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Building an Environmentally & Socially Responsible Future

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October 10, 2014

Mr. Todd Sax, Assistant Chief
Mobile Source Control Division
California Air Resources Board
Via Web Upload

Re: Comments on Technology and Fuels Assessment Workshops

Dear Mr. Sax:

On behalf of Gladstein, Neandross & Associates LLC, (GNA), I am pleased to submit these comments regarding the Technology and Fuels Assessment workshops conducted by ARB in September 2014. GNA is one of America's leading consulting firms for transportation energy, fuels and emissions issues. For more than two decades, our scientists and engineers have been working closely with government agencies, vehicle manufacturers, fuel providers and end user fleets to commercialize and deploy progressively lower-emitting transportation technologies.

We commend ARB staff for preparing this comprehensive review of the many complex issues associated with simultaneously restoring healthful ambient air quality, mitigating climate change, and fostering economic growth in California. We profoundly understand the tough challenges you face. Our comments below are arranged by the date of each workshop, and the various Power Point presentations used by staff to lead discussions.

Overarching comments for all three workshops

- We suggest clarifying the final output that ARB will use for its Technology and Fuels Assessment. It's unclear if this will be revisions to the Power Point decks, or some type of report / narrative. We recommend the latter, to better cover all the nuances of these complex issues.

- We concur with ARB's focus on ZEV technologies. Clearly, California's ability to meet aggressive, essential goals for improving ambient air quality and mitigating climate change must heavily rely on non-combustion technologies such as BEVs and FCVs. While there are many challenges to address, such technologies will need to systematically penetrate non-road goods movement sectors that are currently powered almost exclusively by large diesel engines. However, progress towards achieving zero tailpipe emissions will continue to be iterative and gradual; this is especially true for large non-road applications. The Assessment slides acknowledge this by implying that diesel ICE vehicles are likely to be dominant in the goods movement sector for decades to come. Many slides describe technological approaches through which diesel engines are expected to remain viable and continue reducing emissions of criteria pollutants, air toxics and GHGs. Tough

tradeoffs associated with achieving these objectives are acknowledged, but characterized as being "solvable."

- By contrast, the tone on alternative fuel ICE engines significantly seems less optimistic about their future role in California's transportation sector. We recommend expanded discussions about the strong potential for heavy-duty natural gas engines, in particular, to play major roles in California's long-term, sustainable goods movement systems. This is not just because natural-gas-fueled ICE vehicles and vessels are immediately available to reduce ozone-precursor and restore healthful air quality in our urban areas. They are on the long-term path to provide *near-zero* criteria pollutant and very low fuel-cycle GHG emissions.

- ARB should be consistent in its message about this important issue. In July 2014 the Board approved $250,000 in state funding for a research proposal from UC-Davis (#2780-279), entitled "Potential to Build Current Natural Gas Infrastructure to Accommodate the Future Conversion to Near-Zero Transportation Technology." The specific justification for this award provided by ARB staff was the following (bold text added):

  > *"In accordance with Health and Safety Code section 39701, research is needed to provide strategies to maximize the current market penetration of fuel infrastructure that can accommodate alternative fuels in the long-term,* ***which will ease the transition to a zero or near-zero transportation sector in the future****."*[1]

- Heavy-duty natural gas engines – which are already the benchmark for low NOx and PM emissions – will continue to improve in their emissions performance. We agree that diesel engines will continue to make strides to improve their environmental performance. We also strongly believe that heavy-duty natural gas engines have even greater potential to be on a very positive trajectory. While upstream leakage of methane gas is definitely an important issue, leakage rates are rapidly being reduced through industry best practices, market dynamics and regulatory forces. This bodes well for California's ability to meet its very challenging goals in the nexus between energy and environment. In sum, we believe that ARB should better acknowledge and highlight California's clear need to continue deploying progressively lower-emitting natural gas engines, as a key part of our long-term strategy to attain these complex, inter-related environmental goals.

[1] ARB Resolution 14-22, Potential to Build Current Natural Gas Infrastructure to Accommodate Future Conversion to Near-Zero Transportation Technology, ttp://www.arb.ca.gov/board/books/2014/072414/prores1422.pdf

- We recommend that ARB delay making hard conclusions about the relative climate-change implications of heavy-duty vehicle fuels and technologies. Given the tremendous uncertainty about methane leakage – and all the efforts that are underway to better control and characterize this complex phenomenon – it is both premature and counter-productive. We are already seeing a chilling effect on valuable momentum underway today in California by both manufacturers and end users to deploy goods movement vehicles and equipment powered by natural gas engines. Again, heavy-duty NGVs are *cornerstones* of California's ongoing efforts to attain ozone NAAQS and meet other key state environmental / energy objectives. As the facts become better understood via results of the many underway and planned methane leakage studies, it will be possible to make accurate comparisons about the GWP of various transportation fuel pathways.

