Summary and Analysis of Comments: Control of Emissions of Air Pollution from Locomotive Engines and Marine Compression Ignition Engines Less than 30 Liters Per Cylinder

Chapter 5
Costs and Economic Impacts

Assessment and Standards Division
Office of Transportation and Air Quality
U.S. Environmental Protection Agency

EPA United States Environmental Protection Agency

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5. COSTS AND ECONOMIC IMPACTS

What We Proposed:

The comments in this section correspond to Section V of the preamble to the proposed rule, and are targeted at the costs and economic impacts of the program. A summary of the comments received, as well as our response to those comments, are located below.

5.1 Engineering Costs

What Commenters Said:

Tidewater Inc., (Tidewater) commented that the NPRM seems to insist on carrying forward the Highway model; one engine per vehicle. The commenter noted that there is no discussion in the rule under consideration about any sharing of exhaust treatment, not even for Tier 4 engines. The commenter stated that it believes that there may be possibilities of integrating some of the vessel's 'hotel' systems such as sanitary and or heating or cooling systems in such a way that could trap or otherwise reduce emissions and associated power requirements. The commenter also stated that it believes this option probably has not been explored since the vision of Engine and Environmental control manufacturers tend to focus on single engine packages. The commenter stated that the NPRM does not seem to allow for any such holistic solutions that may address emissions of the whole vessel, rather than each engine individually.

Tidewater noted that the design, fabrication, and operations of marine vessels entirely different from the model for locomotives. The commenter stated that it is not sure what the asking price of a locomotive is, but suspected that the cost of the diesel engine is about 90% of that cost, and that the locomotive is designed around the engine. The commenter then noted that on a typical maritime vessel the cost of the engine is closer to 10%. The commenter noted that it has seen costs for new construction vessels (talking about off-shore vessels (OSVs)) between $ 20,000,000 and $ 40,000,000, depending on capabilities. The commenter stated that it believes this inversion of cost ratios reflects a basic divergence in the importance of engines to vessel design between locomotives and commercial marine vessels.

The Engine Manufacturers Association (EMA) commented that care must be taken to ensure that the cost impacts of the marine engine emission standards to do not rise to the level where they threaten to undermine the ability of domestic vessel manufacturers and operators to compete effectively in the maritime industry. The commenter stated that it believes that the aftertreatment, fuel, and urea costs presented in the NPRM are understated—such that the total costs are likely to be much higher than indicated. The commenter stated that the impact of increased backpressure on fuel consumption is thus a key issue. The commenter noted that increased aftertreatment backpressure allows smaller aftertreatment systems but can cause higher fuel consumption, which implies that the increased backpressure expected from aftertreatment installations will increase engine fuel consumption.

EMA also stated that it completed a preliminary analysis of the potential cost impacts of the proposed Tier 3 and Tier 4 standards for marine engines. EMA worked with TIAX, LLC to construct an engine cost model that would take anticipated capital and operating expenses into account. This analysis focused on the engine cost impacts of the proposed Tier 4 standards, as applied to commercial marine vessels powered by engines greater than 600 kW. TIAX began by assessing what baseline engine-out emissions were likely to be before utilization of selective catalytic reduction (SCR) and diesel particulate filter (DPF) aftertreatment systems, and then analyzed the relative size and efficiencies (and thus costs) of the aftertreatment systems that would be required to meet the proposed Tier 4 standards. The commenter noted that the TIAX analysis focused solely on engine-related costs, not on the "additional and very significant" costs associated with redesigning and building new vessels to accommodate the anticipated Tier 4 aftertreatment systems. The cost analysis[1], focused specifically on three general applications of commercial marine engines - engines used in tugboats, ferries, and trawlers. TIAX made the following considerations for each of those applications: the size and efficiency of the aftertreatment systems that would be required, the component costs of those aftertreatment systems, the catalyst volume ratios, the catalyst filter lives, the urea consumption rates, and the impacts on engine maintenance and fuel efficiency. The commenter noted that pages 34-36 of the TIAX analysis (Docket Number OAR-2003-0190-0575.1, p.66) shows the modeled capital cost impacts on the three general applications of commercial marine engines.

