Appendix J

Cost Calculations

Cost Calculations

Part I: Cost Increase and Cost-Effectiveness of Proposed Ship Auxiliary Engine Rule

Under Part I, we estimate the cost and cost-effectiveness of the proposed regulation. The analysis includes estimates of the capital and recurring costs, the total present value cost of the proposal, and the total annual cost. The cost and cost-effectiveness values are used in Chapter VIII of the staff report.

Part II: Cost Increase and Cost-Effectiveness of Proposed Ship Auxiliary Engine Rule (Upper-End Cost Estimate for Ship Modifications)

Under Part II, we estimate the same cost and cost-effectiveness parameters as in Part I above, except that we assume higher capital costs to determine an upper-end cost estimate. Specifically, we assume that 50 percent of the capital costs estimated to occur upon implementation the proposed rule will occur in all subsequent years.

Part III: Cost Increase for a Cruise Ship to the Use of Distillate Fuel on a Round Trip Visit to POLA/LB from Enseñada

Under Part III, we estimate the cost increase resulting from compliance with the proposed regulation for a typical cruise ship voyage from Los Angeles to Enseñada and back. This analysis was presented during a May 17, 2005 public workshop. The added cost for this particular voyage was estimated because this is the most common type of cruise ship voyage associated with a California port. Some of the assumptions used in this analysis have been modified slightly in the cost analysis presented in the staff report, as we have refined the figures in the latest version of the cost analysis in the staff report. However, this example is only designed to provide a general approximation of the added cost of the proposed regulation for a typical voyage associated with a California port visit.

Part IV: Cost Increase and Cost-Effectiveness Related to the Use of Distillate Fuel by Ships at Dockside and in California Coastal Waters

Under Part IV, we estimate the cost increase and cost-effectiveness resulting from compliance with the proposed regulation for a typical cargo ship voyage from Asia to Los Angeles. This analysis was presented during a May 17, 2005 public workshop. The added cost for this particular voyage was estimated because this is a typical cargo ship voyage associated with a California port. As with Part III, some of the assumptions used in this analysis have been modified slightly in the cost analysis presented in the staff report. The cost-effectiveness estimates in this analysis are only associated with a typical vessel scenario, and should not be used for the overall cost-effectiveness of the proposed regulation.

Part I
Cost Increase and Cost Effectiveness of
Proposed Ship Auxiliary Engine Rule

I. ASSUMPTIONS:

1. Fuel change from the most common grade of heavy fuel oil (IFO 380) to marine gas oil (MGO)
2. Fuel Prices based on average of Bunkerworld prices from 3/05-9/05 for three ports as follows:

Fuel Prices ($)

Fuel	Fujairah	Singapore	Rotterdam	Average
MGO	512	504	523	513
IFO 380	261	264	243	256
Cost Difference	251	240	280	**257**

3. Price differential between lower sulfur MGO compared to standard MGO subject a limit of 1.5% sulfur limit based "Advice on the Costs to Fuel Producers and Price Premia Likely to Result from a Reduction I the Level of Sulphur in Marine Fuels Marketed in the EU," Beicip-Franlab, April 2002, as follows:

Low Sulphur DMA Price Premium

Fuel % Sulfur	Premium versus 1.5%S DMA (euro/tonne)	Ave. premium in $/tonne (@ 0.83 $ per euro)
0.2%	12-19	$18.68
0.1%	14-21	$21.08

4. Auxiliary generators (and gensets on diesel electric vessels) are medium speed diesel engines
5. Emission factors as follows, based on Entec Report, 7/02, Table 2.10 (except that the PM emission factor using residual fuel/HFO @2.5% sulfur is 1.5 g PM/kW-hr), and some PM and SOx emission factors modified based on different sulfur levels. To adjust SOx emission factor for different sulfur levels, used 98% conversion of fuel sulfur to SOx and a molecular weight ratio of SO_2/S of 2. For sulfate PM, used a 2% conversion of fuel sulfur to sulfate PM, and a molecular weight ration of SO_4 x $7H_2O$/S of 7.