- We suggest adding a table to describe and differentiate the three main technological approaches to commercializing natural gas engines in high-horsepower goods movement applications: 1) dedicated SI NG engines, 2) dual fuel engines, and 3) direct injection. Differentiating these combustion technologies is important, as there are significant implications to their efficiency, emissions, life cycle costs, and ability to displace diesel fuel.

- A recurring theme through all three workshops was that SCR exhaust aftertreatment can reduce NOx emissions down to very low levels on large diesel engines. The impression is given that SCR-equipped high-horsepower diesel engines will carry California's goods movement sectors well into the future, until ZEV technologies achieve sustainable commercialization. To be more complete in this discussion, we recommend adding a cautionary note that the real-world NOx-reduction performance of SCR-equipped heavy-duty trucks under low-speed, low-load conditions can be quite high. These in-use "off-cycle" NOx emissions from diesel trucks are strong reminders that we should not overly rely on one fuel and technology. We need to complement deployments of SCR-equipped heavy-duty vehicles (across all goods movement sectors) with natural gas engines that are being shown capable of maintaining very low NOx emissions throughout their useful lives. This will significantly improve the likelihood that we can simultaneously meet critical air quality, energy, and economic goals laid out in ARB's Technology Assessment and Sustainable Freight strategy.

Workshop #1 (September 2, 2014): On-Road HDVs (Trucks and Buses)

- We suggest better consistency of language when describing the potential for heavy-duty natural gas engines to meet "near-zero" NOx levels. The slides presented on Day 1 indicated ARB staff are "optimistic" that heavy-duty NG engines can

"eventually" meet the targeted level of 0.02 g/bhp-hr NOx. Later, during Q&A, staff emphasized that this can happen "quickly." We suggest that you consistently use this latter terminology, which we believe to be more accurate based on GNA's extensive experience working with heavy-duty natural gas engine OEMs.

- As ARB notes, heavy-duty hybrid-electric EVs (HEVs) have strong potential to help achieve California's goals in the transportation sector. We agree that in-use emissions from HEVs must be "carefully scrutinized" because of their duty cycle dependency and system integration complexities. Notably, future heavy-duty hybrids fueled by natural gas will probably not need SCR for exhaust aftertreatment; this bodes well for obviating emissions problems involving integration and duty cycle issues.

WORKSHOP 2 (September 3, 2014): TRUs, Rail and Fuels

Rail

- ARB has provided a solid discussion about efforts by locomotive OEMs and the railroads to commercialize and deploy LNG locomotives. While there remain many technical, economic, logistical and regulatory issues to address, large-scale deployments are likely to happen due to compelling life-cycle economics. This is an example of ways that ARB can better integrate its outputs from the Technology Assessment workshops with its goals under the Sustainable Freight initiative, which rightfully puts a strong emphasis on economic competitiveness.

- We recommend that ARB provide discussion about the solid prospects for natural gas locomotive engines to achieve NOx levels significantly below Tier 4 levels, while also yielding significant GHG benefits. Direct injection approaches such as Westport's HPDI technology (~92% diesel substitution) are not sufficiently mentioned in the Rail Handout or other descriptions. Direct-injection natural gas technology is very promising for mainstream use in rail applications. This was evident nearly 20 years ago, when very low NOx levels were achieved under the Gas Rail USA program at SwRI, when tested on a single-cylinder natural gas locomotive engine equipped with late-cycle high-pressure direct injection. This program was able to achieve a NOx reduction of 77% compared to the baseline diesel locomotive engine (NOx levels down to 2.8 g/bhp-hr). Over the last two decades, much more development work has been done to reduce NOx levels from natural gas locomotive engines. And, because direct injection technology utilizes compression ignition (diesel-equivalent efficiency) while achieving very high diesel substitution rates, it has strong potential to meet GHG-reduction goals cited under California's sustainable freight and goods movement strategies.

- ARB's "Rail Handout" table needs additional work for parallel form and objectivity. For example, in the "Operational Considerations" column, hydrogen fuel cell locomotives are listed as being "compatible with national fleet if there's a national infrastructure." LNG locomotives are cited for their "need for tender, NG fueling infrastructure." Of course, fuel cell powered freight trains will also need to include tender cars carrying large volumes of either compressed or liquefied hydrogen. The "Key Challenges" column for the "Fuel Cell" locomotive row has no entry. Is this an oversight? Clearly, there will be many tough challenges associated with fuel cell locomotives.

- We recommend noting that heavy-duty natural gas engines in rail applications will probably not need to be equipped with SCR systems to control NOx. As in all higher-horsepower sectors, this offers an inherent advantage for natural gas as a major rail fuel to deliver and maintain very low lifetime NOx emissions.

