percent of the engines to a new standard the next year, companies would need to expend considerable engineering resources (staff and test cell time) to develop the new calibrations. We have estimated that each engine platform would require a team of 3 engineers and 4 technicians plus laboratory test cell resources working for one year to develop the additional calibrations which Option 2c would require (implementation of Tier 4 NOx standards 1 year after Tier 4 PM standards for ½ of the engines).

We estimate the cost of this team for one year at $1 million.[4] Consistent with our estimation of the number of engine platforms in each power category used for the proposal, this engineering effort ($1 million per engine platform for ½ of the platforms in the 175-750 hp category) adds approximately $20 million dollars to Option 2c as compared to the proposal.

Engine Variable Costs

Option 2c relies on the same engine hardware cost estimates as for the proposal, which are described in Chapter 6 of this draft RIA. Where appropriate, we have shifted the engine variable hardware costs in time to match the implementation dates of Option 2c. Specifically for 175 - 750 hp category, the PM filter system hardware has been pulled forward by one year. The NPV of the engine variable costs through 2030 is approximately $160 million more than the proposal. The annual engine variable costs are shown in Figure 12.4.1.1.2-1.

Equipment Fixed Costs

Chapter 6 of this draft RIA presents a detailed discussion of our methodology for estimating equipment fixed costs, which is dominated by our estimates for equipment redesign costs. In this sub-section we will discuss the impact of Option 2c on the equipment fixed costs for the 175-750 hp category equipment.

For the 175 - 750 hp engine category, Option 2b pulls ahead the proposed 0.01 g/bhp-hr PM standard ahead by one year to 2010. This is followed by 50 percent of the engines meeting the proposed NOx standard in 2011, and finally 50 percent of the engines must meet the final NOx standard in 2014. Therefore, we have estimated Option 2b will require a major equipment redesign for all of the equipment in 2010, followed by a minor redesign effort in 2011 for 50 percent of the equipment and in 2014 for 50 percent of the equipment. We have estimated that each of these minor redesign efforts will cost ½ of the major redesign costs estimated for the proposal. Compared to the proposal, Option 2b increases the equipment redesign costs for the 75-175 hp category by approximately $70 million.

Equipment Variable Costs

We have estimated the impacts on equipment variable costs in the same manner as done for engine variable costs by eliminated costs where appropriate and shifting them up a year or two or back a year or two where appropriate. These changes increase the NPV through 2030 by $10 million relative to the equipment variable costs expected under the proposal.

Total Engine/Equipment Cost

Based on the estimations provided above, we have estimated the Option 2b will result in an increase in the net-present value of the engine and equipment costs through 2030 of approximately $300 million dollars.

12.4.2.5 Option 2d

This option is described in Figure 12.1.2-5 in Section 12.1 of this draft RIA. Option 2d is the same as the proposal but with the addition of a 0.30 g/bhp-hr NOx standard applied to engines in the 25-75 hp category. These NOx standards would be phased in over three years from 2013 through 2015. Option 2d has the same fuel program as the proposal.

As discussed in Section 12.6.2.2.5, we do not believe a 0.30 g/bhp-hr NOx standard is appropriate for engines in this power category, and therefore we have not provided a cost estimate for Option 2d.

12.4.2.6 Option 2e

This option is described in Figure 12.1.2-6 in Section 12.1 of this draft RIA. Option 2e requires the same PM standards and implementation schedule as the proposal, but there are no Tier 4 NOx standards. Option 2e has the same fuel program as the proposal.

12.4.2.6.1 Fuel Costs for Option 2e

Option 2e has no changes in the fuel program compared to our proposal, therefore the estimated fuel costs (e.g., the cents/gallon estimates) are no different from the proposal. However, the elimination of the NOx standard does impact our fuel consumption impacts. As discussed in Chapter 6.2.3 of this draft RIA (Engine Operating Costs), a combined NOx adsorber - PM filter system can result in a net increase in fuel consumption of as much as one percent, while a PM filter only system can result in a net increase in fuel consumption of as much as two percent. Therefore, removal of the NOx control program results in an increase in the operating costs of Option 2e as compared to our proposal. The net present value of this increase through 2030 is approximately $460 million.

12.4.2.6.2 Engine and Equipment Costs for Option 2e

Engine Fixed Costs

Option 2e requires no NOx related fixed costs as compared to our proposal. Eliminating these costs reduces the cost of Option 2e relative to our proposal by approximately $130 million.

Engine Variable Costs

Option 2e removes any new NOx related variable costs from the program. The NPV of the engine variable costs for Option 2e through 2030 is approximately $3.4 billion less than the proposal. The annual engine variable costs are shown in Figure 12.4.1.1.2-1.

Equipment Fixed Costs

We have estimated that Option 2e has a minimal impact on the equipment redesign costs compared to the proposal because the equipment manufacturers will be modifying their products in order to add PM filters under Option 2e, and we believe there are minimal differences for equipment manufacturers for packaging a NOx adsorber and a PM filter as compared to packaging only a PM filter. However, the proposal does include a minor redesign cost estimate for 50 percent of the equipment in the 75-750 hp categories in 2014 due to the implementation of the 0.30 g/bhp-hr NOx standard for ½ of the engines. We have eliminated this cost from Option 2e. Compared to the proposal, Option 2e reduces the equipment redesign costs by approximately $120 million.

Equipment Variable Costs

Option 2e removes any new NOx related variable costs from the program. The NPV of the equipment variable costs for Option 2e through 2030 would be approximately $170 million less than the proposal due to less sheet metal required to house exhaust emission control devices and fewer bolts and brackets needed to secure those devices.

Total Engine/Equipment Cost

Based on the estimations provided above, we have estimated the Option 2e will result in a decrease in the net-present value of the engine and equipment costs through 2030 of approximately $3.8 billion dollars.

12.4.3 Other Options

12.4.3.1 Option 3

This option is described in Figure 12.1.2-7 in Section 12.1 of this draft RIA. Option 3 imposes no Tier 4 standards for engines used in above-ground mining equipment (AGME). Option 2e has the same fuel program as the proposal.

12.4.3.1.1 Fuel Costs for Option 3

Option 2e has no changes on the cost of fuel relative to our proposal. However, the operating costs for AGME are lower than in our proposal due to the elimination of PM filter maintenance requirements and our estimate of a one percent fuel consumption increase due to PM filters. This results in a decrease in the net-present value of Option 3 of approximately $80 million as compared to the proposal through 2030.

12.4.3.1.2 Engine and Equipment Costs for Option 3

Mining equipment is defined for this analysis as certain equipment types over 750hp as described in Section 12.6.2.2.7 of this draft RIA. This includes equipment types such as excavators, off highway trucks, wheel loaders, crawler tractor/dozers and off-highway tractors.

Engine Fixed Costs

Because these engines are used in equipment other than the AGME, Option 3 has no impact on the engine fixed costs.

Engine Variable Costs

We have removed the variable costs associated with the Tier 4 proposal from the AGME engines (i.e., PM filters and NOx adsorbers) to evaluate the impact of Option 3. The NPV of the engine variable costs for Option 3 through 2030 is approximately $380 million less than the proposal. The annual engine variable costs are shown in Figure 12.4.1.1.2-1.

Equipment Fixed Costs

Option 3 would remove any equipment redesign requirements for the AGME. This reduces the costs of Option 3 by approximately $10 million relative to the proposal.

Equipment Variable Costs

We have eliminated the equipment variable costs for the >750 hp AGME for Option 3. These changes reduce the NPV through 2030 by approximately $20 million relative to the equipment variable costs expected under the proposal.

Total Engine/Equipment Cost

Based on the estimations provided above, we have estimated that Option 3 would result in a decrease in the net-present value of the engine and equipment costs through 2030 of approximately $410 million dollars.

12.4.3.2 Option 4

Option 4 is described in Figure 12.1.2-8 in Section 12.1 of this draft RIA. Option 4 is similar to the proposal, but it requires locomotive and marine diesel fuel sulfur levels to be controlled to a level of 15ppm in 2010.

12.4.3.2.1 Fuel Costs for Option 4

The total fuel costs from Chapter 7 of the Draft RIA comprising the refining and distribution and additive costs for Option 4 are summarized in the following tables.

Table 12.4.3.2.1-1
Total Fuel Costs for Option 4 (cents per gallon)

Option	Specification	Year	Refining Costs (¢/gal)	Distribution & Additive Costs (¢/gal)	Total Costs (¢/gal)
Nonroad, Locomotive and Marine go to 15 ppm in 2010	500 ppm NR, L & M	2007+	2.2	0.3	2.5
	15 ppm NR, L & M (total incl 2007)	2010+	4.6	0.4	5.0

Table 12.4.3.2.1-2
Net Operating Costs for Option 4 Incremental To The Proposal (millions)
(Net present values through 2030 at 3% discount rate)

Specification	Gallons	Fuel costs*	Net maintenance costs	Total operating costs
15 ppm fuel	57,760	$3,100	$20	$1,770
500 ppm fuel	-54,910	-$1,350		

* Note that the incremental fuel costs presented here are calculated as: [proposal $/gal] multiplied by [proposal gallons] minus the [option $/gal] multiplied by [option gallons]. This is not mathematically equivalent to the difference in gallons multiplied by the difference in $/gal.

These fuel costs and other related operating costs (i.e., maintenance savings) result in an increase in the net-present value of Option 4 of approximately $1.8 billion through 2030 as compared to the proposal.

12.4.3.2.2 Engine and Equipment Costs for Option 4

Option 4 has the same engine standards program and implementation dates as the proposal, and therefore the same costs.

12.4.3.3 Option 5a

This option is described in Figure 12.1.2-9 in section 12.1 of this draft RIA. Option 5a has the same fuel program as the proposal but the engine/equipment program differs from the proposal in that no new standards would be implemented for <75 horsepower engines.

12.4.3.3.1 Fuel Costs for Option 5a

Option 5a has no changes on the cost of fuel relative to our proposal. However, the operating costs for <75 horsepower engines are lower than in our proposal due to the elimination of some operating costs for these engines. Specifically, both the PM filter maintenance requirements and our estimate of a two percent fuel consumption increase due to PM filters would be eliminated for all 25 to 75 horsepower engines. Also, CCV maintenance costs would be eliminated for all engines <75 horsepower. Note that oil change maintenance savings would still be realized by these engines as they would be under the proposal. The elimination of these operating costs would result in a decrease in the net-present value of Option 5a of approximately $530 million as compared to the proposal through 2030.

12.4.3.3.2 Engine and Equipment Costs for Option 5a

Engine Fixed Costs

Option 5a would eliminate the need for R&D expenditures described in Chapter 6 as CDPF-only and DOC/engine-out R&D. It would also eliminate the need for tooling expenditures on those engine platforms having sales strictly in the <75 horsepower category. This option would also eliminate proposal-related certification costs for all <75 horsepower engines. Together, these cost reductions would total $140 million relative to the proposal.

Engine Variable Costs

We have removed the variable costs associated with the Tier 4 proposal from the <75 horsepower engines (i.e., DOCs, PM filters, fuel systems, EGR systems, CCV systems) to evaluate the impact of Option 5a on engine variable costs. The NPV of the engine variable costs for Option 5a through 2030 is approximately $3 billion less than the proposal. The annual engine variable costs are shown in Figure 12.4.1.1.2-1.

Equipment Fixed Costs

Option 5a would eliminate any equipment redesign requirements for <75 horsepower equipment. This would reduce the equipment fixed costs of Option 5a by $80 million relative to the proposal.

Equipment Variable Costs

We have eliminated the equipment variable costs for <75 hp equipment for Option 5a. These changes reduce the NPV through 2030 by approximately $70 million relative to the equipment variable costs expected under the proposal.

Total Engine/Equipment Cost

Based on the estimations provided above, we have estimated that Option 5a would result in a decrease in the net-present value of the engine and equipment costs through 2030 of approximately $3.3 billion dollars.

12.4.3.4 Option 5b

This option is described in Figure 12.1.2-10 in section 12.1 of this draft RIA. Option 5b has the same fuel program as the proposal but the engine/equipment program differs from the proposal in that the 2008 standards would remain in effect indefinitely and no CDPF forcing standards would be implemented for 25 to 75 horsepower engines.

12.4.3.4.1 Fuel Costs for Option 5b

Option 5b has no changes on the cost of fuel relative to our proposal. However, the operating costs for <75 horsepower engines are lower than in our proposal due to the elimination of some operating costs for these engines. Specifically, both the PM filter maintenance requirements and our estimate of a two percent fuel consumption increase due to PM filters would be eliminated for all 25 to 75 horsepower engines. Note that, unlike Option 5a, CCV maintenance costs would be incurred for all engines <75 horsepower; also, note that oil change maintenance savings would still be realized by these engines as they would be under the proposal. The elimination of CDPF-related operating costs would result in a decrease in the net-present value of Option 5b of approximately $490 million as compared to the proposal through 2030.

12.4.3.4.2 Engine and Equipment Costs for Option 5b

Engine Fixed Costs

Option 5b would eliminate the need for R&D expenditures described in Chapter 6 as CDPF-only R&D. It would also eliminate the need for CDPF-only tooling expenditures on those engine platforms having sales strictly in the 25 to 75 horsepower category. This option would also eliminate proposal-related certification costs for 25 to 75 horsepower engines beyond 2008. Together, these cost reductions would total $60 million relative to the proposal.

Engine Variable Costs

We have removed the variable costs associated with the 2013 standards of the Tier 4 proposal for 25 to 75 horsepower engines (i.e., PM filters, fuel systems, EGR systems) to evaluate the impact of Option 5b on engine variable costs. The NPV of the engine variable costs for Option 5b through 2030 is approximately $1.9 billion less than the proposal. The annual engine variable costs are shown in Figure 12.4.1.1.2-1.

Equipment Fixed Costs

Option 5b would eliminate any equipment redesign requirements for 25 to 75 horsepower equipment associated with the 2013 standards. This would reduce the equipment fixed costs of Option 5b by $40 million relative to the proposal.

Equipment Variable Costs

For Option 5b, we have eliminated the equipment variable costs for 25 to 75 hp equipment associated with the 2013 standards. These changes reduce the NPV through 2030 by approximately $70 million relative to the equipment variable costs expected under the proposal.

Total Engine/Equipment Cost

Based on the estimations provided above, we have estimated that Option 5b would result in a decrease in the net-present value of the engine and equipment costs through 2030 of approximately $2.1 billion dollars.