Estimated Emission Factors (g/kw-hr)

Pollutant	HFO @ 2.5% sulfur	MGO @ 0.5% sulfur	MGO @ 0.1% sulfur
NOx	14.7	13.9	13.9
SOx	11.1	2.1	0.4
PM	1.5	0.38	0.25

6. Emission reductions for PM are as follows: 2.5% sulfur IFO 380 to 0.5% sulfur MGO ~ 75%, 2.5% sulfur IFO 380 to 0.1% sulfur MGO ~ 83%, 0.5% sulfur MGO to 0.1% sulfur MGO ~ 34%.
7. Emission reductions for NOx are as follows: IFO 380 to MGO ~6%, no impact from sulfur levels
8. Emission reductions for SOX: 2.5% sulfur IFO 380 to 0.5% sulfur MGO ~ 80%, 2.5% sulfur IFO 380 to 0.1% sulfur MGO ~ 96%, 0.5% sulfur MGO to 0.1% sulfur MGO ~ 80%.
9. Specific fuel consumption: 227 g fuel/k/W-hr for IFO 380 and 217 for MGO (ENTEC Table 2.10)
10. Per 2005 CARB Ship Survey, excluding passenger cruise ships, 72% of ship auxiliary engines operate on residual fuel (28% on distillate). Ninety-two percent of cruise ships engines use residual (8% distillate). Overall, estimate 78% of fuel used is residual and 22% is distillate, based on Ship Survey results, and considering higher fuel consumption by cruise ships within 24 nm.
11. Ship auxiliary engine emissions as follows from ARB's preliminary ship emissions inventory update using 24 nm boundary: 33.5 TPD NOx, 3.00 TPD PM, and 23 TPD SOx
12. Estimated average retrofit cost of $100,000 per vessel except for diesel-electric vessels. Diesel-electric vessels are estimated to range from $100,000 to $500,000.
13. An estimated 95 cargo vessels and 17 passenger cruise ships (diesel-electric) visiting California will require retrofits on initial implementation. This is based on about 1,945 cargo vessels visiting CA using 2004 CSLC data (and subtracting out passenger cruise ships) and assuming 5% of cargo ships require retrofits per 2005 ARB Ship Survey (15 cargo ships reported need to perform modifications out of 318 cargo ships). The estimate for passenger cruise ships is based directly on the ARB Survey since there was almost complete participation in the Survey by this segment of the industry (41 out of 44 vessels reported by the CSLC). This analysis does not attempt to estimate the cost of retrofitting additional vessels that visit California ports for the first time in subsequent years due to the variety of factors influencing this estimate, as discussed in staff report.

II. CALCULATIONS:

1. Estimated Fuel Consumption

33.5 Ton NOx/day x 365 day/yr x 2000 lb NOx/Ton NOx x 454 g NOx/lb NOx x kw-hr/14.7 g NOx x 227 g fuel/kw-hr x lb fuel/454 g fuel x ton fuel/2000 lb fuel x tonne fuel/1.1 ton fuel = 171,688 or ~172,000 tonne fuel

Per note above, we estimate about 78% of fuel consumed is residual and 22% is distillate, thus **134,000 tonne residual** and **38,000 tonne distillate**

2. Estimated Emission Reductions

NOx:
134,000 tonne residual x 1.1 ton/tonne x 2000 lb/ton x 454 g/ton x kw-hr/227 g fuel x 14.7 g NOx/kw-hr x lb. NOx/454 g NOx x ton NOx/2000 lb. NOx = 9,118 tpy NOx x 6% reduction =
573 tpy (1.5 TPD) NOx reduction

PM:
Residual to 0.5% distillate: 134,000 tonne residual x 1.1 ton/tonne x 2000 lb/ton x 454 g/ton x kw-hr/227 g fuel x 1.5 g PM/kw-hr x lb./454 g x ton /2000 lb. = 974 tpy PM x 75% reduction = 730 tpy (2.00 tpd) PM reduction

Residual to 0.1% distillate: 974 tpy PM x 83% reduction = 808 tpy (2.2 tpd) PM reduction

Distillate (0.5%) to 0.1% distillate: 38,000 tonne distillate x 1.1 ton/tonne x 2000 lb/ton x 454 g/ton x kw-hr/217 g fuel x 0.38 g PM/kw-hr x lb. PM/454 g PM x ton PM/2000 lb. PM = 73 tpy PM x 34% reduction = 25 tpy (0.07 tpd) PM reduction

Total reduction @ 0.5% sulfur MGO: **730 tpy (2.0 tpd) PM**
Total reduction @ 0.1% sulfur MGO**: 796 tpy (2.2 tpd) PM**

SOx:
Residual to 0.5% distillate: 134,000 tonne residual x 1.1 ton/tonne x 2000 lb/ton x 454 g/ton x kw-hr/227 g fuel x 11.1 g SOx/kw-hr x lb. /454 g x ton /2000 lb. = 7,208 tpy SOx x 80% reduction = 5,766 tpy (15.8 tpd) SOx reduction

