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**To**: Daniel Hawelti

California Air Resources Board

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**From:** Dawn Fenton

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**Subject**: **Volvo Group Comments on CARB Draft Technology Assessment: Lower NOx Heavy-Duty Diesel Engines**

**Introduction**

Volvo Group appreciates the opportunity to comment on the technology assessment “Draft Heavy-Duty Technology Assessment: Lower NOx Heavy-Duty Diesel Engines, September 2015,” by the California Air Resources Board. We welcome a methodical approach to assess the technical readiness, feasibility, suitability and impacts of various technologies as a matter of responsible policy development and rulemaking process. Volvo recognizes that this is a challenging and complex task, and we stand ready to assist. We reference the sections and page numbers of the document in our comments.

Volvo Group is one of the world’s leading manufacturers of trucks, buses, construction equipment and marine and industrial engines. The Group also provides complete solutions for financing and service. Volvo Group, which employs some 100,000 people worldwide, has production facilities in 19 countries and sells its products in more than 190 markets. In the United States, Volvo Group employs 12,000 people and has nine manufacturing plants in six states.

The staff report looks at the challenges of creating lower NOx heavy-duty diesel engines during the next five-to-ten years, while preserving capability to meet future greenhouse gas (GHG) regulated requirements. The report concludes that “the extent of further NOx reductions remain to be determined, but progress certainly is possible.” Volvo’s view is that the technical and regulatory communities are just at the starting point of this journey, but we are hopeful that technically capable, reliable, durable, and commercially viable solutions can be developed to achieve these goals. Many of the systems, especially aftertreatment enhancements, are at the research phase, with true costs and long term capabilities still unknown. We believe it’s premature to characterize the report as a “technology assessment”, because, as the report states, the technologies have not yet been evaluated for their effectiveness toward the targets, nor have their associated compromises or costs been quantified. The report offers a broad array of technical solutions for consideration in this effort and opens the discussion about advantages and limitations, and it is very useful for this purpose.

In moving forward, there are specific issues which future reports must appropriately and technically consider before drawing conclusions:

* Successful demonstration of the Federal Test Procedure is an important, but not singular goal in the effort to reduce NOx emissions from heavy-duty vehicles. The technology evaluation must also include compliance with Not-to-Exceed requirements, and even more importantly, consideration for the array of duty cycles witnessed in the real world, especially those involving light loads and stop-and-go operations prevalent in urban areas and congested freeways. While mentioned in the subject report, these operating modes must be part of the basis for evaluation in the technology assessment process if significant emissions reductions are truly to be achieved in the most challenged areas of California and elsewhere.
* Implications on weight, packaging constraints, maintenance requirements, and regulated diagnostic requirements must also be considered as part of any assessments of new technology viability.
* While Volvo agrees that there are many policy options that could significantly contribute to the reduction of ozone in California, the report should not confuse such policy issues with technology issues. For example, “improvements to in-use compliance programs” does not contribute to a discussion about “using engine-based strategies and…advanced catalyst formulations” (p.III-1).

Volvo Group agrees that there are a sufficient number of technologies available to lend some optimism to early demonstrations of significant NOx reductions, and Volvo Group looks forward to supporting the work to determine if durable, commercially viable technology packages can be defined through a rigorous, data-driven process. The small measure of technical content in the report appears to be based on information from an engine manufacturer and from exhaust aftertreatment suppliers. The Volvo Group approaches technology evaluation to include integration of the engine and aftertreatment systems into the powertrain and ultimately the complete vehicle. The report acknowledges on page III-1: “It is not expected that a single emission control strategy will reduce emissions significantly on its own.” Careful integration of multiple new technologies with a systems engineering approach is absolutely critical to understanding the advantages and limitations of technology combinations. Incorporating a low-NOx engine into a vehicle must provide our customers with the ability to safely and efficiently perform their duties. Compromises to performance or fuel economy must be considered.

**Technical issues**

On ES-4, comparisons are made between diesel and natural gas engine emissions. In the heavy-duty market, appropriate engine applications should be based on duty-cycle, since natural gas engines are typically relegated to the lower performance end of the Class 7-8 market due to their reduced torque and limited operating range (some of those limitations and more are noted on ES-5). This is why, despite the promise of future lower-NOx natural gas engines, they do not serve as a potential replacement for diesels in many segments.