12.5 Costs per Ton

For those Program Options where both inventory impacts and cost impacts were generated, it was possible to calculate an incremental cost per ton relative to the proposal. These incremental costs per ton for the Program Options are shown in Table 12.5-1. Note that the cost in Table 12.5-1 are expressed in billions of dollars and the emission reductions in tons of emissions. A brief discussion of how the increment costs per ton were determined is presented below. Note that there is no discussion of cost per ton for Options 1a, 1b, 2a, and 2d, since these Options were determined to be impractical due to infeasibility or other significant concerns, and thus, no costs were calculated.

Table 12.5-1
Incremental Cost per Ton for Alternatives
(Incremental to the Proposal)

Option		NOx+NMHC	PM	SO_2
1	cost ($billion)	-	$1.7	-
	reductions (tons)	11,000	6,000	-191,000
	cost/ton ($/ton)	n/a	$265,000	n/a
2b	cost	-	$1.2	-
	reductions	36,000	54,000	17,000
	cost/ton	n/a	$22,000	n/a
2c	cost	-	$0.8	-
	reductions	16,000	20,000	17,000
	cost/ton	n/a	$41,000	n/a
2e	cost	-$3.1	$12.4[b]	-
	reductions	-5,407,00	1,126,000	-
	cost/ton	$600	$11,000[b]	n/a
3	cost	-$0.2	-$0.2	-
	reductions	-751,000	-30,000	-
	cost/ton	$300	$8,300	n/a
4	cost	-	$0.6	$1.2
	reductions	-	9,000	114,000
	cost/ton	n/a	$64,000	$10,300
5a	cost	-$0.4	-$3.4	-
	reductions	-334,000	-209,000	-
	cost/ton	$1,100	$16,500	n/a
5b	cost	-$0.4	-$2.2	-
	reductions	-333,000	-121,000	-
	cost/ton	$1,100	$18,300	n/a

[a] Qualitative analysis only of options 1a, 1b, 2a, and 2d due to the options being impractical due to infeasibility or other significant concerns.
[b] In the analysis of the proposed program, the cost for 15ppm fuel is split 50/50 between NOx and PM. For option 2e, with no NOx program, all of the 15 ppm fuel cost is attribute to PM resulting in a new cost effectiveness estimate for PM. The PM cost here is the proposal total cost less the proposal SOx cost less the NOx+NMHC savings of Option 2e. For 2e we present the incremental cost effectiveness of the lost NOx tons and the new cost effectiveness of the Tier 4 PM tons.

12.5.1 Incremental Cost per Ton for Option 1

The incremental cost per ton for the lost SO_2 tons due to delaying the introduction of 500 ppm fuel by one year should be roughly the same as the long term SO_2 cost per ton of the 500 ppm fuel program. The cost per ton of SO_2 for that program is $90 (see Table 8.7-1 of this draft RIA). This value is so low because the costs of the 500 ppm fuel program are estimated to be essentially zero due to large maintenance savings expected to occur. In other words, the maintenance savings associated with the 500 ppm sulfur fuel nearly offset the cost of the fuel. See Section 8.4 of this draft RIA for more detail.

The fundamental goal of Option 1 is to introduce new PM controls earlier than the proposal. Therefore, the incremental costs associated with this option – for 15 ppm sulfur fuel two years earlier than the proposal and for PM technology on >75 horsepower engines two years earlier than the proposal – are all attributed to PM. These costs were presented in section 12.4.1.1 as $720 million for fuel and other operating costs and $990 million for engines/equipment for a total of roughly $1.7 billion. The PM tons gained, presented in Table 12.2.3-2, would be 6,000 tons. This results in an incremental cost per ton of PM (i.e., incremental to the proposal) of $265,000.

For NOx+NMHC, the small change in the emission reduction is due to the implementation of the transient test two years early. The feasibility and cost for industry to meet the transient test two years early is not made since this aspect of the option is not a primary consideration in considering this approach. No cost estimate was made for the additional development cost necessary to meet a transient test two years early, so no estimate of the cost per ton of NOx+NMHC is made.

In summary, this alternative gives up virtually free SO_2 reductions to gain very expensive PM tons ($265,000 per ton).

12.5.2 Incremental Cost per Ton for Option 2b

The goal of Option 2b is to introduce new PM controls earlier than the proposal. Therefore, the incremental costs associated with this option – for 15 ppm sulfur fuel one year earlier than the proposal and for PM technology on >25 horsepower engines one year earlier than the proposal – are all attributed to PM. Section 12.4.2.3 discussed the costs of this option as $540 million for fuel and other operating costs and $640 million for engines/equipment for a total of roughly $1.2 billion more than the proposal. Table 12.2.3-2 shows that Option 2b gets 54,000 more tons of PM reduction than does the proposal. This results in an incremental cost per ton of PM of $22,000.

For SO_2 and NOx+NMHC, this option has incidental reductions beyond the proposal due to the sulfur difference between 500 ppm and 15 ppm in 2009 (therefore a larger SO_2 reduction) and the one year early introduction of the transient test procedures (therefore a larger NOx+NMHC reduction). No cost estimate was made for the additional development cost necessary to meet a transient test one year early, so no estimate of the cost per ton of NOx+NMHC is made.

In summary, this alternative gets early PM reductions but has to pay more than double the rate paid under the proposal ($22,000 per ton vs. $9,300 per ton).

12.5.3 Incremental Cost per Ton for Option 2c

The fundamental goal of Option 2c is to introduce new PM controls earlier than the proposal. Therefore, the incremental costs associated with this option – for 15 ppm sulfur fuel one year earlier than the proposal and for PM technology on 175 to 750 horsepower engines one year earlier than the proposal – are all attributed to PM. The costs were presented in section 12.4.2.4 as $530 million for fuel and other operating costs and $300 million for engines/equipment, while Table 12.2.3-2 shows the foregone PM reductions to be 20,000 tons. This results in an incremental cost per ton of PM of $41,000.

This option has incidental SO_2 and NOx+NMHC reductions beyond the proposal due to the sulfur difference between 500 ppm and 15 ppm in 2009 (therefore a larger SO_2 reduction) and the one year early introduction of the transient test procedures (therefore a larger NOx+NMHC reduction). No cost estimate was made for the additional development cost necessary to meet a transient test one year early, so no estimate of the cost per ton of NOx+NMHC is made.

In summary, this alternative gets early PM reductions but has to pay more than three times the rate paid under the proposal ($41,000 per ton vs. $9,300 per ton).

12.5.4 Incremental Cost per Ton for Option 2e

Option 2e reduces compliance costs by eliminating new NOx standards. This option presents legal concerns since we would be giving up achievable NOx emission reductions solely for cost reasons, and cost considerations are not to be the driving factor in making decisions under CAA section 213(a)(3); rather, the overriding goal of this CAA section is air quality (see, for example, <u>Husqvarna AB v. EPA</u>, 254 F. 3d 195, 200 (D.C. Cir. 2001)). Our purpose here, however, is not to address the legality of such a program, but rather to analyze it's merits. Therefore, for the sake of illustration, while the resultant compliance costs would be lower than the proposal, all would be attributed to PM control. The discussion in section 12.4.2.6 noted that the net present value of Option 2e costs would be roughly $3.3 billion dollars less than the proposal ($3.8 billion less for engines/equipment but $460 million more for fuel and other operating costs) while giving up over five million tons of NOx reductions. The cost per ton of these foregone NOx emissions (i.e., dollars saved divided by tons given up) can be estimated at $600 per ton.

For PM and SO_2, there is no change in the reduction realized under this alternative since neither the fuel program nor the new PM standards are different than the proposal. However, if a new cost per ton estimate for the whole program were made for PM, the cost effectiveness would change since the total cost of the 15 ppm sulfur reduction (i.e., sulfur reduction to enable technology) would only be applied to PM. The new cost per ton estimate for PM under this alternative would be $11,000 (as compared to $9,300 under the proposal). Note that this $11,000 cost per ton represents a cost per ton for such a program, not an incremental cost per ton relative to the proposal. For SO_2, there would be no incremental cost per ton since both costs and SO_2 reductions would be equal to the proposal.

In summary, this alternative gives up substantial, feasible NOx reductions at $600 per ton in the same timeframe as our Tier 2 passenger car program (NOx+NMHC cost per ton >$2,000) and the HD 2007 program (>$2,000 per ton). As a PM and SO_2 program, this option is an attractive control option, although PM tons are more expensive than they are under the proposal.

12.5.5 Incremental Cost per Ton for Option 3

This option is basically the same as the proposal except that mining equipment >750 horsepower is exempted from all engine standards. As such, this option roughly estimates the per engine, or equipment, cost per ton for adding or subtracting mining equipment (we do not address here the legal basis, or lack of one, for this option). The cost savings realized for this approach include variable costs for engine hardware, and fixed and variable equipment costs for mining equipment. These savings assume that other nations would also adopt this approach, otherwise no savings would be realized for equipment fixed costs because one product would likely be made worldwide (the engine variable cost savings would still be realized). The savings also include less fuel consumed by these pieces of equipment because without the PM trap they would not incur the one percent fuel economy impact and no PM trap maintenance for these pieces of equipment.

Section 12.4.3.1 presented the incremental costs of this option as $80 million saved on fuel and other operating costs and $410 million saved on engine/equipment costs for a total increment of $490 million saved. However, these savings come at the expense of lower NOx+NMHC and lower PM reductions. Table 12.2.3-2 shows the foregone NOx+NMHC and PM reductions to be 751,000 and 30,000 tons, respectively. Assuming a perfect 50/50 split of costs for these pollutants results in an incremental cost per ton of PM lost of $8,300 an incremental cost per ton of NOx+NMHC lost of $300.

In summary, this alternative gives up substantial feasible and relatively inexpensive (compared to other mobile source programs) NOx+NMHC and PM tons.

12.5.6 Incremental Cost per Ton for Option 4

Option 4 leaves the engine program the same as the proposal but includes locomotive and marine fuel in the requirement for 15 ppm fuel. PM reductions are realized due to the reduced engine out sulfur to sulfate conversion from existing locomotive and marine engines. SO_2

reductions are realized due to the reduced engine out SO_2 from the fuel (98% of the fuel sulfur is exhausted from the engine as SO_2).

The incremental costs for this option were presented in section 12.4.3.2 as $1.8 billion for fuel and other operating costs with no costs for engines/equipment. The PM reductions gained are shown in Table 12.2.3-2 as 9,000 tons and the SO_2 reductions gained are shown as 114,000 tons. To estimate the cost per ton reduction for this alternative, one-third of the incremental 15 ppm fuel cost is attributed to PM with the balance being attributed to SO_2. The resulting incremental cost per ton for PM is $64,000 and the incremental cost per ton of SO_2 is $10,300.

In the absence of new engine standards enabled by the 15 ppm sulfur fuel (i.e., for locomotive and marine engines), the cost per ton of emissions reduction for this option does not look as favorable as some of the other options listed here. However, we would anticipate that a fuel program such as this would be done in conjunction with new technology forcing emission standards enabled by this clean fuel. In fact, as discussed in Section 6.C of the preamble, it is our intention to develop an Advanced Notice of Proposed Rulemaking (ANPRM) for such a control option in the near future. Were this option to include new the control technology enabled by 15 ppm sulfur fuel, we believe it is likely that the program would look very favorable. The cost per ton estimates for Option 3 would likely be a good surrogate for an estimation of such a program for locomotive and marine engines (i.e., the program would be very cost effective compared to other PM emission control programs).

12.5.7 Incremental Cost per Ton for Option 5a

This option is similar to the proposal except that no new standards would be implemented for <75 horsepower engines. In other words, engines <50 horsepower would remain at Tier 2 levels and 50 to 75 horsepower engines would remain at Tier 3 levels. As such, this option roughly estimates the per vehicle cost per ton for adding or subtracting the <75 horsepower elements of the engine program. The cost savings realized for this approach include variable costs for engine hardware and equipment hardware in the <75 horsepower category, and fixed costs for engine R&D, tooling, and certification, and equipment redesign in the <75 horsepower category. These savings assume that other nations would also adopt this approach, otherwise no savings would be realized for equipment fixed costs because one product would likely be made worldwide (the engine variable cost savings would still be realized). The savings also include less fuel consumed by 25 to 75 horsepower pieces of equipment because without the PM trap they would not incur the two percent fuel economy impact associated with the PM trap. Further, 25 to 75 horsepower pieces of equipment would not incur the PM trap related maintenance costs and all engines <75 horsepower would not incur the CCV maintenance costs because CCV systems would not be required.

Section 12.4.3.3 presented the incremental costs of this option as $530 million saved on fuel and other operating costs (i.e., lower operating costs) and $3.3 billion saved on engine/equipment costs for a total increment of $3.8 billion saved. However, these savings come at the expense of lower NOx+NMHC and lower PM reductions. Table 12.2.3-2 shows the foregone NOx+NMHC and PM reductions to be 334,000 and 209,000 tons, respectively. Attributing these costs to NOx+NMHC and PM according to the cost allocations shown in Table 8.1-2 results in an incremental cost per ton of PM lost of $16,500 and an incremental cost per ton of NOx+NMHC lost of $1,100.

In summary, this alternative gives up substantial feasible (compared to other mobile source programs) NOx+NMHC and PM tons.

12.5.8 Incremental Cost per Ton for Option 5b

This option is similar to the proposal except that the 2008 standards for <75 horsepower engines would remain in effect indefinitely and no new PM trap forcing standards would be implemented for 25 to 75 horsepower engines nor new EGR forcing NOx standards for 25 to 50 horsepower engines. As such, this option roughly estimates the per engine, or equipment, cost per ton for adding or subtracting the 2013 standards for 25 to 75 horsepower engines (we do not address here the legal basis, or lack of one, for this option). The cost savings realized for this approach include variable costs for engine hardware and equipment hardware associated with the 2013 standards, and fixed costs for engine R&D, tooling, and certification, and equipment redesign associated with the 2013 standards. These savings assume that other nations would also adopt this approach, otherwise no savings would be realized for equipment fixed costs because one product would likely be made worldwide (the engine variable cost savings would still be realized). The savings also include less fuel consumed by 25 to 75 horsepower pieces of equipment because without the PM trap they would not incur the two percent fuel economy impact associated with the PM trap. Further, 25 to 75 horsepower pieces of equipment would not incur the PM trap related maintenance costs.