EMA commented that the modeled capital cost impacts estimated by TIAX are significantly higher than the cost impacts presented in the proposed rule. The commenter specifically noted EPA's estimated per engine capital costs for compliance with the Tier 4 standards in 2016 ranging from $17,300 (for Category 1 (C1) engines) to $64,100 (for Category 2 (C2) engines) (72 FR 16018). The commenter noted that the TIAX cost analysis suggests that these capital costs may have been underestimated by as much as a factor of 3 to 5 on a per engine basis.

EMA commented that the TIAX cost analysis also assessed the engine-related operating cost impacts of the proposed Tier 4 rulemaking. The commenter noted that TIAX found (as did EPA) that urea costs will be the dominant operating cost occasioned by the aftertreatment-forcing Tier 4 standards. The commenter noted that TIAX projected (pp.37-39 of the TIAX report) urea consumption rates as high as 6.8% to 10.8% of the engine's diesel fuel consumption rate, whereas EPA projected a 4% urea consumption rate (Draft Regulatory Impact Analysis (RIA), p.5-62). The commenter also noted that a 1% fuel consumption penalty (due to higher exhaust back-pressures) was estimated in the rule, which is in line with TIAX's assessment. The commenter stated that, overall, the TIAX analysis equates the operating cost impacts of the Tier 4 standards (specifically, in the tugboat application) to a 4% fuel economy penalty, which equates to approximately $360,000 per year—which the commenter believes indicates that the operating cost impacts may double what EPA projected. EMA suggested that EPA reassess and

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1 See Appendix D of EMA's public comments- docket numbers OAR-2003-0190-0584.1, 0585.1, 0586.1.

restate the cost analyses before finalizing the rule.

The Passenger Vessel Association (PVA) commented that it believes this rule will have a negative impact on the passenger vessel industry and small businesses. The commenter stated that the NPRM did not consider the costs of the proposed regulations on the ultimate consumer. The commenter further noted that the cost of new engines and in some cases, associated aftertreatment, falls squarely on the entrepreneurial, family-owned businesses of the passenger vessel industry. PVA stated that specific cost impacts on its members and industry at-large are known to be substantial but are not able to be estimated due to the lack of individual corporate and industry aggregate data. The commenter also noted that many of the small businesses represented in the industry are supported by ancillary non-seasonal businesses and other small business endeavors and related businesses using vessel business assets such as catering. The commenter stated that many public operations are supported, in part, through subsidies while private industry generally must cover expenses on a daily basis; and that both may be constrained to recover costs imposed by the rule by unsympathetic public utility commissions, unfavorable business cycles, and/or competition for discretionary spending (landside restaurants, amusements, museums, aquariums, etc). The commenter noted anecdotally that multiple operators have said that a good year is one where business is strong enough to pay off last year's loans and show enough profit to be credit-worthy enough to borrow in the upcoming off season.

General Electric Transportation (GE) also commented that it believes the Draft RIA substantially underestimated the cost of achieving the standards. GE noted that the proposal indicated that EPA relied heavily on the transfer of learning from the truck and nonroad sectors to reduce the costs for locomotive and marine engines. The commenter stated that, due to the unique nature of the locomotive application, and considering that a significant portion of the cost is operational, it believes that the ability to leverage the truck and nonroad sectors is limited. The commenter stated that in its analysis of the expected costs of compliance with the regulation, that analysis has highlighted areas where EPA either: (1) severely underestimated the cost; or (2) failed to identify costs that will be incurred. The commenter further stated that it believes that the Draft RIA and Notice of Proposed Rulemaking (NPRM) took little or no account of the significant redesign that will be required for the locomotive, the unique operating environment as compared to trucks, or the need for increased reliability (since trucks can break down and pull off the highway but trains cannot simply pull off the tracks).