Residual to 0.1% distillate: 7,208 tpy PM x 96% reduction = 6,920 tpy (19.0 tpd) SOx reduction

Distillate (0.5%) to 0.1% distillate 36,000 tonne distillate x 1.1 ton/tonne x 2000 lb/ton x 454 g/ton x kw-hr/217 g fuel x 2.1 g SOx/kw-hr x lb./454 g x ton /2000 lb. = 404 tpy SOx x 80% reduction = 323 tpy (0.89 tpd) SOx reduction

Total SOx reduction @ 0.5% sulfur: **5,766 tpy (16 tpd) SOx**
Total SOx reduction @ 0.1% sulfur**: 7,243 tpy (20 tpd) SOx**

3. Estimated Costs

Fuel (Recurring) Costs:
Fuel Increase for 0.5% average sulfur (no cap) MGO:
134,000 tonne residual x $257 extra/tonne **= $34 million**

Fuel Increase for 0.1% sulfur MGO:
134,000 tonne residual x $278 extra/tonne = $37 million
38,000 tonne MGO x $21 extra/tonne = $798,000
Total Difference = $**38 million**

Retrofit (Capital) Costs:

Cargo Vessels: 1,900 cargo vessels x 5% estimated to requiring modifications per ARB Ship Survey x $100,000/vessel = **$9.5 million**
Diesel-Electric/Cruise Ships: 17 vessels x $100,000-500,000 = **$1.7 to 8.5 million**

Total Retrofit Costs: $**11 to $18 million**

Total Present Value Cost of the regulation over 5 year life

Retrofits
One time capital cost (retrofits) in 2007: $11 to 18 million
Present value @5% and one year: 11 to 18 million/1.05= $10.5 to 17.1 million

Fuel costs:
2007-2009: Using MGO at 0.5% sulfur: present value of $33 million annually over three years:
$34 million x $[(1.05)^3 – 1/(0.05)(1.05)^3$ = 93 million
2010-2011: Using 0.1% sulfur MGO: present value of $38 million in 2010 and 2011 is 38 mill/1.05^4 + 38 mill/1.05^5= $31.3 million + $29.8 million = $61 million

Total Present Value of vessel modifications and added fuel costs:
$10.5-17.1 million (modifications) + $93 million (fuel for 2007-2009) + $61 million (fuel for 2010-2011)
~ $165-171 million

Note: Costs based on existing businesses. Does not attempt to forecast growth or changes in industry practices in future.

Total Annual Cost:

Annualized retrofit costs 11-18 million x CRF of 0.2309 (using 5 yrs., 5%) = $2.5-4.2 million

For 2007-2009: 34 million + 2.5 to 4.2 million = $36.5 to 38.2 million **~ 38 million**
For 2010-2011: 38 + 2.5 to 4.2 million = $40.5 to 42.2 million **~ 42 million**

4. Cost Effectiveness

Option 1: Attribute total annual cost to each pollutant individually
2007-2009:
NOx: $38 million/573 Ton NOx = **$66,000/Ton**
PM: $38 million/730 Ton PM = **$52,000/Ton**
SOx: $38 million/5,766 Ton SOx = **$6,600/Ton**

2010-2011:
NOx: $42 million/573 Ton NOx = **$73,000/Ton**
PM: $42 million/796 Ton PM **= $53,000/Ton**
SOx: $42 million/7,243 Ton SOx = **$5,800/Ton**

Option 2: Attribute half of the total annual cost to PM and half to NOx+ SOx.

2007-2009:
PM: $19 million/730 Ton PM = **$26,000/Ton**
NOx+SOx: $19 million/6,339 Ton SOx+NOx = **$3,000/Ton**

2010-2011:
PM: $21 million/796 Ton PM **= $26,000/Ton**
NOx+SOx: $21 million/7,816 Ton SOx+NOx = **$2,700/Ton**

Part II
Cost Increase and Cost-Effectiveness of
Proposed Ship Auxiliary Engine Rule
(Upper-End Cost Estimate for Ship Modifications)

I. ASSUMPTIONS:

1. Fuel change from the most common grade of heavy fuel oil (IFO 380) to marine gas oil (MGO)
2. Fuel Prices based on average of Bunkerworld prices from 3/05-9/05 for three ports as follows:

Fuel Prices ($)