Section 12.4.3.4 presented the incremental costs of this option as $490 million saved on fuel and other operating costs (i.e., lower operating costs) and $2.1 billion saved on engine/equipment costs for a total increment of $2.6 billion saved. However, these savings come at the expense of lower NOx+NMHC and lower PM reductions. Table 12.2.3-2 shows the foregone NOx+NMHC and PM reductions to be 333,000 and 121,000 tons, respectively. The foregone NOx+NMHC reduction relative to the proposal is almost identical for Option 5b as it was for Option 5a although it is slightly lower due to the NMHC reduction realized by the addition of DOCs under Option 5b that would not be realized under Option 5a. Attributing these costs to NOx+NMHC and PM according to the cost allocations shown in Table 8.1-2 results in an incremental cost per ton of PM lost of $18,300 an incremental cost per ton of NOx+NMHC lost of $1,100.

In summary, this alternative gives up substantial feasible (compared to other mobile source programs) NOx+NMHC and PM tons.

12.6 Summary and Assessment of Alternative Program Options

Having presented each of the alternative Program Options and their associated inventory impacts, benefits, costs, and cost-effectiveness in the preceding sections, we here provide a comparative summary of these Options and an assessment of the rationale, issues, and feasibility of each one.

12.6.1 Summary of Results of Options Analysis

As we developed the program we are proposing in today's Notice of Proposed Rulemaking, we evaluated a number of alternative Program Options with regard to the scope, level, and timing of the standards to ensure that we were looking at the full range of possible control options. Table 12.6.1-1 contains a summary of the alternative Program Options we considered and the expected emission reductions, costs, and monetized benefits associated with them in comparison to the proposal. These Program Options cover a broad range of possible approaches and serve to provide insight into the many other program design alternatives not expressly evaluated further.

While we are interested in comments on all of the alternatives presented, we are especially interested in comments on two alternative scenarios that we believe merit further consideration in developing the final rule; a primary one-step program (Option 1), and a requirement that the second step of sulfur control to 15 ppm in 2010 apply to locomotive and marine diesel fuel in addition to nonroad diesel fuel (Option 4).

Table 12.6.1-1
Summary of Alternative Program Options
(Incremental to the Proposal)

Option	Fuel Standards	Engine Standards	Estimated Relative Inventory Impacts[c] (NPV tons thru 2030; 3% discount)	Estimated Cost Impacts - $Billion (NPV thru 2030; 3%)	Estimated Benefits Stream - $Billion[e] (NPV thru 2030; 3%)
Proposal ***(inventory impacts, costs and benefits reported below for the options are compared to the proposal)***					
	• 500 PPM in 2007 for NR, loco/marine • 15 ppm in 2010 NR only	• >25 hp: PM AT introduced 2013 • >75 hp: NOx AT introduced and phased-in 2011-2013 • <25 hp: PM stds in 2008 • 25-75 hp: PM stds in 2008 (optional for 50-75 hp)	Relative to baseline: 1,126,000 PM 4,952,000 SO2 5,591,000 NOx+NMHC	$16.7	$550[b]
1-Step Fuel Options					
1	• 15 ppm in 2008 for NR only • 500 ppm in 2008 for loco/marine	• < 50 hp: PM stds only in 2009 • 25-75 hp: PM AT stds and EGR or equivalent NOx technology in 2013; no NOx AT • >75 hp: PM AT stds phasing in beginning in 2009; NOx AT phasing in beginning in 2011	6,000 PM -191,000 SO2 11,000 NOx+NMHC	$1.7[d]	$.2[b]
1a	• 15 ppm in 2008 for NR, loco/marine	• PM AT introduced in 2009-10 • NOx AT introduced in 2011-12	129,000 PM -63,000 SO2 1,843,000 NOx+NMHC	a	$59
1b	• 15 ppm in 2006 for NR, loco/marine	Same as 1a	a		
2-Step Fuel Options					
2a	Same as proposal except – • 500 ppm in 2006 for NR, loco/marine	Same as proposal	18,000 PM 228,000 SO2 0 NOx+NMHC	a	$7[b]
2b	Same as proposal except – • 15 ppm in 2009 for NR	Same as proposal except – • Move PM AT up 1 year for all engines > 25 hp (phase in starts 2010)	54,000 PM 17,000 SO2 36,000 NOx+NMHC	$1.2[d]	$16[b]
2c	Same as proposal except – • 15 ppm in 2009 for NR	Same as proposal except – • Move PM AT up 1 year for all engines 175-750 hp (phase in starts 2010)	20,000 PM 17,000 SO2 16,000 NOx+NMHC	$0.8[d]	$6[b]

Option	Fuel Standards	Engine Standards	Estimated Relative Inventory Impacts[c] (NPV tons thru 2030; 3% discount)	Estimated Cost Impacts - $Billion (NPV thru 2030; 3%)	Estimated Benefits Stream - $Billion[e] (NPV thru 2030; 3%)
2d	• Same as proposal	Same as proposal except – • Phase-in NOx AT for 25-75hp beginning in 2013	0 PM 0 SO2 751,000 NOx+NMHC	a	$10[b]
Other Options					
3	• Same as proposal	Same as proposal except – • Mining equipment over 750 hp left at Tier 2	-30,000 PM 0 SO2 -751,000 NOx+NMHC	-$0.5	-$18[b]
4	Same as proposal except – • loco/marine fuel to 15 ppm in 2010	Same as proposal	9,000 PM 114,000 SO2 0 NOx+NMHC	$1.8	$6[b]
5a	• Same as proposal	Same as proposal except- • No Tier 4 standards <75 hp	-209,000 PM 0 SO2 -334,000 NOx+NMHC	-$3.8	-$70
5b	• Same as proposal	Same as proposal except- • No new <75hp standards after 2008 (i.e., no CDPFs in 2013)	-121,000 PM 0 SO2 -333,000 NOx+NMHC	-$2.6	-$43

[a]Qualitative analysis only. Option is impractical due to infeasibility or other significant concerns. See the draft RIA for a detailed discussion
[b]By benefits transfer method
[c]Net Present (2004) Value impacts through 2030, using a 3% discount rate, relative to the proposed program. Positive values mean that the Option produces greater emission reductions from baseline than the proposed program.
[d]Cost estimates do not include the costs due to potential for limited product offerings and market disruptions in the engine/equipment and/or fuel markets. See Section V of this preamble and the draft FIA for a detailed discussion.
[e]Benefits do not include CO, VOC, air toxics, ozone, and PM welfare benefits. See Section V.F of this preamble and the draft RIA for additional discussion.

12.6.2 Discussion of Rationale, Issues, and Feasibility Assessment of Options

Each of the Program Options defined and presented in Section 12.1 is discussed here in terms of the rationale for considering the option, issues surrounding the option, and our assessment of the feasibility of the option. Inventory impacts for each option are presented in Section 12.2, health and environmental benefit comparisons are presented in Section 12.3, and comparative cost and cost-effectiveness for these Program Options is presented in Sections 12.4 and 12.5, respectively.

12.6.2.1 One-Step Options

12.6.2.1.1 Option 1

In defining Option 1 we focused on designing a program with long-term engine standard levels identical to those being proposed, implemented as early as possible under a one-step approach to nonroad fuel desulfurization, and structured such that both engine and fuel requirements and timing would have a high likelihood of being technologically feasible. In doing so, we recognized the need to account for a number of factors:

- The need for 15 ppm maximum sulfur nonroad diesel fuel to enable highly-sulfur sensitive emission control technology on nonroad engines,
- The need to coordinate refinery investments to desulfurize nonroad diesel fuel with similar efforts already mandated for this industry for highway diesel fuel and gasoline in the same general timeframe,
- The need to provide adequate lead time for the migration of relevant emission control technologies from the highway sector,
- The need to provide adequate stability periods for Tier 3 standards and for Tier 2 standards for engines under 50 hp, and
- The workload of engine and equipment manufacturers in preparing hundreds of engine models and thousands of machine models for Tier 4 compliance.

The resulting Option 1 program design is reflected in Figure 12.1.1-1. The one-step fuel change occurs in 2008. This is one year later than the proposal's first step, but it provides 15 ppm maximum sulfur nonroad diesel fuel two years earlier than the proposal's second step does. In Option 1, locomotive and marine diesel fuel is desulfurized to 500 ppm in 2008 as well, one year later than under the proposal.

These fuel program differences yield both positive and negative impacts on relative emissions reductions. Early sulfate PM reductions in the existing fleet would be delayed a year such that no PM reductions would occur in 2007. The Tier 4 PM standard for <25 hp engines and the transitional PM standard for 25-50 hp engines would both be delayed a year to 2009, and the transitional PM standard for 50-75 hp engines would be eliminated. These differences come about because these PM standards depend on the availability of nonroad diesel fuel with sulfur levels below 500 ppm, which under the one-step fuel option does not happen until the shift to 15 ppm fuel in 2008. This delays any potential PM standards to 2009 at earliest and, in the case of 50-75 hp engines which have new Tier 3 standards taking effect in 2008, makes it unworkable to adopt the transitional standard at all because these engines (and the machines using them) would need to be redesigned for new emission standards in 2008, again in 2009, and yet again in 2013, as discussed below. Even we were to have the transitional standard take effect in 2010 or 2011 instead of 2009 in order to pace the redesign process more evenly, these rapid redesigns would likely be unacceptably costly.

The most important impact of this Option 1 fuel regulation schedule is the potential for high-efficiency exhaust emission control to occur as early as the 2009 model year. Even accounting for the other factors listed above, such as the need to provide adequate lead time for the migration of relevant emission control technologies from the highway sector, PM filters can be introduced earlier on a large segment of nonroad diesel engines under Option 1. Our consideration of these factors in setting a NOx standard schedule, particularly the need for technology migration lead time, leads us to conclude, however, that the earlier availability of 15 ppm sulfur fuel would not lead to earlier implementation of NOx adsorber technology. The completion of the NOx technology phase-in for the highway sector will occur in 2010. We believe that 2011 would remain as the earliest model year that this technology could begin to phase into the nonroad diesel sector, as proposed.

Although earlier introduction of PM filter technology is made possible by the earlier availability of enabling fuel, the need for adequate lead time to transfer PM filter technology from the highway sector to the wide variety of nonroad diesel applications, and the need for a coordinated PM/NOx phase-in to avoid large and costly redesign workload burdens, result in a somewhat complex phase-in schedule for Option 1. (For analysis of an option that does not take much account of this constraint, see section 12.6.2.1.2 on Option 1a below.) Specifically, we would phase in standards as indicated in Figure 12.1.1-1. Engines in the 175-750 hp category would be subject to the 0.01 g/bhp-hr PM filter-based standard in 2009, when the regulated fuel becomes available, but only for 50% of a manufacturer's U.S.-directed production. The other 50% would meet this PM standard beginning in 2011, concurrent with initiation of the 0.30 g/bhp-hr NOx adsorber-based standard for 50% of production. This makes it possible to optimize the PM filter technology transfer process by focusing on the most "highway-like" engine platforms in this power category first, and also to reduce the engineering workload by redesigning many engine families, comprising half of production, to meet PM and NOx standards simultaneously in the 2011 model year. The NOx phase-in would then be completed in 2014, as under the proposal, allowing five years of stability for the 50% of production redesigned for PM control in 2009 before the redesign for NOx in 2014. All in all, this approach increases the opportunity for a manufacturer to coordinate product redesign strategies for new standards with product redesign cycles driven by marketing and other concerns, while still achieving substantial PM filter introduction in 2009.

The phase-in for engines in the 75-175 hp category would follow the same pattern, but one year later, to account for the need to spread the workload, and also to provide additional time to transfer highway technology to engines in this category, as is done under the proposal and in past tiers of standards. Note that this approach to phasing in standards helps to optimize the redesign strategies to reduce workload burden, but not as well as under the proposal. It also does not fully mitigate concerns over shortened Tier 3 stability periods under Option 1, reduced to two years for some engines (50% of 75-100 hp engines).

For engines over 750 hp, we have retained the proposal's 50% phase-in approach in 2011-2013. We believe that decoupling the PM and NOx phase-in for this category by implementing the PM standard one or two years earlier could potentially create severe problems. These engines typically are used in low sales volume machines that have long normal product cycles. Early PM control would not only result in two Tier 4 redesigns steps for some of these engines and machines, but would also shorten the Tier 2 stability period.

The implementation issue is somewhat simpler for engines below 75 hp because of the lack of NOx-adsorber based standards. For the engines below 25 hp it is simplified even further by the lack of PM filter-based standards. These would be subject to a non-PM filter-based standard in 2009, when the regulated fuel becomes available. (See Section 4.1.1 for a discussion of how fuel sulfur degrades the efficiency of diesel oxidation catalysts used for PM control.) We believe that PM filter technology for 25-75 hp engines is constrained primarily by highway technology transfer considerations, and thus would be implemented in Option 1 in 2013 as under the proposal. This is late enough that it would still make sense under Option 1 to adopt transitional PM standards as in the proposal, even with the one-year delay to 2009 caused by the delay in fuel regulation. However, transitional standards would not be applied under this option to the 50-75 hp engines in this category because of the conflict with Tier 3 timing discussed above.

12.6.2.1.2 Option 1a

The analysis for Option 1a shows what added environmental benefits would be possible under a very aggressive approach to engine standard-setting, compared to the proposal and to the more technologically feasible Option 1. On the fuel side, Option 1a would go further than the proposal and Option 1 by regulating locomotive and marine diesel fuel to the 15 ppm maximum sulfur level along with other nonroad diesel fuel in 2008. Issues associated with regulating locomotive and marine fuel to 15 ppm sulfur are discussed in section 12.6.2.2.8. Otherwise the approach to fuel regulation is identical to that taken in Option 1.

The Option 1a approach to engine standards applies the 0.01 g/bhp-hr PM standard to engines of all sizes: in 2009 for engines >175 hp and in 2010 for engines <175 hp. This is 2-5 years earlier than under the proposal for engines above 75 hp. For 25-75 hp engines, it is three years earlier and at a 50% lower emission level (0.01 compared to 0.02 g/bhp-hr), but without the proposed 2008 transitional PM standard that is tied to regulating fuel in two steps. For engines

<25 hp, the Option 1a approach to PM standard-setting is two years later than the proposed Tier 4 standard but at a PM filter-based level 97% lower than the proposed 0.30 g/hp-hr level. Although Option 1a's two-year phase-in of the PM standard in 2009-2010 follows the logic that fuel desulfurization must precede the application of PM filters, and directionally addresses the critical workload and technology transfer issues detailed in section III of the proposal, we do not believe that this analytical option is technologically feasible with respect to PM standard-setting, for reasons discussed in Chapter 4 and in section III of the preamble to the proposal.