GE commented that for its cost analysis, it used both fixed costs (engineering development, design, and validation of the new locomotive requirements) and operational costs (the cost of operating the locomotive throughout its life). GE commented that it believes that the research and development (R&D) costs estimated in the proposal are underestimated. GE estimates that, for GE only, the corporate R&D would be $20.6 million versus the EPA estimate of $14.9 million for the entire locomotive industry (note that the commenter's dollar figures are net present values at 3%). The commenter further stated that the engine-line research is also underestimated – GE-only for Tier 3, $12.0 million versus EPA estimate for the industry of $2.8 million; GE-only for Tier 4, $42.4 million versus EPA estimate for the industry of $5.1 million. GE also estimates $47.0 million for miscellaneous development where EPA estimated $2.1 million. In total, the commenter estimates the GE-only research at $124.3 million as compared to the EPA estimate for the entire industry of $27.1 million. The commenter also stated that it disagrees with EPA with regard to hardware costs and operating costs, with the GE-only costs estimated at $9.5 billion versus the EPA estimate for the locomotive and marine industries of $1.2 billion (note that these costs are net present values at 7%). The driver of the disparity here is attributed by the commenter to be the difference in DPF costs ($82,500 estimated by GE versus $62,600 estimated by EPA) and SCR costs ($153,000 estimated by GE versus $82,500 estimated by EPA) which result in a $1.5 billion difference between the commenter and EPA. The operating cost differential of $6.8 billion are attributed by the commenter to result from EPA underestimating DPF maintenance costs, overstating the DPF maintenance interval, ignoring SCR maintenance costs, underestimating urea consumption by 20%, and understating the urea cost ($2.27/gallon estimated by the commenter versus $1/gallon by EPA). The commenter argued that EPA includes no costs for overhaul of aftertreatment devices which, the commenter believes, will require some level of overhaul during their operational life. Finally, the commenter stated that EPA has underestimated the fuel impact by estimating the fuel consumption penalty at 1% versus 1.5% by the commenter, estimating the fuel cost at $1.28/gallon versus $2.20 by the commenter, and estimating no fuel impact due to the SCR system versus an 8% fuel consumption penalty necessary to compensate for SCR deterioration over time. GE noted that the statutory language that EPA invokes clearly requires standards to be achievable in light of the costs imposed and the time frame available to achieve them. Moreover, the commenter stated, EPA is required to consider the energy impacts - particularly where such impacts would increase greenhouse gases. GE further commented that it believes EPA's determination that use of SCR would not lead to increased fuel costs is facially invalid and must be corrected. Lastly, GE stated that, while EPA may well decide that the costs of a rule are outweighed by its expected benefits, it is inconsistent with the statutory language on which EPA relies to substantially underestimate the costs of a rule in making an achievability determination.

Letters:
Engine Manufacturers Association (EMA) OAR-2003-0190-0575.1
General Electric Transportation (GE) OAR-2003-0190-0590.1
Passenger Vessel Association (PVA) OAR-2003-0190-0576.1
Tidewater Inc. OAR-2003-0190-0557

Our Response:

With regard to the Tidewater comment about the NPRM insisting on carrying forward the highway model – one engine per vehicle. This is not the case. We are supportive of manufacturers finding inventive ways of complying with the emissions standards. This has always been our approach – to set performance standards rather than design standards thereby leaving the design open for ingenuity on the part of industry. For our cost analysis, it is simply most straight forward to estimate a set of aftertreatment devices for each engine rather than estimating how many engines may be "bundled" together to take advantage of a single large set of aftertreatment devices. This costing methodology by no means prohibits industry from doing otherwise provided they meet the standards.

GE commented that we had underestimated the R&D costs and pointed out that we relied heavily on a transfer of learning from highway and other sectors to the locomotive and marine sectors. GE disagrees with our expectation of such a transfer, but bases their disagreement on the fact that most of the costs are operating costs thus making the ability to leverage the truck and nonroad sectors limited. The comment does not address whether or not the transfer of learning could occur with respect to R&D, which is the only place we argued that the transfer would occur. Hence, we continue to believe that GE can, will, and probably already has learned from other industries. GE estimates their corporate R&D expense to be $20.6 million, versus our estimate of $14.9 million for the entire locomotive line-haul industry. What was not clear in our draft analysis is that we estimated corporate R&D expenditures by manufacturer and then allocated those expenditures across the market segments into which the manufacturer was expected to sell engines. As such, we actually had estimated that GE would spend $19.1 million on corporate R&D, or roughly $15 million discounted at 3%. We allocated half of GE's R&D to locomotive line-haul, and half to marine C2. We did the same with the other locomotive line-haul manufacturer, EMD. The result being the $14.9 million estimate allocated to line-haul. Therefore, once we compare the appropriate numbers, we actually estimated GE's corporate R&D to be $15 million while GE estimated their corporate R&D to be $20.6 million. Were we to eliminate our expectation for learning transfer, we would estimate GE's corporate R&D at roughly $30 million (3% net present value (NPV)). While we disagree strongly with GE's assertion that learning is unlikely to occur, we have adjusted our expected learning effects such that manufacturers selling only into the locomotive and marine sectors will incur 70% of the corporate R&D incurred for the 2007 highway rule while the draft analysis used a factor of 49% (70% x 70%). As a result, our corporate R&D estimates line up with GE's estimated corporate R&D. While we do not necessarily believe that this is a more correct estimate than that in our draft analysis, we prefer to be conservative. Note that we have made this change not only for GE but for any manufacturer that sells only into the locomotive and marine markets and is expected to have corporate R&D expenditures for Tier 4.