On ES-6, the report describes the Southwest Research project investigating low-NOx engine technology, noting that this project is expected to be completed by the end of 2016. Later in the report (V-1) the project is described in more detail. We draw two conclusions from this portion of the report:

1. Definitive conclusions about different technologies cannot yet be drawn because the test is still in process; and
2. Even when the test is complete, it represents only the first step toward assessing low-NOx engine and aftertreatment technologies. Additional evaluation on real world cycles at the vehicle level, as well as NTE compliance capability, diagnostic functions, weight, packaging, durability, reliability, maintenance requirements and other factors will be necessary, along with an assessment of product, development, and maintenance costs.

Page ES-9 refers to the Southwest Research project, and its goal to demonstrate 0.02 g/bhp-hr NOx emissions while complying with other standards and “not incur a GHG penalty”. Because the foreseen timeframe for regulated low NOx requirements is in the 2023+ timeframe, the demonstration should include capability to meet engine greenhouse gas targets in that timeframe. This would imply a GHG target equivalent to the 2024 or even 2027 levels proposed by EPA and NHTSA in the recently proposed GHG Phase 2 rule for medium- and heavy-duty vehicles. Staff should also consider whether even more ambitious GHG targets should be set for this technology assessment work, as CARB has stated on numerous occasions that they intend to promulgate more aggressive targets than EPA and NHTSA should they remain as proposed in the final rule.

The need to respect GHG and fuel consumption targets in the modern era is obvious, but the sensitivity to fuel consumption should be maintained in all technology considerations. Many of the technologies proposed for evaluation have power demand and fuel consumption implications (close-coupled SCR catalyst, heated ammonia generation, air-assisted urea injectors, electrically heated catalyst, exhaust fuel burners, wastegate turbocharger, increased idle speed, in-cylinder post injection, intake air throttling, and higher EGR rates). The accounting of all these impacts when combining technology sets should be maintained during all phases of this effort to ensure the GHG targets can be fulfilled.

It is also important that the SwRI demonstration (extended to all regulatory requirements and real-world performance as described earlier) meet the 0.05 g/bhp-hr N2O target proposed in Phase 2, because N2O is an important parameter in aftertreatment NOx control, and is sensitive to many of the modifications being considered in the project.

On ES-9, the report notes that manufacturers typically certify their engines to levels below the standard to “protect themselves against non-compliance due to minor increases in emissions in-use,” and to “include deterioration factors to account for any increase in emissions over the useful life.” The report then states that manufacturers today have compliance margins of 10-to-60% below the current standard, and, coupled with statements from an engine manufacturer, concludes that “diesel engines are likely to be certified to the optional NOx emission standard of 0.10 g/bhp-hr by 2016.” And later, at page VI-1, the report concludes that this achievement can be reached “at minimal or zero” technology development cost. The report should clarify that, while perhaps some subset of engine manufacturers *may* have plans to certify diesel engines to 0.10 g/bhp-hr for the 2016 model year (if CARB has such knowledge), CARB does not foresee that most diesel engine manufacturers will be capable of certifying their 2016 engines to that level. The compliance margins observed in the certification data are indeed necessary to ensure compliance to all regulated requirements, and manufacturers will certainly need to maintain proportionate margins for any reduced certification levels as well.

Several technologies are described as being interesting by virtue of their low thermal mass because they are thereby capable to heat up to effective levels quickly in an FTP. As mentioned earlier, FTP capability is less important than real-world capability, and the simple fact is that the ability to heat up quickly also results in cooling down quickly. This means that emissions performance will be compromised more quickly upon entering light load or stop-and-go conditions.

In a similar vein, certain technologies such as NOx adsorbers and ammonia storage devices may prove to be effective in limited, short-duration operating conditions, such as during an FTP demonstration, but would be saturated (NOx adsorbers) or depleted (ammonia storage devices) beyond effectiveness in many real-world operating regimes.

More generally speaking, technologies that have been adapted from light-duty applications, such as thin-wall substrates, should not be assumed capable to survive in the heavy-duty environment. Peak exhaust temperatures driven by full load operation are experienced only rarely and for a few seconds in light-duty applications, compared to frequent or sustained periods of several minutes in heavy-duty applications when accelerating or climbing a hill. Moreover, the regulated and expected useful life is much longer in the heavy-duty sector than in the light-duty sector.