For NOx control, Option 1a applies a similar 2-year phase-in: in 2011 for engines >175 hp and in 2012 for engines <175 hp. These later NOx start dates compared to those of the Option 1a PM standards directionally reflect the need for additional development time after similar standards fully phase in for heavy-duty highway diesel engines in 2010, in order to transfer this technology to nonroad applications. This phase-in of NOx standards results in an Option 1a Tier 4 program with NOx adsorber-based standards fully phased in three years earlier than under the proposal for engines >175 hp, and two years earlier than under the proposal for 75-175 hp engines, although for all of these engines >75 hp, the proposal begins phasing in the NOx standard (at a 50% of sales level) in the same year that Option 1a begins its NOx control requirement (at 100%). For engines <75 hp, Option 1a's 0.30 g/bhp-hr NOx standard would yield over 90% better NOx control than the non-NOx adsorber-based standards under the proposal. As concluded above for PM control, however, we do not believe that this analytical option is technologically feasible with respect to NOx standards-setting, for reasons discussed in Chapter 4 and in section III of the preamble to the proposal.

One additional major complication created by Option 1a's focus on getting PM control as early as possible is the very large additional workload, especially for equipment manufacturers, created by having two major Tier 4 redesign steps coming two years apart for every engine, first for PM in 2009-2010, and then for NOx in 2011-2012. Moreover, these major redesigns follow quite closely on the major engine and equipment redesign effort in 2006-2008 for Tier 3 (and Tier 2 for engines >750 hp), with Tier 3 stability periods as short as 2 years for many engines. Stability periods this short would be unprecedented in EPA mobile source programs for technology-forcing standards such as those required by Tier 3 and the proposed Tier 4. Furthermore, the Option 1a approach would result in an overlap of implementation schedules for nonroad Tier 4 standards and the highway HDDE emission control program that phases in over 2007-2010. A number of engine manufacturers participate in both markets, and thus would likely be certifying and marketing new highway engines in 2009 and 2010, concurrent with the turnover of their entire nonroad engine product line to meet the new nonroad diesel PM standard in the same years. This could put a serious strain on their engineering resources and add to the cost of the program, potentially to the extent of making the program infeasible.

Based on the above discussion and the analyses performed for this option described in this Chapter, we conclude that Option 1a would not be appropriate for proposal. In particular, we do not believe that the set of engine standards under Option 1a would be technologically feasible.

12.6.2.1.3 Option 1b

This alternative, a variation of Option 1a, would implement a 15 ppm sulfur cap for all nonroad, locomotive, and marine diesel fuel starting on June 1, 2006 for refiners and importers. The rationale behind doing so would be to move up the program for NRLM fuel to coincide with the initial implementation of the 15 ppm cap for highway diesel fuel. The engine standards would be unchanged in comparison to Option 1a. They would still be initiated starting with the 2009 model year for PM and 2011 model year for NOx. Thus, this alternative, relative to Option 1a, would be a pure fuel program, moving up the 15 ppm sulfur standard by two years.

We have examined this alternative from a number of angles relative to the proposal and Option 1a:

1) The need for further sulfur dioxide and PM emission reductions in this timeframe,
2) Its impact on the desulfurization technology used to meet the 15 and 500 ppm caps,
3) The leadtime available for refiners to meet the 15 and 500 ppm standards in 2006,
4) The impact on the supply of highway diesel fuel, and
5) The potential cost-effectiveness and cost-benefit of the additional sulfur control.

Because this option only affects fuel sulfur content and not engine emission standards, the only air quality benefits are reduced sulfur dioxide and sulfate PM emissions. The need for these reductions is just as great in 2006-7 as they are in the 2008-2010 timeframe. As outlined in Chapter 2, ambient fine PM levels are currently above the NAAQS for fine PM. Ambient fine PM levels in 2006-2007 are more likely to be near current levels than those in 2008-2010, given that less time is available for current emission controls, like the 2007 highway diesel program, to take effect. Thus, moving up the 15 ppm standard should be considered for its air quality impacts. These emission reductions and their resulting benefits are shown in Sections 12.2.2 and 12.3, respectively.

However, a 2006 implementation date for a 15 ppm sulfur cap on all NRLM fuel does not appear to allow sufficient leadtime for refiners to design and construct new desulfurization equipment. Leadtime for the proposed 2007 500 ppm NRLM diesel fuel cap was evaluated in Chapter 5.3. There it was determined that refiners needed 2.25-3.25 years after the final rule in order to design and construct new hydrotreaters to produce 500 ppm fuel. This analysis considered the fact that the 500 ppm cap could be met using well established, conventional hydrotreating technology. More time would be required to design and construct equipment to produce 15 ppm nonroad diesel fuel. Even ignoring this additional time, a 2006 implementation date would only allow refiners facing the minimum required leadtime enough time to meet the one-step fuel standards. A 2006 implementation date would allow no time for the generation of early sulfur reduction credits which might allow some refiners additional time to meet the one-step fuel standards. Also, it is difficult to project that any refiners would be able to meet these standards early even if the program granted such credits. Thus, we must conclude that the 2006 one-step option would not be technically feasible due to insufficient leadtime for refiners and importers to meet the 2006 fuel sulfur standards. For this reason, we were unable to develop any reliable cost estimates for this option.

In addition to leadtime concerns, applying a 15 ppm sulfur cap for NRLM diesel fuel in 2006 to coincide with the implementation of the highway diesel fuel program would raise workload concerns for the industry, impacting not only the successful implementation of this rulemaking, but also the highway rule. A 15 ppm cap on NRLM fuel in 2006 could have seriously adverse consequences on the supply of highway diesel fuel and thus, the successful implementation of the 2007 highway diesel fuel program. We added the temporary compliance option to the 2007 highway diesel fuel program to ease implementation in 2006 and assure sufficient supply of highway diesel fuel. The temporary compliance option allows 20% of highway diesel fuel to remain at 500 ppm until 2010. Starting a 15 ppm NRLM cap in 2006 would essentially negate the benefit of the temporary compliance option, as the volume of high sulfur nonroad diesel fuel is roughly 15% of highway diesel fuel volume. We have not evaluated the degree that highway fuel supply would be negatively impacted, however, the impact would be directionally negative.

Since this option is not feasible, we were not able to derive costs, and therefore cost per ton or cost/benefit values that correspond to it. However, under the hypothetical where leadtime was not a constraint on feasibility, we can still provide some general assessments. Applying a 15 ppm cap in 2006 for all NRLM fuel would reduce refiners' ability to utilize lower cost, advanced desulfurization technologies to meet the 15 ppm nonroad diesel fuel sulfur cap. This is discussed in Chapters 5 and 7 above. In 2006, we would project that few if any refiners would utilize advanced technologies. This would increase the cost of 15 ppm fuel by roughly 10% compared to Option 1 where 40% of refiners are estimated to be able to take advantage of these technologies and more than 20% in comparison to today's proposal. This impact on cost would last for roughly 15 years, or as long as this equipment was in use. Other than this increase in costs, the incremental cost effectiveness and cost-benefit ratio would be expected to be of a similar magnitude to that for option 4 as discussed in chapter 12.6.2.2.8 below. Thus, a rough estimate suggests that if this option were feasible, the benefits would still be substantial and costs would be reasonable, but not nearly as well as is true for the proposal or a long term 500 ppm cap.

12.6.2.2 Two-Step Options

12.6.2.2.1 Proposed Program

The proposed program is included in this Chapter for the purpose of comparison with the alternative regulatory options analyzed. We believe it to be a feasible program that meets the Agency's requirements under the Clean Air Act. The proposed program is described in detail in the preamble to the proposal and the feasibility of the proposed engine and fuel requirements is discussed in detail in Chapters 4 and 5 of the draft RIA.

12.6.2.2.2 Option 2a

This alternative would move up the 500 ppm sulfur cap for NRLM diesel fuel one year, to June 1, 2006 for refiners and importers. The rationale behind doing so would be to move up the 500 ppm cap for NRLM diesel fuel to coincide with the initial implementation of the 15 ppm cap for highway diesel fuel. The aftertreatment-based engine PM emission standards would not be moved up. They would still be initiated starting with the 2011 model year. Thus, this alternative, relative to the proposal, would be a pure fuel program, moving up the 500 ppm fuel controls of the proposal by one year.

We have examined this alternative from a number of angles relative to the proposal:

1) The need for further sulfur dioxide and PM emission reductions in this timeframe,
2) Its impact on the desulfurization technology used to meet the 15 and 500 ppm caps,
3) The leadtime available for refiners to meet the 15 and 500 ppm standards in 2006,
4) The impact on the supply of highway diesel fuel, and
5) The potential cost-effectiveness and cost-benefit of the additional sulfur control.

Because this option only affects fuel sulfur content and not engine emission standards, the only air quality benefits are reductions of sulfur dioxide and sulfate PM emissions. The need for these reductions should be just as great in 2006 as they are in the 2007-2010 timeframe. As outlined in Chapter 2, ambient fine PM levels are currently above the NAAQS for fine PM in many areas of the country. Ambient fine PM levels in 2006 are more likely to be near current levels than those in 2007-2010, given that less time is available for current emission controls, like the 2007 highway diesel program, to take effect. Thus, moving up the 500 ppm cap should be considered for its direct air quality impacts. These emission reductions and their resulting health and welfare benefits are shown in Section 12.2 and 12.3, respectively.

Applying the 500 ppm cap in 2006 as opposed to 2007 should have little impact on the refining technology used. In Chapter 5, we project that conventional hydrotreating technology which has been used for over 10 years to produce 500 ppm diesel fuel would be used by refiners to meet a 500 ppm cap in 2007. This would also be the case for a 2006 standard, if refiners had sufficient time to build new equipment.

However, a 2006 implementation date for the 500 ppm NRLM sulfur cap does not appear to allow sufficient leadtime for refiners to design and construct new desulfurization equipment. Leadtime for the proposed 2007 500 ppm NRLM diesel fuel cap was evaluated in Chapter 5.3. There it was determined that refiners needed 2.25-3.25 years after the final rule in order to design and construct new hydrotreaters to produce 500 ppm fuel. A 2006 implementation date would only allow refiners facing the minimum required leadtime enough time to comply. A 2006 implementation date would allow no time for the generation of early sulfur reduction credits which might allow some refiners additional time to meet the two-step fuel standards. Also, it is difficult to project that any refiners would be able to meet these standards early even if the program granted such credits. Thus, we must conclude that the 2006 two-step option would not be technically feasible due to insufficient leadtime for refiners and importers to meet the 2006 fuel sulfur standards. For this reason, we were unable to develop any reliable cost estimates for this option.

In addition to leadtime concerns, as with Option 1b, moving up the 500 ppm standard to coincide with the implementation of the highway diesel fuel program would also raise workload concerns for the industry impacting not only the successful implementation of this rulemaking, but also the highway rule. A 500 ppm standard in 2006 could have an adverse impact on the supply of highway diesel fuel and thus, the successful implementation of the 2007 highway diesel fuel program. We added the temporary compliance option to the 2007 highway diesel fuel program to ease implementation in 2006 and assure sufficient supply of highway diesel fuel. The temporary compliance option allows 20% of highway diesel fuel to remain at 500 ppm until 2010. Starting the 500 ppm NRLM cap in 2006 would increase the strain on the design and construction industries, as not only the 2007 highway diesel fuel program, but also the Tier 2 gasoline program are being implemented in the same timeframe. It would also increase the amount of capital which would need to be raised by the refining industry. We have not evaluated the degree that highway fuel supply would be negatively impacted. However, the impact would be directionally negative.

Since this option is not feasible, we were not able to derive costs, and therefore cost per ton or cost/benefit values that correspond to it. However, were more time given prior to implementation of the 500 ppm cap, such that leadtime was no longer a constraint on feasibility, the option essentially turns into the proposed requirement for 500 ppm beginning June 1, 2007 (with its associated costs, emission reductions, and benefits).

12.6.2.2.3 Option 2b

Compared to the proposal, Option 2b pulls the 15 ppm maximum sulfur fuel requirement forward by one year to 2009. It also pulls all of the PM filter-based PM standards forward by one year to take advantage of the earlier fuel availability.

Moving up the 15 ppm standard for nonroad diesel fuel by one year would increase refining costs two ways. One, it would increase the cost of nonroad diesel fuel produced between June 1, 2009 and June 1, 2010 by 2.4 cents per gallon (from the 2.2 cent per gallon cost of 500 ppm nonroad diesel fuel to the 4.6 cent per gallon cost of 15 ppm nonroad diesel fuel in 2009). (See Table 12.4.2.3.1-1 above.) Two, it would increase the cost of nonroad diesel fuel produced after June 1, 2010 by 0.2 cents per gallon, as the cost of producing 15 ppm nonroad diesel fuel would be 4.4 cents per gallon for the proposed implementation date of June 1, 2010.

Moving up the 15 ppm standard for nonroad diesel fuel by one year would also make the nonroad diesel fuel sulfur program more stringent than the highway diesel fuel sulfur program, which does not require 100% of highway diesel fuel to meet a 15 ppm cap until June 1, 2010.

Some of the synergies obtained by the proposed program would also be lost. Roughly 20 refineries are projected to start producing both 15 ppm highway diesel fuel and 15 ppm nonroad diesel fuel in 2010. Requiring the production of 15 ppm nonroad diesel fuel at the same time that the last 20% of highway diesel fuel must meet this standard would allow these two projects to be fully coordinated, if not become a single project. Also, the three year interval between the proposed 500 ppm and 15 ppm caps for nonroad diesel fuel is roughly equal to the life of a desulfurization catalyst. Thus, many refiners would be bringing their 500 ppm desulfurization unit down for catalyst replacement right about the time that the additional equipment needed to meet the 15 ppm cap would need to be tied in. Implementing the 15 ppm cap one year earlier would require refiners to either replace their existing catalyst earlier than necessary or bring the unit down the next year again for another catalyst replacement.