GE also provided details regarding what we termed "engine-line R&D" in our draft analysis, and they point out a considerable discrepancy between our estimate of $2.8 million and $5.1 million for Tiers 3 and 4, respectively (3% NPVs for the entire locomotive line-haul industry). In contrast, GE estimates GE-only costs of $12 million and $42.4 million for Tiers 3 and 4, respectively. According to our database, GE builds two engines, a 12 and a 16 cylinder engine that are, by our analysis, built on the same engine line given that both engines have 10.9 liters/cylinder so are, we estimate, built on the same engine line. Importantly, we estimated Tier 3 R&D of $1.6 million/line and Tier 4 R&D of $6.5 million/line. Therefore, we actually estimated GE's engine-line research at $8.1 million (~$7.4 million NPV at 3%). Clearly, our estimate is much lower than GE's, but we wanted to clarify our estimates and how they pertain to GE-only versus the industry. The EPA numbers pointed to by GE as industry estimates distribute costs over loco and marine engines which GE does not clarify in their comments. Based on GE's input and in the interests of being conservative, we have revised our final analysis such that both GE and EMD will incur engine-line R&D of $12 million and $42 million for Tiers 3 and 4, respectively (3% NPVs).

In their comments, EMA provided a breakdown of aftertreatment device costs for marine applications that differ from those estimated in our draft analysis. However, considerable differences exist between the two methodologies making comparisons difficult. Notably, EMA estimated no learning effects, as we did, and EMA estimated larger device volumes relative to the engine displacement than estimated by EPA. Note that, for the final analysis, we have revised our diesel oxidation (DOC) volume to engine displacement ratio to be 0.8:1 which is consistent with our technological feasibility write up (in the draft analysis, we used a ratio of 0.5:1). That change has little impact on our results or the discrepancy between our estimates and EMA's. The table below shows a summary of the EMA estimates along with our best attempt at presenting our costs in EMA's format to make comparisons easier.

Source	Engine displacement per EMA comments (L) →	34	107.5	164	277.5
EPA	Catalyst size (L)	85	269	410	694
	Catalyst+canning ($)	5838	17588	26621	44767
	Injectors (reductant dosing & controls)	1306	3070	4425	7148
	Housing & mixing duct (vessel hardware)	2666	2934	4141	4555
	NOx sensor	200	200	200	200
	Markup	1313	3319	4861	7959
	Total	11323	27112	40248	64629
EMA	Catalyst size (L)	136	430	656	1110
	Catalyst+canning ($)	3136	9915	15128	25594
	Injectors (reductant dosing & controls)	1500	3000	6000	10500
	Housing & mixing duct (vessel hardware)	7585	16710	18183	20200
	NOx sensor	3500	3500	3500	3500
	Markup	4716	9938	12843	17938
	Total	20437	43063	55564	77732