Fuel	Fujairah	Singapore	Rotterdam	Average
MGO	512	504	523	513
IFO 380	261	264	243	256
Cost Difference	251	240	280	**257**

3. Price differential between lower sulfur MGO compared to standard MGO subject a limit of 1.5% sulfur limit based "Advice on the Costs to Fuel Producers and Price Premia Likely to Result from a Reduction I the Level of Sulphur in Marine Fuels Marketed in the EU," Beicip-Franlab, April 2002, as follows:

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Fuel % Sulfur	Premium versus 1.5%S DMA (euro/tonne)	Ave. premium in $/tonne (@ 0.83 $ per euro)
0.2%	12-19	$18.68
0.1%	14-21	$21.08

14. Auxiliary generators (and gensets on diesel electric vessels) are medium speed diesel engines
15. Emission factors as follows, based on Entec Report, 7/02, Table 2.10 (except that the PM emission factor using residual fuel/HFO @2.5% sulfur is 1.5 g PM/kW-hr), and some PM and SOx emission factors modified based on different sulfur levels. To adjust SOx emission factor for different sulfur levels, used 98% conversion of fuel sulfur to SOx and a molecular weight ratio of SO_2/S of 2. For sulfate PM, used a 2% conversion of fuel sulfur to sulfate PM, and a molecular weight ration of $SO_4 \times 7H_2O$/S of 7.

Estimated Emission Factors (g/kw-hr)

Pollutant	**HFO @ 2.5% sulfur**	**MGO @ 0.5% sulfur**	**MGO @ 0.1% sulfur**
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16. Emission reductions for PM are as follows: 2.5% sulfur IFO 380 to 0.5% sulfur MGO ~ 75%, 2.5% sulfur IFO 380 to 0.1% sulfur MGO ~ 83%, 0.5% sulfur MGO to 0.1% sulfur MGO ~ 34%.
17. Emission reductions for NOx are as follows: IFO 380 to MGO ~6%, no impact from sulfur levels
18. Emission reductions for SOX: 2.5% sulfur IFO 380 to 0.5% sulfur MGO ~ 80%, 2.5% sulfur IFO 380 to 0.1% sulfur MGO ~ 96%, 0.5% sulfur MGO to 0.1% sulfur MGO ~ 80%.
19. Specific fuel consumption: 227 g fuel/k/W-hr for IFO 380 and 217 for MGO (ENTEC Table 2.10)
20. Per 2005 CARB Ship Survey, excluding passenger cruise ships, 72% of ship auxiliary engines operate on residual fuel (28% on distillate). Ninety-two percent of cruise ships engines use residual (8% distillate). Overall, estimate 78% of fuel used is residual and 22% is distillate, based on Ship Survey results, and considering higher fuel consumption by cruise ships within 24 nm.
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II. CALCULATIONS:

1. Estimated Fuel Consumption

33.5 Ton NOx/day x 365 day/yr x 2000 lb NOx/Ton NOx x 454 g NOx/lb NOx x kw-hr/14.7 g NOx x 227 g fuel/kw-hr x lb fuel/454 g fuel x ton fuel/2000 lb fuel x tonne fuel/1.1 ton fuel = 171,688 or ~172,000 tonne fuel

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573 tpy (1.5 TPD) NOx reduction

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Total reduction @ 0.5% sulfur MGO: **730 tpy (2.0 tpd) PM**
Total reduction @ 0.1% sulfur MGO**: 796 tpy (2.2 tpd) PM**

SOx:
Residual to 0.5% distillate: 134,000 tonne residual x 1.1 ton/tonne x 2000 lb/ton x 454 g/ton x kw-hr/227 g fuel x 11.1 g SOx/kw-hr x lb. /454 g x ton /2000 lb. = 7,208 tpy SOx x 80% reduction = 5,766 tpy (15.8 tpd) SOx reduction

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Total SOx reduction @ 0.5% sulfur: **5,766 tpy (16 tpd) SOx**

Total SOx reduction @ 0.1% sulfur**: 7,243 tpy (20 tpd) SOx**

3. Estimated Costs

Fuel (Recurring) Costs:
Fuel Increase for 0.5% average sulfur (no cap) MGO:
134,000 tonne residual x $257 extra/tonne **= $34 million**

Fuel Increase for 0.1% sulfur MGO:
134,000 tonne residual x $278 extra/tonne = $37 million
38,000 tonne MGO x $21 extra/tonne = $798,000
Total Difference = $**38 million**

Retrofit (Capital) Costs:

Cargo Vessels: 1,900 cargo vessels x 5% estimated to requiring modifications per ARB Ship Survey x $100,000/vessel = **$9.5 million**
Diesel-Electric/Cruise Ships: 17 vessels x $100,000-500,000 = **$1.7 to 8.5 million**

All Vessels
2007 Retrofit Costs: $**11 to $18 million**
2008-2011 Retrofit Costs (50% of initial 2007 costs): **$5.5 to 9 million annually**

Total Present Value Cost of the regulation over 5 year life

Ship Modifications
Modifications in 2007: $11 to 18 million
Present value in 2006 @5%: 11 to 18 million/1.05= $10.5 to 17.1 million

Ship Modifications each year from 2008 to 2011: $5.5 to 9 million
Present value in 2006 @5%: $5.5 to 9 million x $[(1.05)^4 – 1/(0.05)(1.05)^4]$ = ($19.5 to $31.9 million)/$1.05^2$ = $17.7 to $28.9 = $18 to 29 million

Total Present Value of Ship Modifications: $30 million to $46 million

Added Fuel Costs
Fuel costs (2007-2009): Using MGO at 0.5% sulfur: present value of $34 million annually over three years:
$34 million x $[(1.05)^3 – 1/(0.05)(1.05)^3]$ = $93 million
2010-2011: Using 0.1% sulfur MGO: present value of $38 million in 2010 and 2011 is 38 mill/1.05^4 + 38 mill/1.05^5= $31.3 million + $29.8 million = $61 million

Total Present Value of vessel modifications and added fuel costs:
$30 to 46 million (modifications) + $93 million (fuel for 2007-2009) + $61 million (fuel for 2010-2011) **~ $184-200 million**

Note: Costs based on existing businesses. Does not attempt to forecast growth or changes in industry practices in future.

Total Annual Cost:

Cost Summary for Total Annual Cost (millions)

Type of Cost	**2007**	**2008**	**2009**	**2010**	**2011**
Added Fuel Cost	34	34	34	38	38
Ship Retrofits Cost	11-18	5.5-9	5.5-9	5.5-9	5.5-9
Total Annual Cost	45-52	40-43	40-43	44-47	44-47

Overall Average Total Annual Cost (2007-2011):
\$184-200 million x $[0.05(1.05)^5/(1.05)^5-1]$ = **\$42 to 46 million**

4. Cost Effectiveness

Option 1: Attribute total annual cost to each pollutant individually

2007-2009:
NOx: \$42-46 million/573 Ton NOx = **\$73,000 - \$80,000/Ton**
PM: \$42-46 million/730 Ton PM = **\$58,000 - \$63,000/Ton**
SOx: \$42-46 million/5,766 Ton SOx = **\$7,300 - \$8,000/Ton**

2010-2011:
NOx: \$42-46 million/573 Ton NOx = **\$73,000 - \$80,000/Ton**
PM: \$42-46 million/796 Ton PM **= \$53,000 - \$58,000/Ton**
SOx: \$42-46 million/7,243 Ton SOx = **\$5,800 - \$6,400/Ton**

Option 2: Attribute half of the total annual cost to PM and half to NOx+ SOx.

2007-2009:
PM: \$21-23 million/730 Ton PM = **\$29,000 - \$32,000/Ton**
NOx+SOx: \$21-23 million/6,339 Ton SOx+NOx = **\$3,300 - \$3,600/Ton**

2010-2011:
PM: \$21-23 million/796 Ton PM **= \$26,000 - \$29,000/Ton**
NOx+SOx: \$21-23 million/7,816 Ton SOx+NOx = **\$2,700 - \$2,900/Ton**

Part III
Cost Increase for a Cruise Ship to the Use of Distillate Fuel on a Round Trip Visit to POLA/LB from Enseñada

I. Assumptions:

Fuel change from bunker (IFO 380) to marine gas oil (MGO)
Fuel Costs based on Bunkerworld 4/19/05 Singapore prices: \$247/MT bunker & \$469/MT for MGO
Total engine power of 30 MW for transiting, 13 MW maneuvering, and 7 MW hotelling
Ship port visit is 8 hours hotelling, 10 hours transiting (using 100 nm LA to Mexico and 20 knots x2 for round trip), and 2 hours maneuvering
Specific fuel consumption: 213 g fuel/k/W-hr for IFO 380 and 203 for MGO (ENTEC Report, Table 2.8)

II. Calculations:

<u>Power</u>

(8 hrs. hotelling x 7,000 kW) + (10 hrs. transiting x 30,000 kW) + (2 hrs. maneuvering x 13,000 kW) = 382,000 kW-hr.