In addition, Option 2b would involve a number of engine program considerations beyond those analyzed for the proposed program. The primary effect of the pull-forward of PM control is, of course, one-year earlier PM reductions. Over the very long-term the emissions impacts of phase-in schedule differences diminish to zero, but during the phase-in years and shortly thereafter, the differences can be substantial, given the over 90% PM reduction achieved by each new engine entering the fleet meeting the proposed Tier 4 standard. Section 12.2 analyses these impacts in detail.

The one-year pull-forward of PM standards would decouple PM and NOx control for many engines. Engines <25 hp would be unaffected because there are no PM filter-based standards for them. However, 25-50 hp engines would require redesign for PM control in 2012 and redesign for NOx control in 2013. This could create substantial increases in engineering workload for both engine and equipment manufacturers attempting to carry out the double redesign for two consecutive model years. This increase might conceivably be mitigated somewhat by coordinated advance planning, such as by engine manufacturers anticipating NOx-based changes to their engines and exhaust systems (NOx/PM exhaust emission control device canning dimensions, for example), and providing these specifications to their equipment manufacturer customers a year before those changes are actually made to allow for a single machine redesign effort. Given the large impacts that even modest standards changes have had on equipment designs in Tier 2, and the difficulty some engine manufacturers have had in providing their customers with design specifications and prototypes very far ahead of time, it is not clear that such pre-planning would be very effective.

Like engines <25 hp, engines in the 50-75 hp range would not experience a PM/NOx standard decoupling under Option 2b because we are not proposing to change the NOx+NMHC standard from the 2008 Tier 3 standard level for these engines. Engines above 75 hp would experience this decoupling, however. For 75-175 hp engines, PM filters would be applied in 2011, and NOx adsorbers would begin to phase in in 2012. For 175-750 hp engines, PM filters would be applied in 2010, and NOx adsorbers would begin to phase in in 2011. For engines >750 hp, PM filters would be applied to 50% of engines in 2010. In 2011 and 2012, a recoupled NOx/PM redesign strategy could be pursued with 50% of engines requiring both NOx and PM

Tier 4 controls. However, the standards would then be decoupled again as the remaining 50% of engines are fitted with PM filters in 2013, and then NOx adsorbers in 2014. As for 25-50 hp engines, some comprehensive pre-planning could help mitigate the costs of decoupling, but past experience makes it doubtful that much of this could be assumed. All in all, Option 2b is likely to result in a large increase in engineering workload for engine and equipment manufacturers.

In addition, earlier long-term PM standards would shorten the stability periods for previous standards accordingly. The 0.22 g/bhp-hr transitional PM standard for 25-75 hp engines would be in effect for only four model years, 2008-2011, instead of five. Likewise, previous-tier standards for >75 hp engines would be in effect for three or four years, depending on engine size. These shortened stability periods may not directly impact the feasibility of standards, but would certainly have an adverse impact on manufacturers' ability to accomplish all required redesigns without increasing engineering staffs and would also reduce the number of years available to recover fixed costs.

We have not done a detailed analysis of the technological feasibility of PM filter application one year earlier than under the proposal. The earliest Option 2b application date, 2010 for engines above 175 hp, is three years after similar technologies will be required for HDDEs. Although we believe that this is likely to provide adequate lead time to accomplish the transfer of this technology to some nonroad diesel applications, it is not clear that this could be accomplished for 100% of the 175-750 hp nonroad engines and 50% of the >750 hp engines by 2010, and for all other nonroad diesel engines above 25 hp shortly after this. Even with engine platforms on which this accelerated schedule could be accomplished, we would anticipate costs to rise due to the shortened opportunity for learning from highway experience and the resulting need for basic R&D to develop PM control technology directly in the nonroad sector.

Finally, we expect that under Option 2b, the technology review for engines under 75 hp, discussed in section III.G of the proposal, would need to occur in 2006 rather than 2007, to allow adequate lead time should program adjustments be deemed appropriate. Given the large experience base expected to accumulate during 2007 as highway engines equipped with advanced PM and NOx emissions controls take to the road in large numbers, the one-year earlier review schedule would be unfortunate.

Based on the above discussion and the analyses performed for this option described in this Chapter, we conclude that Option 2b would not be appropriate for proposal. In particular we see the large increase in engine and equipment manufacturers' workload for redesign, the shortened stability periods for previous-tier standards, and the need for additional R&D expenditures for some degree of parallel nonroad/highway emission control development work, as large potential barriers to implementing this option.

12.6.2.2.4 Option 2c

Option 2c is very similar to Option 2b except that PM filter-based standards would be pulled forward by one year only for 175-750 hp engines. All points of the above discussion on Option 2b are relevant here except of course that discussion points specific to <175 hp and >750 hp engines would not apply. Engines in the 175-750 hp category comprise a large segment of the emissions inventory, of the engine families, and of the total U.S. nonroad engine sales. As a result the environmental impact of Option 2c, though not as large as that of Option 2b, is substantial compared to the proposed program, especially in the early years of Tier 4. Likewise, the adverse impacts of the Option 2c PM pull-forward on the engine and equipment manufacturing industries would be large, though more focused on those manufacturers with products in this power range. This is significant because there are many manufacturers who do not offer products in this range and so would be affected only indirectly. Some of these might benefit by the added year of experience gained from the use of PM filters on 175-750 hp engines before PM filters are required on their own products. On the other hand, manufacturers who do not have ready access to this experience base may find themselves at a disadvantage compared to their better-connected competitors.

Although these considerations may be significant, we do not see them as critical to the feasibility and cost impacts of Option 2c. Instead, we believe the primary engine and equipment issues involved in Option 2c are the above-discussed engineering workload impacts caused by the decoupling of PM and NOx standards for 175-750 hp engines, the shortened stability periods for the Tier 3 standards, and the possible feasibility concerns raised by shortened lead time available for transferring technology from the highway sector.

Based on the above discussion and the analyses performed for this option described in this Chapter, we conclude that Option 2c would not be appropriate for proposal, for the same key reasons described above for Option 2b, though to a lesser degree and with a corresponding lesser emission benefit.

12.6.2.2.5 Option 2d

The proposed program does not apply the NOx adsorber-based 0.30 g/bhp-hr NOx standard to engines below 75 hp for reasons explained in Chapter 4 and in section III of the preamble to the proposal. The Option 2d analysis evaluates the environmental and cost impact of applying this standard to 25-75 hp engines, phased in at 50-50-50-100% over 2013-2016, similar to the NOx phase-in approach taken for larger engines, though on a later schedule. Although we do not believe this approach to be appropriate at this time, we have included this matter in the proposed 2007 technology review as discussed in section III.G of the preamble.

The 25-75 hp category comprises a large and growing segment of the nonroad diesel engine population. Although on a per-engine basis these engines typically emit far less NOx over their lifetime than larger engines, they make up a significant NOx source category, as can be seen in comparing the NOx inventory for Option 2d with that for the proposal (see section 12.2). In addition to the NOx reductions, the application of NOx adsorbers to 25-75 hp engines would recover some of the fuel economy impact due to use of actively-regenerated PM filters on these engines.

The application of NOx adsorbers to 25-75 hp engines would add a sizeable cost to these engines. However, we would not expect the added cost for advanced NOx control to include the cost of modifying the engines themselves to accommodate NOx adsorbers (e.g., electronic common rail fuel systems) because these costs would likely be incurred in meeting our proposed 0.02 g/bhp-hr Tier 4 PM standard, as discussed in Chapter 6. Although under Option 2d the 0.30 g/bhp-hr NOx standard for 25-75 hp engines in 2013 would replace the proposed 3.5 g/bhp-hr NOx+NMHC Tier 4 standard in the same year, the cost of meeting the 3.5 g standard (via EGR or equivalent technology) would not be eliminated, because engine-out emissions performance on this order or better must be achieved to meet the 0.30 g standard employing NOx adsorbers with control efficiencies on the order of 90%. (In fact the 50-75 hp engines must meet this 3.5 g standard in 2008 under Tier 3 requirements.)

The Option 2d program would establish a Tier 4 program implementation schedule that stretches out to 2016, well over a decade from today. Although in principle we support the aim of the industries we regulate to have long-term regulatory certainty and stability, we must balance this with the fact that our understanding of how diesel pollution impacts human health and the environment is the subject of numerous ongoing studies and so is likely to develop and evolve over the next few years, and also with the likelihood that the rapid pace of emission control technology development (often with unexpected innovations along the way) will likewise continue to advance in the years ahead. Standard-setting in this rulemaking with 2016 implementation dates may be inadvisable, and better taken up in the 2007 technology review planned in the proposal.

Based on the above discussion and the analyses performed for this option described in this Chapter, as well as the present concerns with technological feasibility voiced in Chapter 4 of this draft RIA and in Chapter III of the preamble, we conclude that Option 2d would not be appropriate for proposal.

12.6.2.2.6 Option 2e

The Option 2e program is identical to the proposal except that no new NOx standards would be set in Tier 4. Any changes in NOx control from these engines would be incidental, resulting from adoption of the test procedure changes for the Tier 4 PM control program. This analytical option obviously presumes that Tier 4 nonroad diesel NOx control would either not be needed to address air quality concerns or would not be feasible (presumptions we believe are unfounded). These issues are discussed in detail in Chapters 2 and 4 of this draft RIA, and in sections II and III of the preamble to the proposal.

We have assumed no changes to the proposed fuel program in analyzing Option 2e because the proposed fuel desulfurization, though critical to enabling high-efficiency NOx exhaust emission control, is also needed to enable PM filter technology as explained in section III.F of the proposal preamble. The first step in the two-step fuel desulfurization proposal is also primarily a PM-focused action. Finally, the fact that we are proposing PM filter-based standards before or coincident with Tier 4 NOx standards in all relevant power categories, means that the timing of fuel changes under a PM-only option would be unchanged from the proposal.

As discussed in Chapter 4, diesel PM filters can be designed to operate effectively with or without the application of NOx adsorbers in the exhaust stream. In fact under the proposal, some engines are expected to employ PM filters without NOx adsorbers for phase-in model years or, for 25-75 hp engines, for all Tier 4 model years. There are economies of integration available to engine designers working to both the PM and NOx control objectives, such as from combining PM and NOx control functions into a single can or even into integrated internal structures, but even so we would expect that PM-only systems would cost significantly less than combined systems. Some engine designs that do not currently employ sophisticated fuel injection controls could conceivably continue without these under a PM-only option, but we believe that the need for active regeneration of PM filters in many nonroad applications, combined with the growing trend toward application of electronic controls for performance reasons or to meet Tier 2/Tier 3 standards, would tend to mitigate this opportunity. Equipment designers would likely see no or only modest cost advantages to PM-only systems beyond the NOx control hardware itself because the Tier 4 program is structured to minimize multiple Tier 4 redesigns as much as possible, and the likelihood of integrated NOx/PM exhaust emission controls reduces the need for additional brackets and the like.

A PM-only program would be expected to result in added operating costs compared to the proposed program due to the increased fuel consumption of PM filter-equipped engines, not offset by the fuel economy gains of NOx adsorber systems. This matter is discussed in detail in Chapter 6.

We believe that Option 2e would be highly inappropriate. In particular, we believe that a lack of new NOx standards in Tier 4 would fail to adequately address the serious air quality concerns discussed in Chapter 2, and to meet our obligations under section 213(a)(3) of the Clean Air Act which requires the Agency to develop standards reflecting the greatest emission reductions feasible, taking cost, noise and safety concerns into consideration. In doing so, consideration of cost is to be a subordinate consideration, unless costs are somehow exorbitant. See, e.g. <u>Husqvarna AB v. EPA</u>, 254 F. 3d 195, 200 (D.C. Cir. 2001); <u>Lignite Energy Council v. EPA</u>, 198 F. 3d 930, 933 (D.C. Cir. 1999). Here, very substantial NOx reductions – on the order of millions of tons – are technically feasible. The costs of achieving these reductions is not exorbitant. Moreover, the Tier 4 proposal would set stringent PM standards to be implemented in the 2011-2014 timeframe, followed by some period of stability before any new standards beyond Tier 4 would take effect, if found appropriate. Not including new NOx standards in this same timeframe would leave the nonroad diesel sector as a dominant source of NOx emissions for many years to come, at a time when other NOx source categories would have finished implementing stringent measures to deal with NOx-related air quality problems.

12.6.2.2.7 Option 3

As described in section 12.1.2 of this chapter, Option 3 is an exemption from regulation in this rule for very high power engines (>750 hp) used in above-ground mining equipment (AGME). Some have expressed the view that the very large off-highway trucks and earth movers, over 750 hp, used in above-ground mine and quarry operations may constitute a special case worthy of special consideration because of a number of factors:

- They operate remote from populated areas;
- They have very low annual sales volumes and therefore high redesign costs;
- They are used in extreme conditions where aftertreatment will not be durable.

However, the above concerns with applying Tier 4 standards to > 750 hp AGME engines must be balanced with the emissions contribution and the health and welfare concerns from the engines, as well as EPA's assessment that Tier 4 standards for the >750 hp engines used in AGME are technologically feasible and otherwise appropriate under the Clean Air Act. It thus appears that any such exemption would lack a convincing legal rationale, given that mining engines have already been held to be properly subject to regulation under section 213, see Engine Manufacturers Ass'n v. EPA, 88 F. 3d 1075, 1098 (D.C. Cir. 1996) and, as explained below, further reductions in PM and NOx emissions from these engines is technically feasible at reasonable cost.

Large nonroad mining equipment is used in many areas spread across the United States. It is often assumed that the very large AGME is concentrated in western states. Information provided to EPA by a nonroad equipment manufacturer who participates in the >750 hp mining equipment market indicates that in the past decade the western states (not including the west coast states) account for nearly 30 percent of the >750 hp AGME sales. However, the eastern US also has a high share of >750 hp mining equipment. Information provided to EPA by a nonroad equipment manufacturer who participates in the >750 hp mining equipment market indicates that in the past decade, more than 40 percent of the >750 hp equipment was sold to the states in the Ohio River valley. Considering the concentration of coal mining in these states the high use of these large machines in the Ohio River valley should not be suprising.[5]

In general, it is reasonable to project that most above-ground mines are not located in urban areas. However, pollution problems such as ozone and haze are not local but regional problems due to the long-range transport of emissions. In addition, mines are not always in remote rural areas but are some times in or near urban areas. In connection with our original nonroad engine rulemaking in 1994, the American Mining Congress submitted as part of its public comment a report from the TRC Environmental Corporation which states that 40 mine sites are located in ozone nonattainment areas.[6] See Engine Manufacturers Ass'n v. EPA, 88 F.