**Technology Costs**

Page ES-10 includes an estimation by the Manufacturers of Emissions Control Association that the “incremental cost of future advanced technologies” to achieve 0.02 g/bhp-hr NOx to be approximately $500. It is far too early in this investigation to make any reasonable estimation of costs, as the research is not at all close to demonstrating technical capability, especially considering the full range of requirements that effective commercial systems must meet. Likewise, neither the makeup of this cost figure, nor an adequate description of the components and systems that theoretically make up this figure were provided. Volvo is concerned that uninformed parties will be quick to capture this figure without merit, and recommends it be removed from the assessment, or, at minimum, be appropriately represented as preliminary speculation without substantiation.

Cost implications should not be studied only on the basis of incremental component costs nor should they be based on optimistic projections of suppliers eager to have products ushered into the market place by regulation. Development costs, supporting hardware, control module and sensor requirements, operating costs, maintenance costs, and increased warranty costs should all be included in any cost estimation. Fuel consumption rates are inherent to the controls of the program, but increases in urea consumption rates will be important to understanding operating costs. To what extent will the NOx sensor be depended upon in the control scheme at these very low levels, and with what long-term accuracy requirements and associated cost increase? OBD development and demonstration costs represent a significant portion of R&D expense for manufacturers today and should not be excluded from consideration in this analysis.

The GHG Phase 2 regulation, and any additional stringency imposed by CARB to meet California’s ambitious climate change goals, will require huge product development investments and impose significant resource demands on the heavy-duty truck and engine industries. Manufacturer resources were heavily stressed to deliver singular technologies in the “Clean Diesel” development era (EGR for 2004, DPFs for 2007, and SCR for 2010). GHG Phase 2 regulation, by contrast, proposes the launch of multiple complex new technology packages simultaneously, aimed at different market segments. Adding Low NOx technology development and deployment will be an enormous burden, so it will be important to accurately assess all these costs and development challenges.

Volume impacts should also be considered, because we don’t know the full regulatory landscape for lower NOx in the US. If California’s uniquely challenging air quality issues are addressed via a non-harmonized CARB NOx standard, the incremental costs will be even higher than those built on assumption of nationwide sales volumes.

In “Next Steps” (p. IX-1), the report notes that “ARB should continue to provide incentive funding for low-NOx heavy-duty engines to encourage engine manufacturers to develop and certify engines that meet the optional NOx standards.” The incentives will be critical because the customer does not derive direct operational benefit from low NOx technologies. Manufacturers will require significant, long-term incentive commitments to have the confidence to foresee an active market for low NOx products before launching the investments necessary to industrialize them.

**Closing comments**

The heavy-duty sector is coming off a decade of dramatic improvements to traditional diesel engine technology. While advances have been significant, there has also been a learning curve associated with the integration of these new technologies. In fact, those technologies are still striving to attain full acceptance in the market and have even spawned new markets for glider kit vehicles that avoid these emissions systems. CARB’s concerns expressed in various fora about durability and warranty issues are testament to the fact that this “learning curve” is ongoing. Volvo fully agrees with CARB’s view that “heavy-duty diesel internal combustion engines will continue to play a major role in the passenger and freight transportation industry of the nation.” Manufacturers will be heavily taxed to develop the high efficiency and low NOx technologies of the future and customers will avoid new products with high cost and poor reliability. It’s for these reasons that it’s critical that the identification, development, and regulation of low NOx technologies be conducted with careful analysis and data-driven decisions. Adequate time must be given to the complete validation process. Missteps can lead to premature technology offerings of marginal interest to fleets and owner-operators, which will only serve to delay the implementation of the cleanest, most efficient technologies.

Volvo fully supports ARB’s call for an “integrated approach” to developing and deploying advanced technologies as stated in the Technology Assessment Overview released in April. Such an approach will lead to greater consideration of whole vehicle emissions and performance. It also would strongly suggest that ARB look beyond engine regulations as the sole method of measuring progress on many environmental issues. Integration should refer not only to the intersection between the fueling infrastructure and the vehicle, but also to the integration of emission reductions gained from improvements to the complete vehicle – not just to the engine.

Volvo continues to encourage CARB to implement policies that can bring significant reductions to NOx emissions without technology development, such as accelerating the pace of replacement of older, higher emitting vehicles. We also remind you that giving manufacturers the flexibility to implement *vehicle* efficiency technologies according to customer needs, rather than imposing strict engine standards, enables the inherent NOx reductions that come from reduced engine work demand through aerodynamics and reduced rolling resistance where effective.