Discrepancies exist in the catalyst sizing where EMA estimated 4x engine displacement to our 2.5x, the catalyst+canning costs (where EPA is actually higher), and the reductant dosing systems (at least for the larger engines and larger SCR systems). But, the largest discrepancies exist in the housing and mixing duct costs (which we termed vessel hardware and SCR marinizing and did not include as SCR system costs in our draft analysis), the NOx sensor costs and markups. Regarding catalyst sizing, our cost estimate is consistent with our technological feasibility argument so we refer the reader to Chapter 4 of the Final RIA. As for the reductant dosing system, we believe that the controls for such should not vary by engine size so that the only varying cost should be the dosing hardware. Our cost estimates actually agree for the smaller systems, despite our lower SCR system volumes. However, for the larger engines, EMA's estimate doubles for a system only 52% larger than their 430 liter system, and then increases another 75% for a system 70% larger than their 656 liter system. By contrast, our estimates increase 44% for a system 52% larger and again 62% for a system 69% larger. It appears that this is a result of EMA's scaling of these systems with reductant volume flow by application rather than by engine size. Such an approach further exacerbates the difficulty of making a direct comparison of cost estimates. We also find it difficult to understand EMA's estimates for NOx sensor costs. These sensors need to measure NOx concentration and one per exhaust run would be sufficient. The sensors needed for marine applications (and locomotive applications for that matter), are not any larger than those needed for highway and/or nonroad applications where cost estimates of less than $200 are becoming the norm. Also, our markups are considerably different, with EMA's stated as a flat 30% without any detail as to what is covered by that markup. Our markups are detailed as labor overhead at 40%, warranty at a 3%

claim rate, manufacturer carrying cost at 4% and dealer carrying cost at 3%. Lastly, our estimates include learning factors (not presented in the table above) while EMA's did not. Our learning factors, which are consistent with most of our recent rulemaking cost analyses, result in costs decreasing by roughly 20% at each learning step. In our methodology, we estimated that one such learning step will occur before the Tier 4 standards take effect. That learning step is a result of our Tier 2 light-duty highway rule, our 2007 heavy-duty highway rule, and our nonroad Tier 4 rule. We then estimated yet another learning step two years into the Tier 4 standards. In contrast, EMA appears to have estimated no learning in their estimates despite several years between now and Tier 4 implementation. In the end, our estimates are consistent with what we are told in confidential meetings by suppliers, although this is a claim also made by EMA.

Similar comparisons can be made between the DPF and DOC estimates in our draft cost analysis versus those in the EMA comments. Again, the largest discrepancies are injector costs which EMA estimated to range from $1,500 to $4,500 per engine, depending on size, while we estimated no costs for injectors because we believe that DPF regeneration can be controlled via in-cylinder fuel controls. We also have the same type of discrepancies in what EMA terms housing and mixing duct costs, markup costs, and learning factors as described above for SCR systems.

GE also provided estimates for aftertreatment devices -- $82,500 for a DPF and $153,000 for SCR, both are per-locomotive costs – versus our lower estimates. However, GE provided no details, stating only that their estimates were based on input from the aftertreatment industry.

After reviewing and analyzing the comments and associated aftertreatment cost estimates, we continue to believe that our estimates are good and can see no reason to revise them, except in the area of vessel related costs associated with the aftertreatment devices. The EMA comments also included SCR-related costs at the vessel level. Those costs were also higher than our costs and included costs for reductant tank heaters, pumps, and a reductant dosing panel with controls. We believe that costs for these elements were not adequately characterized in our draft analysis and have included them in our final analysis. However, we still differ from EMA with respect to reductant tank size and related costs, where our costs are lower due, in part, to our estimate of a 4% reductant consumption rate (reductant consumption = 4% of fuel consumption) while EMA estimated a rate between 6.8% and 10.8%. Also, for our final analysis, we have removed the reductant tank and dosing controls from our SCR costs and included them instead in our vessel (or equipment) related costs. As a result, our SCR costs appear to have decreased slightly (due to removal of reductant tank, etc.) while our vessel (equipment) related costs have increased.

5.2 Cost Effectiveness

What Commenters Said:

The Northeast States for Coordinated Air Use Management (NESCAUM) commented that, according to its review of the Draft RIA, the combined NOx-PM reduction cost-effectiveness of the locomotive remanufacturing standard is approximately $456 per ton in the year 2020. The commenter stated that it believes the locomotive remanufacturing component of the regulation is extremely cost-effective, compared to other strategies available to the Northeast States.

Letters:
Northeast States for Coordinated Air Use Management (NESCAUM) OAR-2003-0190- 0551.1

Our Response:

We agree with the commenter.