3d at 1098 (national regulation of nonroad engines used in above-ground mining is justified under section 213 because some of those engines are used in nonattainment areas).

Even in the western states, air pollution from mining equipment is a concern for state and tribal air quality agencies. EPA has recently received comments from the Western Regional Air Partnership supporting further controls on nonroad engines, equipment and fuel, specifically including mining equipment, in order to comply with EPA's regional haze regulations.[7]

Another reasons which some have suggested as grounds for exempting >750 hp engines used in AGME from the proposed Tier 4 standards is the low sales volume and high redesign costs of the engines and the equipment. It is generally correct that for this category of nonroad equipment, annual sales volumes are low, typically on the order of 50 or fewer for a given equipment model, and in many cases fewer than 10. Therefore, the costs of equipment redesign must be spread over a small number of sales. Our proposal for the >750 hp category provides significant flexibilites to address these concerns. This includes a phase-in of all standards (not just NOx and VOC) over three years, as well as the provisions for averaging, banking, and trading and the transition program for equipment manufacturers which are discussed in section VII of the proposed preamble. In fact, the >750 hp category is a separate category under the TPEM which would allow many AGME manufacturers to defer using any Tier 4 technology engines for a full seven years, until 2019.

In addition, the costs of equipment redesign must be put in the context of the high sales price of these types of equipment, which is commonly > $1 million. We should also note that exempting > 750 hp engines used in AGME would not reduce the research & development costs for engine manufacturers. Many of these large engines would still need to meet the proposed Tier 4 standards for applications other than AGME, such as cranes, large oil field equipment, and non-mining applications of off-highway trucks, excavators, etc. Table 12.6.2.2.7-1 below is a list of the nonroad equipment categories and estimated 1998 U.S. population used in EPA's NONROAD model which have engines >750 hp, including those we have projected are used in AGME and those which are not (based on our engineering expertise and discussion with engine and equipment manufacturers).

Table 12.6.2.2.7-1
Nonroad Equipment Categories Which Use Engines >750hp and Estimated Population

> 750 hp Equipment Category	Used in Above-ground Mining?	Est. 1998 U.S. Population[a]
Crawler Tractor/Dozers	Yes	6,097
Excavators	Yes	408
Off-Highway Tractors	Yes	848
Off-highway Trucks	Yes	4,574
Rubber Tire Loaders	Yes	2,633
Bore/Drill Rigs	No	911
Chippers/Stump Grinders	No	118
Cranes	No	19
Crushing/Processing Equipment	Yes	4
Forest Eqp - Feller/Bunch/Skidder	No	12
Other Agricultural Equipment	No	2
Other Construction Equipment	No	29
Other Oil Field Equipment	No	969
Railway Maintenance	No	36
Specialty Vehicle Carts	No	50
Trenchers	No	11

[a] Estimated 1998 U.S. populations from EPA's draft NONROAD2002 emission inventory model

Some engine engine manufacturers have argued that the engines used in the largest mining applications are so large that the aftertreatment systems cannot be scaled up to such sizes and remain durable (though no manufacturer has provided any specific reasons why this would be so, nor have any data been presented). As discussed in Section III.E. of the preamble and in Chapter 4 of this draft RIA, we recognize that many nonroad equipment types experience harsh and sometimes severe operation conditions. However, as discussed in the preamble and in Chapter 4 of this draft RIA, existing data already indicate that aftertreatment systems can be designed to withstand these harsh environments while maintaining their structural integrity. In fact, many of the actual examples of PM filters which have been used have been for mining applications. Systems have been used in a number of underground mining applications in Europe on equipment ranging from 125 to 275 hp for upto 6,900 hours on a single application.[8] One engine manufacturer, Deutz, developed a PM filter system for engines up to 800 hp. The Deutz system utilized two filters for engines greater than approximately 230 hp, and their largest system relied on two filters which were 62.5 liters each and have been used on engines with displacements of 26 liters.[9] Finally, one integrated engine/equipment manufacturer offers an OEM option of a PM filter based system in a number of their equipment types, including mining equipment.[10]

Based on the information available to us and discussed in section III of the preamble and chapter 4 of the RIA, we believe that exhaust aftertreatment systems can be designed to be durable in-use even for the >750hp engines.

Emissions from >750 hp AGME are a significant portion of the NOx and PM inventory from the nonroad diesel engines. Our modeling indicates that these machines, though low in nationwide sales and population, are not an insignificant part of the NOx and PM inventories. Table VI-1 in the preamble for this proposal shows AGME >750 hp represents 13 percent of the net-present value of the NOx reduction and 2 percent of the PM reduction of our proposal. A graphical representation of the impact on the national inventories of exempting these engines can also be seen in Figures 12.2.2.1-1 (NOx) and 12.2.2.2-1 (PM).

Table 12.2.2.1-1 shows an increase in NOx emissions in 2030 of approximately 103,000 tons, and Table 12.2.2.2-1 shows an increase in PM emission in 2030 of approximately 4,000 tons if the >750 hp AGME were exempted. Table 12.2.3-2 shows that the cumulative, undiscounted emission increase which would occur through 2030 if >750 hp AGME engines were exempted is approximately 742,000 tons of NOx and 30,000 tons of PM.

As discussed in Chapter 12.4, we have estimated the net-present value cost through 2030 of the proposed Tier 4 standards for >750 hp AGME and engines at approximately $490 million. The estimated aggregate cost per ton for the proposed Tier 4 standards for >750 hp AGME is $300/ton for NOx+NMHC and $8,300/ton for PM though 2030. The PM cost per ton value is in line with the estimate for our entire proposal, and the NOx+NMHC estimate is well below the values for the entire proposal. There is no rational way that such costs could be considered so hugely exorbitant or disproportionate (the test under the case law cited earlier) as to justify forgoing the large, achievable emission reductions obtainable from these engines.

Finally, as discussed in Chapter 12.3, we have estimated the net-present value of the monetized health benefits for our proposed standards for >750 hp engines used in AGME through 2030 as being approximately $16 billion.

Based on the information available to us, we do not believe this option should be promulgated. The standards we have proposed for >750 hp AGME engines are feasible and very cost-effective. AGME contributes to the same health and welfare concerns as other nonroad diesel engines, massive emission reductions of PM and NOx from these engines are feasible, and the costs we have estimated for controlling these engines are not excessive, exorbitant, or otherwise inappropriate.

12.6.2.2.8 Option 4

In order to enable the high efficiency exhaust emission control technology to begin to be applied to nonroad engines beginning with the 2011 model year, we are proposing that all nonroad diesel fuel produced or imported after June 1, 2010 would have to meet a 15 ppm sulfur cap. Although locomotive and marine diesel engines are similar in size to some of the diesel engines covered in this proposal, there are many differences (e.g., duty cycles, exhaust system design configurations, size, and rebuild and maintenance practices) that have caused us to treat them separately in past EPA programs.[A] For the same reasons, we are not proposing new engine standards today for these engine categories and as a result, are also not proposing that the second step of sulfur control to 15 ppm in 2010 be applied to locomotive and marine fuel. We are proposing to set a sulfur fuel content standard of 500 ppm for fuel used in locomotive and marine diesel applications. This fuel standard is expected to provide considerable sulfate PM benefits regardless of whether or not we also set more stringent emission standards for these engines.

As discussed in Section IV of the preamble, we are also seriously considering extending the 15 ppm standard to locomotive and marine fuel as early as June 1, 2010 as well. There are several advantages associated with this alternative. First, as reflected in Table 12.2.3-2, it would provide over 9,000 tons of additional sulfate PM benefits and over 114,000 tons of additional SO_2 benefits from 2007 to 2030 (calculated as net present value in 2004). The cost for these additional benefits as shown in Section 12.4.3.2 are $1.8 billion. This cost reflects the incremental cost for reducing the sulfur content of locomotive and marine from 500 ppm to 15 ppm - 2.4 c/gal. The cost also reflects an increase in the long-term per gallon cost of all 15 ppm NRLM diesel fuel of 0.2 c/gal due to the fact that higher cost refiners are now required to produce 15 ppm diesel fuel.

Second, reducing sulfur content of locomotive and marine diesel fuel to 15 ppm in 2010 would simplify the fuel distribution system and the design of the fuel program proposed today since a marker would not be required for locomotive and marine diesel fuel. The marker cost itself is an estimated 0.2 c/gal. While difficult to quantify, additional cost savings would be realized by allowing locomotive and marine fuel to be fungible with nonroad and highway diesel fuel. Furthermore, prices do not necessarily follow costs, and there is reason to believe that the price for 500 ppm locomotive and marine fuel will not necessarily be appreciably lower than if it were required to be 15 ppm. Under the proposal, we expect that a certain amount of marine fuel will be ultra-low sulfur fuel regardless of the standard due to limitations in the production and distribution of unique fuel grades. Where 500 ppm fuel is available, the possible suppliers of fuel will likely be more constrained, limiting competition and allowing prices to approach that of 15 ppm fuel. If we were to bring locomotive and marine fuel to 15 ppm, the pool of possible suppliers could expand beyond those today, since highway diesel fuel will also be at the same standard. It is difficult to provide any quantitative price comparison, but it is entirely possible that the price differential between a 15 ppm and 500 ppm standard for locomotive and marine fuel would be significantly less than the estimated 2.4 c/gal cost differential.

Third, reducing sulfur content of locomotive and marine diesel fuel to 15 ppm in 2010 would help reduce the potential opportunity for misfueling of 2007 and later model year highway vehicles and 2011 and later model year nonroad equipment with higher sulfur fuel. We do not

[A] Locomotives, in fact, are treated separately from other nonroad engines and vehicles in the Clean Air Act, which contains provisions regarding them in section 213(a)(5). Less than 50 hp marine engines were included in the 1998 final rule for nonroad diesel engines, albeit with some special provisions to deal with marine-specific engine characteristics and operating cycles.

anticipate misfueling to be a significant concern under today's proposal, since by 2010 more than 80% of the total number 2 distillate pool is expected to be 15 ppm (see Table 7.1-16 in Chapter 7). Nevertheless, extending the 15 ppm standard to locomotive and marine would increase this percentage to more than 85%, further limiting the sources of fuel on which misfueling could occur either accidentally or intentionally.

Finally, reducing sulfur content of locomotive and marine diesel fuel to 15 ppm in 2010 would allow refiners to coordinate plans to reduce the sulfur content of all of their nonroad diesel fuel at one time. While in many cases this may not be a significant advantage, it may be a more important consideration here since it is probably not a question of whether locomotive and marine fuel must meet a 15 ppm cap, but merely when. As discussed in Section IV of the preamble, it is the Agency's intention to take action in the near future to set new emission standards for locomotive and marine engines that could require the use of high efficiency exhaust emission control technology, and thus, also require the use of 15 ppm sulfur diesel fuel.[B] We anticipate that such engine standards would likely take effect in the 2011-13 timeframe, requiring 15 ppm locomotive and marine diesel fuel in the 2010-12 timeframe.

However, discussions with refiners have suggested there are significant advantages to leaving locomotive and marine diesel fuel at 500 ppm, at least in the near-term and until we set more stringent standards for those engines. First, the locomotive and marine diesel fuel markets could provide a market for off-specification product that is important for refiners, particularly during the transition to 15 ppm for highway and nonroad diesel fuel in 2010. It is possible that significant volumes of 500 ppm diesel fuel would be created in the distribution system during the distribution of 15 ppm fuel. For example, the pipeline interface between 15 ppm diesel fuel and higher sulfur jet fuel would likely contain less than 500 ppm sulfur. Without the ability to sell this fuel to the locomotive and marine diesel fuel markets, this interface would have to be sold as heating oil. The available markets for heating oil could be quite limited, particularly outside the Northeast, causing more fuel to have to be shipped back to refineries for reprocessing at considerable expense. Maintaining a market for locomotive and marine fuel at 500 ppm would provide a market across much of the country where off-specification 15 ppm could be marketed. Waiting just a year or two beyond 2010 for implementing the 15 ppm standard for locomotive and marine would not address long term desires for outlets for off-specification product, but it would address the more critical, near term needs during the transition. Second, waiting just another year or two beyond 2010 is projected to allow virtually all refiners to take advantage of the new lower cost desulfurization technologies. As discussed in Chapter 6 approximately 80 percent of refineries are projected to be able to take advantage of these new technologies with the June 1, 2010 implementation date. We project that just a two year delay to 2012 would permit all refineries to do so, thereby reducing the desulfurization costs for 15 ppm locomotive and marine fuel. Finally, while the monetized benefits of controlling the sulfur level of locomotive

[B]The most recent new standards for locomotives and marine diesel engines (including those under 50 hp) were set in separate actions (63 FR 18977, April 16, 1998 and 67 FR 68241, November 8, 2002).

and marine diesel fuel from 500 ppm down to 15 ppm outweigh the costs (even in the absence of new engine emission standards), the cost per ton for the incremental sulfate PM and SO_2 emission reductions as shown in Table 12.5-1 is $64,000 and 10,300 per ton, respectively. These costs are rather high in comparison to other possible control options.

12.6.2.2.9 Option 5a

The Option 5a program is identical to the proposal except that no new program requirements would be set in Tier 4 for engines under 75 hp. Instead Tier 2 standards and testing requirements for engines under 50 hp, and Tier 3 standards and testing requirements for 50-75 hp engines, would continue indefinitely. This analytical option presumes that Tier 4 nonroad diesel NOx and PM control from these engines would either not be needed to address air quality concerns or would not be feasible (presumptions we believe are unfounded). These issues are discussed in detail in Chapters 2 and 4 of this draft RIA, and in sections II and III of the preamble to the proposal.