<u>Cost</u>
Bunker: 382,000 kW-hr. x 213 g fuel/kW-hr. x lb/454 g x Ton/2,000 lbs x tonne/1.1 ton x \$247/tonne = \$20,121
MGO: 382,000 kW-hr. x 203 g fuel/kW-hr. x lb/454 g x Ton/2,000 lbs x tonne/1.1 ton x \$469/tonne = \$36,413

Cost Increase: ~**\$16,300**

Part IV
Cost Increase and Cost Effectiveness Related to the Use of Distillate Fuel by Ships at Dockside and in California Coastal Waters

I. Assumptions:

Fuel change from bunker (IFO 380) to marine gas oil (MGO)
Fuel Costs based on Bunkerworld 4/19/05 Singapore prices: 247/MT bunker & 469/MT for MGO
Auxiliary engine load of 2MW for all auxiliary generators during hotelling, cruising, and maneuvering
Auxiliary generators are medium speed diesel engines
Ship port visit is 50 hours hotelling, 8 hours transiting, and 2 hours maneuvering (60 total)
Emission factors as follows:

14.7 g NOx/kW-hr with residual (Entec 2002)
13.9 g NOx/kW-hr with MGO (Entec 2002)
1.7 g PM/kW-hr with 2.7% sulfur residual (EPA/Environ 2002)
0.3 g PM.kW-hr with 0.25% sulfur MGO (Entec, 2002)
12.3 g SOx/kW-hr with 2.7% residual (Entec 2002)
1.1 g SOx/kW-hr with 0.25% MGO (Entec 2002)

Specific fuel consumption: 227 g fuel/k/W-hr for IFO 380 and 217 for MGO (ENTEC Table 2.10)
For vessel with fuel tank/pipe modifications necessary: $100k capital cost, 5 trips to a CA port annually, CRF of 0.1294 using 5% interest rate & 10 year project life, work done w/o impact to ship schedule

II. Calculations (w/o ship modifications):

<u>Emission Reductions (for a typical port visit)</u>
NOx: 2,000 kW x (14.7 – 13.9g)/kW-hr x 60 hrs x lb/454 g x Ton/2,000 lbs. = **0.106 Ton (211 lbs) NOx**
PM: 2,000 kW x (01.7 – 0.3g)/kW-hr x 60 hrs x lb/454 g x Ton/2,000 lbs. **= 0.185 Ton (370 lbs) PM**
SO_2: 2,000 kW x (12.3 – 1.1g)/kW-hr x 60 hrs x lb/454 g x Ton/2,000 lbs. **= 1.48 Ton (2960 lbs) SO_2**

<u>Cost</u>
Bunker: 2,000 kW x 227 g fuel/kW-hr x 60 hrs. x lb/454 g x Ton/2,000 lbs x tonne/1.1 ton x $247/tonne = $6,736
MGO: 2,000 kW x 217 g fuel/kW-hr x 60 hrs. x lb/454 g x Ton/2,000 lbs x tonne/1.1 ton x $469/tonne = $12,227

Cost Increase: **$5,491 (for a typical visit per assumptions above)**

Cost Effectiveness

NOx: $5,491/0.106 Ton = **$51,800/Ton**
PM: $5,491/0.185 Ton = **$29,700/Ton**
SOx: $5,491/1.48 Ton = **$3710/Ton**
Combined NOx/SOx/PM: $5,491/1.77 Ton = **$3,100/Ton**

II. Calculations (with ship modifications):

Emission Reductions (same as above multiplied by 5 for five annual port visits)
NOx: 0.106 Ton (211 lbs) NOx x 5 **= 0.53 Ton (1,055 lbs)**
PM: 0.185 Ton (370 lbs) PM x 5 **= 0.925 (1850 lbs)**
SO_2: 1.48 Ton (2960 lbs) SO_2 x 5 **= 7.4 (14,800 lbs)**

Total Cost

Fuel Increase: $5,491 x 5 **=** $27,455
Capital Cost: $100,000 x 0.1294 = $12, 943
Total Cost**: $40,398**

Cost Effectiveness

NOx: $40,398/0.53 Ton = **$76,200/Ton**
PM: $40,398/0.925 Ton = **$43,700/Ton**
SOx: $40,398/7.4 Ton = **$5,460/Ton**
Combined NOx/SOx/PM: **:** $40,398/8.86 Ton = **$4,560/Ton**