We believe that Option 5a would be inappropriate. As discussed in section III.E of the proposal preamble, the 0.02 g/bhp-hr PM standard proposed for 25-75 hp engines in 2013 is feasible, based on the use of high-efficiency PM filters and the availability of nonroad diesel fuel with sulfur levels capped at 15 ppm. As also discussed in section III.E of the proposal preamble, the less stringent PM standards proposed for engines under 75 hp in 2008 are feasible, based on the use of diesel oxidation catalysts and/or engine optimization strategies, and on the availability of nonroad diesel fuel with sulfur levels capped at 500 ppm. In fact, as discussed in section III.E of the proposal preamble, some of today's engines already meet the proposed standards. We believe that the 2008 standards provide a reasonable means of gaining substantial PM reductions from the nonroad diesel sector in the early years of the Tier 4 program, while managing the workload, stability, and technology transfer issues involved, but we are also requesting comment in section III.B.1.d.ii of the proposal preamble on whether it would be better not to set a Tier 4 PM standard in 2008 so that engine designers could instead focus their efforts on meeting a PM-filter based standard for these engines earlier, say in 2012.

Establishing no Tier 4 PM program at all for engines under 75 hp would, on the other hand, leave engines under 50 hp at Tier 2 PM standards levels of 0.60 g/bhp-hr (for <25 hp) and 0.45 g/bhp-hr (for 25-50 hp), and would leave 50-75 hp engines at a Tier 3 PM standard level of 0.30 g/bhp-hr. The resulting in-use emissions levels from these engines would be many times higher than that achieved under the proposed program. As discussed in section 12.2, the overall loss in Tier 4 PM emissions reductions would be correspondingly large, both in the early and the long-term timeframes of the program. This option would also fail to address toxic hydrocarbon concerns, considering the large population of these under 75 hp engines and the fact that they are often used in populated areas and in equipment without closed cabs.

To take no action on under 75 hp engines in this rulemaking would compromise air quality goals and would also greatly increase uncertainty for the engine and equipment manufacturing industry. Due to the continuing growth in sales of these smaller engines and the promising developments that are occurring in diesel emissions control technology, it seems improbable that putting off action to some point in the future would result in more flexibility, more leadtime, or less stringent standards than under this proposal. We believe instead that setting standards now, with plans for a technology review in 2007 for the long-term (2013) standards, appropriately balances the need for Tier 4 program certainty and leadtime with the Agency's commitment to reconsider program requirements where necessary in light of continuing technology progress and demonstration over the next few years.

12.6.2.2.10 Option 5b

The Option 5b program is identical to the proposal except that for engines under 75 hp only the 2008 engine standards would be set. There would be no additional PM filter-based standard in 2013 for 25-75 hp engines, and no additional NOx+NMHC standard in 2013 for 25-50 hp engines. This analytical option presumes that controlling PM from 25-75 hp engines to levels achievable with PM filters would either not be needed to address air quality concerns or would not be feasible (presumptions we believe are unfounded). These issues are discussed in detail in Chapters 2 and 4 of this draft RIA, and in sections II and III of the preamble to the proposal.

Although, unlike Option 5a, Option 5b does involve important PM reductions beginning in 2008, much of the Option 5a discussion in section 12.6.2.2.9 applies here as well. The loss in long-term Tier 4 PM emissions reductions would be large, as discussed in section 12.2, because the PM reductions from engines produced after 2008 would be only on the order of 50% compared to previous-tier engines, instead of the more than 95% reductions available through the use of PM filters. This option could also leave a large unaddressed toxic hydrocarbon concern, depending on the degree to which manufacturers choose to meet the 2008 standards through the use of diesel oxidation catalysts. Overall, we believe that Option 5b would be inappropriate.

Appendix 12A: Certification Fuel Sulfur Levels

The sulfur levels assumed for certification fuel for the purposes of modeling emission benefits of each program option are presented in this appendix. Note that the Tier 1 standards for >750hp engines continued through 2005. Manufacturers subject to these Tier 1 standards are assumed to have certified on fuel having an average sulfur content of 3300ppm, based on existing records of those tests.

As described in Section 12.2.1.1, the cert fuel sulfur levels in the charts below do not always coincide with changes in the required maximum sulfur level for certification fuel. Engine manufacturers are unlikely to make modifications to their engines to take advantage of the lower sulfur requirement for cert fuel until new engine standards make such modifications necessary. The assumed cert fuel sulfur levels were used to establish the proper zero-hour emission factors for new engines. For in-use inventory impacts of these new engines, the emission factors were further adjusted to account for the assumed in-use sulfur levels. Thus, for instance, engines certified on 2000ppm sulfur fuel and then operated on 500ppm fuel would realize a PM benefit relative to the PM certification standard.

Figure 12A-1
Assumed Certification Fuel Sulfur Levels To Establish
Zero Hour Emission Factors Under Option 1 (ppm)

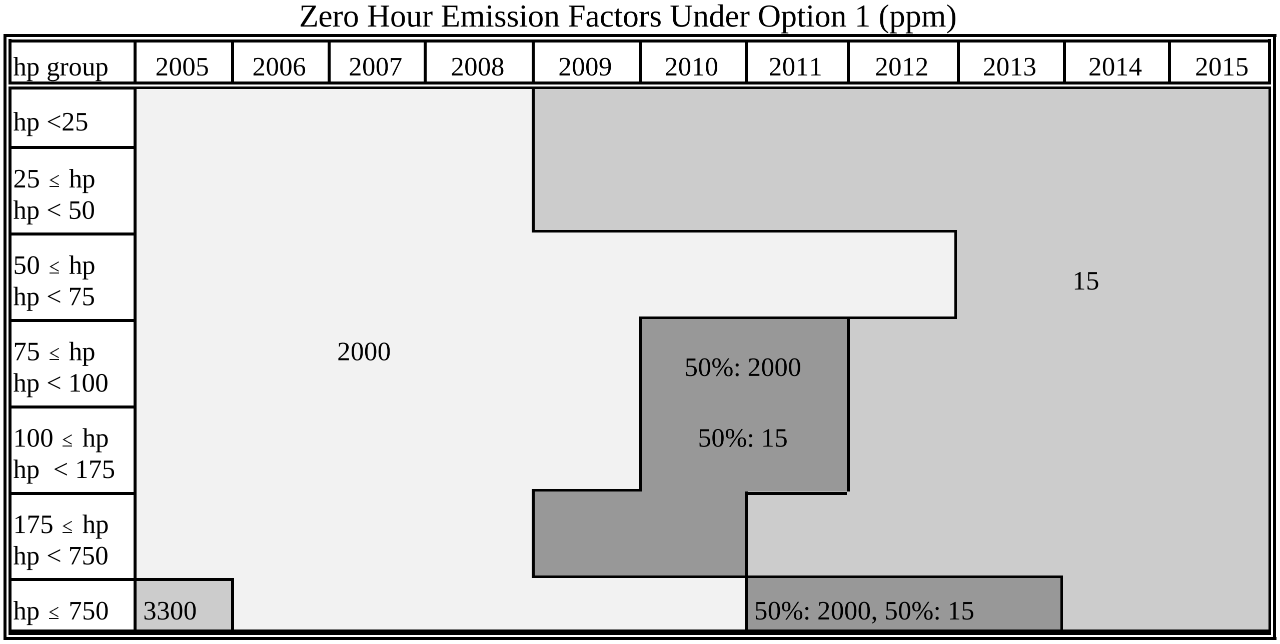


Figure 12A-2
Assumed Certification Fuel Sulfur Levels To Establish
Zero Hour Emission Factors Under Option 1a (ppm)

hp group	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
hp <25											
25 ≤ hp hp < 50											
50 ≤ hp hp < 75											
75 ≤ hp hp < 100			2000					15			
100 ≤ hp hp < 175											
175 ≤ hp hp < 750											
hp ≤ 750	3300										

Figure 12A-3
Assumed Certification Fuel Sulfur Levels for Modeling Under Option 1b (ppm)

hp group	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
hp <25											
25 ≤ hp hp < 50											
50 ≤ hp hp < 75											
75 ≤ hp hp < 100			2000					15			
100 ≤ hp hp < 175											
175 ≤ hp hp < 750											
hp ≤ 750	3300										

Figure 12A-4
Assumed Certification Fuel Sulfur Levels To Establish
Zero Hour Emission Factors Under Proposed Program (ppm)

hp group	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
hp <25											
25 ≤ hp hp < 50											
50 ≤ hp hp < 75					500						
75 ≤ hp hp < 100		2000									
100 ≤ hp hp < 175									15		
175 ≤ hp hp < 750											
hp ≤ 750	3300						50%: 2000, 50%: 15				

Figure 12A-5
Assumed Certification Fuel Sulfur Levels To Establish
Zero Hour Emission Factors Under Option 2a (ppm)

hp group	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
hp <25											
25 ≤ hp hp < 50											
50 ≤ hp hp < 75					500						
75 ≤ hp hp < 100		2000									
100 ≤ hp hp < 175									15		
175 ≤ hp hp < 750											
hp ≤ 750	3300						50%: 2000, 50%: 15				

Figure 12A-6
Assumed Certification Fuel Sulfur Levels To Establish
Zero Hour Emission Factors Under Option 2b (ppm)

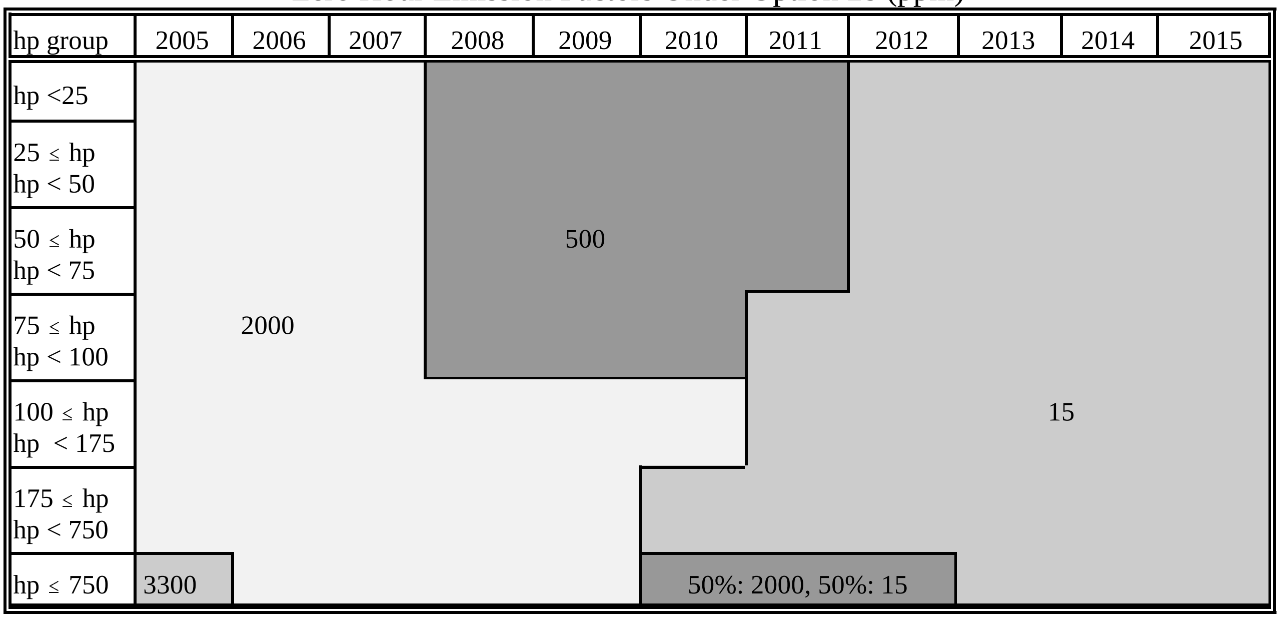


Figure 12A-7
Assumed Certification Fuel Sulfur Levels To Establish
Zero Hour Emission Factors Under Option 2c (ppm)

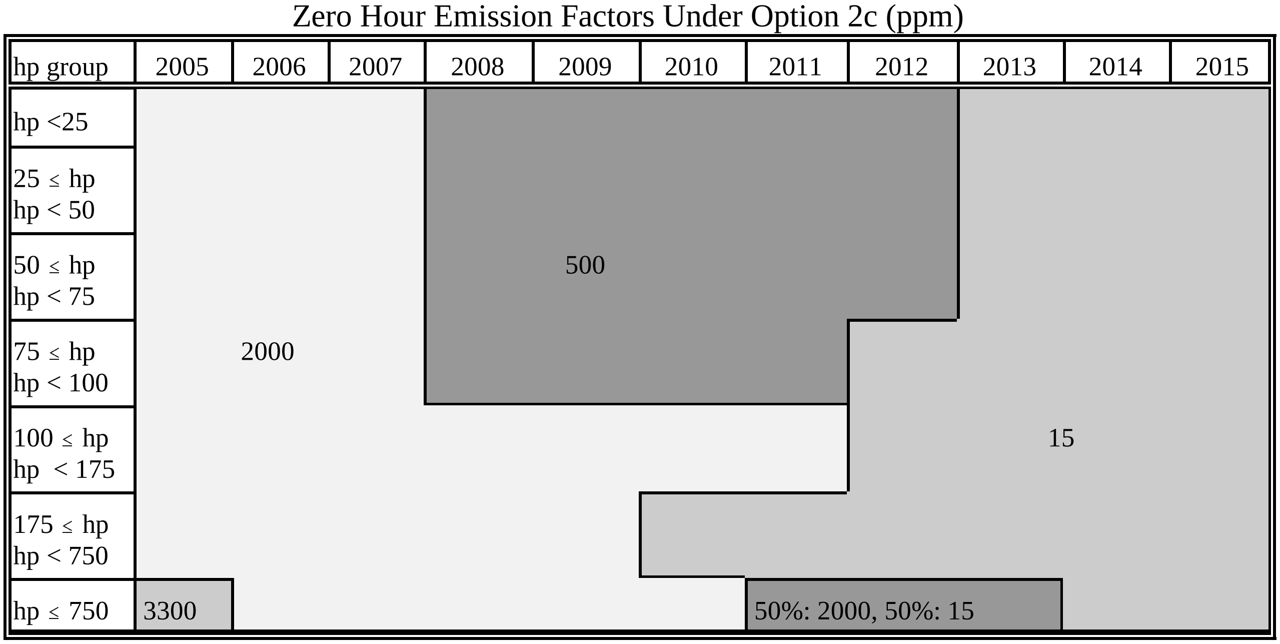


Figure 12A-8
Assumed Certification Fuel Sulfur Levels To Establish
Zero Hour Emission Factors Under Option 2d (ppm)

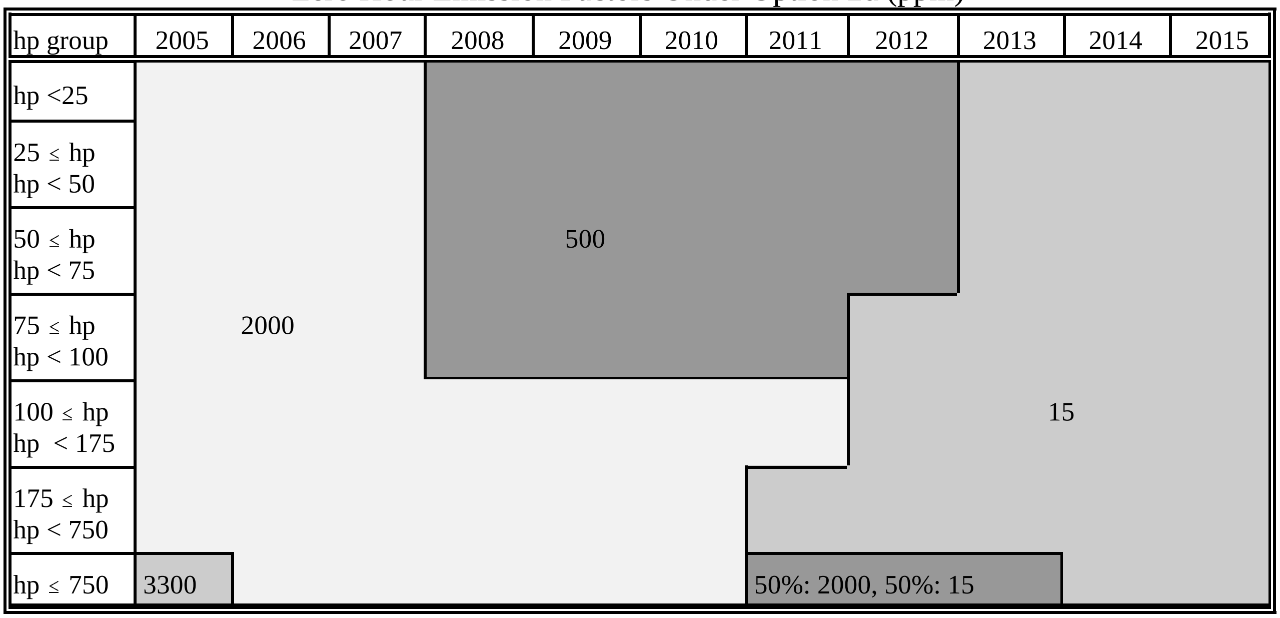


Figure 12A-9
Assumed Certification Fuel Sulfur Levels To Establish
Zero Hour Emission Factors Under Option 2e (ppm)

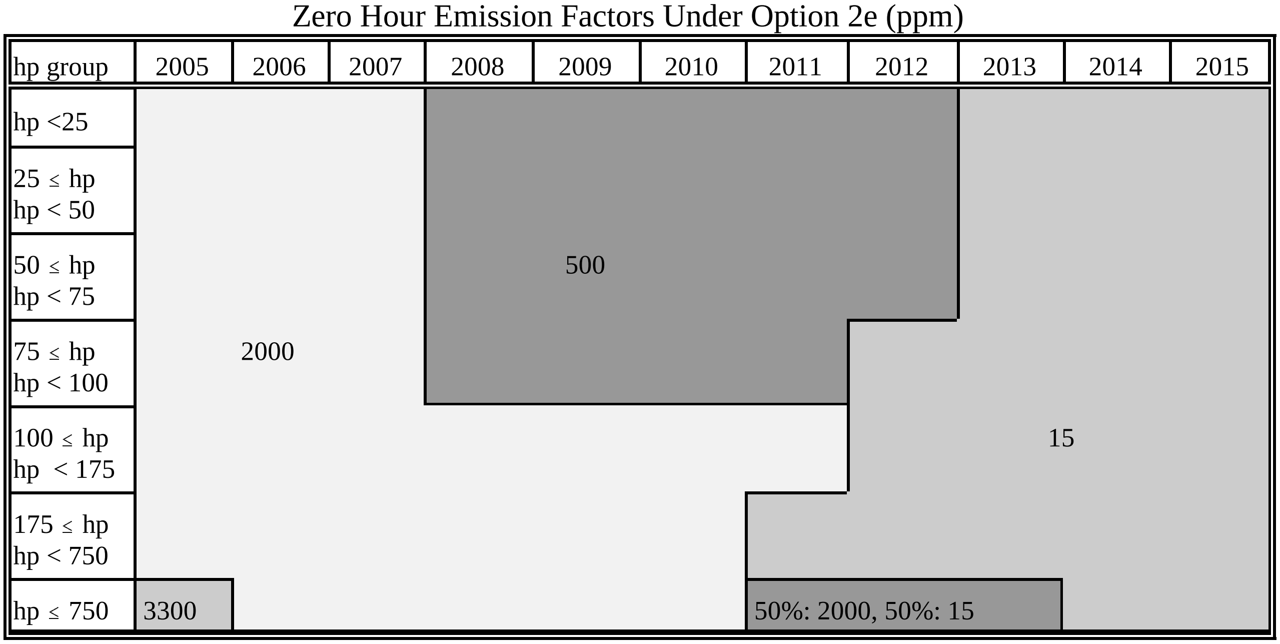


Figure 12A-10
Assumed Certification Fuel Sulfur Levels f To Establish
Zero Hour Emission Factors Under Option 3 (ppm)

hp group	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
hp <25											
25 ≤ hp hp < 50											
50 ≤ hp hp < 75					500						
75 ≤ hp hp < 100		2000									
100 ≤ hp hp < 175									15		
175 ≤ hp hp < 750											
hp ≤ 750	3300						50%: 2000, 50%: 15				

Figure 12A-11
Assumed Certification Fuel Sulfur Levels To Establish
Zero Hour Emission Factors Under Option 4 (ppm)

hp group	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
hp <25											
25 ≤ hp hp < 50											
50 ≤ hp hp < 75					500						
75 ≤ hp hp < 100		2000									
100 ≤ hp hp < 175									15		
175 ≤ hp hp < 750											
hp ≤ 750	3300						50%: 2000, 50%: 15				

Figure 12A-12
Assumed Certification Fuel Sulfur Levels To Establish
Zero Hour Emission Factors Under Option 5a (ppm)

hp group	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
hp <25											
25 ≤ hp hp < 50											
50 ≤ hp hp < 75					500						
75 ≤ hp hp < 100		2000									
100 ≤ hp hp < 175									15		
175 ≤ hp hp < 750											
hp ≤ 750	3300						50%: 2000, 50%: 15				

Figure 12A-13
Assumed Certification Fuel Sulfur Levels To Establish
Zero Hour Emission Factors Under Option 5b (ppm)

hp group	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
hp <25											
25 ≤ hp hp < 50											
50 ≤ hp hp < 75					500						
75 ≤ hp hp < 100		2000									
100 ≤ hp hp < 175									15		
175 ≤ hp hp < 750											
hp ≤ 750	3300						50%: 2000, 50%: 15				

Appendix 12B: Incremental Cost, Emission Reductions, Benefits, and Cost Effectiveness

This Appendix provides incremental costs, incremental emission reductions, marginal cost per ton of emission reduction, and incremental benefits for each in a series of potential control steps. The cost, emission reduction, and cost per ton data are presented in Table 12B-1, and the cost and benefit data are presented in Table 12B-2.

Because the emission reductions represent the change from the preceding baseline level, the order of the control steps affects the estimate of cost per ton. Some, but not all, of the steps specified in Table 12B-1 are components of our proposal. The data presented in Table 12B-1 and 12B-2 are provided as additional information for the reader.

For each control step, the baseline emission levels are presented prior to the introduction of that control step. The first baseline level in the table represents the emissions levels absent any new controls for nonroad engines or nonroad, locomotive and marine fuels. Subsequent baseline levels represent the difference between the preceding baseline level and the reductions from the preceding control steps (i.e., the remaining emissions).

The costs in the table represent approximate costs for each control step, apportioned among various pollutants. Our method for apportioning costs to a particular pollutant is described in Chapter 8, Table 8.1-2. In this case, the apportioning of costs is simplified, somewhat, as each control step has a distinct pollutant focus (i.e., the applications of DOCs/engine-out reductions and CDPFs for PM, even though some NMHC reductions are realized). The costs shown here should be considered as rough approximations, because they have been derived from our program costs by splitting various fixed costs of the program by pollutant and control step. For example, the R&D costs estimated in Chapter 6, and used here, for engines larger than 75 hp were roughly split 67 percent to NOx control and 33 percent to PM control. We have made no estimate of the distinct cost of only doing PM control or only doing NOx control for engines in this horsepower range. We believe that it is likely that R&D costs for either step alone would be higher than represented in this analysis. Nevertheless, for comparative purposes we have presented the costs here.

Table 12B-1
Incremental Cost, Emissions Reductions, and Cost Effectiveness for Various Control Steps
(All values are expressed as 2004 NPV using a 3 percent discount rate)

Control Steps		PM (NPV 2007-2030)	NOx+NMHC (NPV 2007-2030)	SO2 (NPV 2007-2030)
500 ppm Sulfur Nonroad, Locomotive, and Marine Fuel in 2007	Baseline	3,251	21,745	5,273
	Cost	-	-	$0.5
	Reductions	374	0	4,638
	Cost/Ton	-	-	$100
15 ppm Sulfur Nonroad Fuel and Tier 4 PM for >75hp Engines	Baseline	2,877	21,745	635
	Cost	$9.9	-	-
	Reductions	917	137	315
	Cost/Ton	$10,800	-	-
Transitional PM Standards for <75hp in 2008	Baseline	1,960	21,608	320
	Cost	$1.2	-	-
	Reductions	88	1	0
	Cost/Ton	$14,200	-	-
CDPF based PM Standards for 25hp - 75hp in 2013	Baseline	1,872	21,608	320
	Cost	$2.2	-	-
	Reductions	121	0	0
	Cost/Ton	$18,300	-	-
Tier 4 NOx Standards	Baseline	1,751	21,608	320
	Cost	-	$3.3	-
	Reductions	0	5,407	0
	Cost/Ton	-	$600	-
15 ppm Sulfur Locomotive and Marine Fuel in 2010	Baseline	1,751	16,200	320
	Cost	$0.6	-	$1.2
	Reductions	9	0	114
	Cost/Ton	$64,200	-	$10,300
Remaining tons NR, Locomotive and Marine		1,742	16,200	206

Baseline - the NPV of the emission levels prior to the control step (1,000 tons), recalculated after each control step
Cost - the NPV of the annualized costs of the control step ($ billion), apportioned by pollutant
Reductions - the NPV of the emissions reductions from the baseline due to the control step (1,000 tons)
Cost/Ton - the ratio of the Cost and Reductions ($/ton)

The reduction rows in the table represent the emission reductions from the previous baseline level by pollutant for each of the control steps. The cost per ton row simply reflects the ratio of the preceding two rows, defining the cost per ton of reduction realized in the control step. Note that for many of the control steps, reductions in emissions are realized for multiple pollutants, yet we have attributed cost to only one or two pollutants (depending on the primary purpose of the control technology, as discussed in Chapter 8.1). This does not mean that the reductions in the other pollutants can actually be realized for free, only that we have attributed no costs to those reductions. For example, we have attributed all of the costs of the 15 ppm sulfur program to PM control, therefore the “Tier 4 NOx Standards” data shows very low $/ton incremental costs.

Estimates of the cost and dollar benefits of the various control steps are presented in Table 12B-2, below. The cost estimates are the same as for Table 12B-1 (although summed into a single value rather than distributed across multiple pollutants). The benefits estimates are an approximation based upon the benefits estimates for the proposal and the various control options presented previously in Section 12.3 Benefits Comparison. Each of these control steps can be approximated by one or more of the options in Table 12.6-1. For example, the PM portion, of control step, *Transitional PM Standards for <75 hp in 2008*, can be found as the difference between options 5a (no control for <75hp engines) and 5b (no CDPF control for 25hp-75hp engines). As these benefits are based on approximations from other control approaches, the benefits listed in Table 12B-2 should be considered as approximate estimates to the benefits of the various control steps.

Table 12B-2
Cost and Benefits of Various Control Steps
(All values are expressed as 2004 NPV using a 3 percent discount rate)

Control Steps	**Cost ($ Billion) NPV(2007-2030)**	**Benefit ($ Billion) NPV(2007-2030)**
500 ppm Sulfur Nonroad, Locomotive, and Marine Fuel in 2007	$0.5	$230
15 ppm Sulfur Nonroad Fuel and Tier 4 PM for >75 hp Engines	$9.9	$186
Transitional PM Standards for <75hp in 2008	$1.2	$28
CDPF based PM Standards for 25hp - 75hp in 2013	$2.2	$43
Tier 4 NOx Standards	$3.3	$64
15ppm Sulfur Locomotive and Marine Fuel in 2010	$1.8	$6

Chapter 12 References

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3. Final Regulatory Impact Analysis: Control of Emissions from Marine Diesel Engines, November 1999, p. 79 (Docket A-97-50, Document V-B-01).

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5. "Information Regarding Mine Locations in the United States", EPA Memorandum. Copy available in EPA Air Docket A-2001-28

6. "Analysis of Nonroad Engine Emissions in the Mining Industry," TRC Environmental Corporation, July 1993, p. 1.

7. January 28, 2003 letter from the Western Regional Air Partnership to Administrator Whitman. Copy available in EPA Air Docket A-2001-28.

8. "Particulate Traps for Retro-Fitting Construction Site Engines VERT" Final Measurements and Implementation", A. Mayer et. al., SAE paper 1999-01-0116, March 1999. See also "Particulate Traps for Construction Machines: Properties and Field Experience", J. Czerwinski et. al., SAE Paper 2000-01-1923.

9. "The Optimized Deutz Service Diesel Particulate Filter System II", H. Houben et. al., SAE Technical Paper 942264, 1994. See also **"**Summary of Conference Call between US EPA and Deutz Corporation on September 19, 2002 regarding Deutz Diesel Particulate Filter System", EPA Memorandum to Air Docket A-2001-28".

10. "Particulate Traps for Construction Machines: Properties and Field Experience", J. Czerwinski et. al., SAE Paper 2000-01-1923.