Transportation Fuels

- With regard to downstream GHG emissions, such as addressed in the graph on Slide 23 in the "Fuels" presentation, we recommend that ARB more fully summarizes key emerging data from the UC-Riverside and WVU emissions testing programs on heavy-duty trucks. For example, WVU's July 2014 report concluded the following: "The GWP of natural gas vehicles were lower than diesel vehicles for both refuse truck and goods movement application. Methane emissions from natural gas vehicles was not a major contributor to the GWP of exhaust."

- In assuming that diesel and NG tailpipe NOx emissions will be equivalent on future 0.02 g/bhp-hr NOx engines, what has ARB assumed regarding the potential for higher off-cycle NOx emissions from diesel engines at low-speed / low-load conditions?

- We commend ARB for its comprehensive treatment of the complex, rapidly-evolving methane leakage issue. As ARB has described, there is much uncertainty on this subject, there is no standardization of methodology for measuring methane leakage, estimates for leakage rates can vary widely as a function of the methodology used, and there are many new studies and reports underway to better quantify actual leakage rates. Thus, as ARB notes on Slide 57, "high leakage rates in recent studies are unlikely to be representative." We concur. As verified by a recent report released by U.S. EPA, the oil & gas industry has been aggressive about adopting and implementing new "best practices" to dramatically reduce upstream leakage rates. They have recognized that leakage represents valuable lost revenue. We suggest taking a larger focus by recognizing that solutions are rapidly being brought

forth to reduce methane leakage to low levels. The industry is pulling together to be at the forefront of solving this issue, by advocating best practices that can be uniformly implemented across California and America.

- Currently, there is little discussion in the workshop outputs about accounting for / allocating GHG emissions from oil-associated versus non-associated upstream natural gas activities in California. We recommend adding clarity on this important topic. We also recommend providing greater information about the assumptions ARB is making for the future carbon intensity of California's diesel fuel, as the role of unconventional oil increases.

- Several slides in this section and in the Summary portion refer to carbon intensity values cited from CA-GREET 2.0 in the draft LCFS. The methane leakage rates assumed in the GREET 2013 model – and proposed to be adopted into CA-GREET 2.0 – reflect national averages. California natural gas infrastructure is newer than most other regions in the country, resulting in lower Transmission and Distribution leak rates than assumed in the national figures. Using national averages does not accurately reflect the California condition or the best management practices of California utilities and gas transportation systems.

- California receives the majority of its natural gas from within California and four other regions in the U.S. An accurate assessment of the upstream emissions associated with natural gas use in California should recognize the unique attributes of various gas-producing regions, in much the same way that the OPGEE model identifies different carbon intensities for petroleum derived from different regions and geologies.

- We recommend NOT showing (at this time) "break-even points" for CNG- and LNG-fueled heavy-duty vehicles (Slides 83 and 84). This information does more harm than good, by interjecting further uncertainty into an already-complex, poorly defined issue. This will have a chilling effect on valuable momentum underway today in California by both manufacturers and end users to deploy goods movement vehicles and equipment powered by inherently lower-emitting natural gas engines. Heavy-duty NGVs are clearly an essential element of efforts to attain ozone NAAQS and meet other key state environmental / energy objectives. As the facts become better understood via results of many emerging and focused studies, it will be possible to make accurate comparisons about the GWP of various transportation fuel pathways.

- Generally, the workshop slides provide a solid, accurate summary about the benefits and challenges of using RNG and biofuels to meet California's transportation fuel objectives. We recommend additional discussion about the societal benefits of

using RNG as a direct fuel for future ultra-clean heavy-duty NGVs, such as is being done at Waste Management's Altamont Landfill Gas to LNG facility and Clean World's biogas production facility at the Sacramento Transfer Station.

WORKSHOP 3 (September 9, 2014): OGVs, CHC, CHE, and Aviation

- We concur that LNG-powered OGVs will be a key option for marine vessels to meet California's emission-reduction targets. Short-sea shipping applications that are subject to ECA requirements may have particularly compelling economics in favor of LNG use.

- Our comments about potentially high in-use NOx emissions from SCR-equipped diesel engines in other high-horsepower sectors also apply to OGVs, CHC and CHE if they utilize SCR in the future. For OGVs with a 25+ year useful life, it will be especially important to utilize robust low-NOx fuel and technology combinations, such as what can be achieved with LNG marine engines. The OGV discussion expresses concern about potential methane slip from Otto cycle (spark-ignited) marine engines. It would be useful to note here that most currently offered NG engines in the marine sector are compression ignited.

- The conclusion on Slide 11 of the Summary slide deck indicates that in-use emissions from natural gas trucks and buses are "likely a little lower than diesel." This seems incongruous with the data presented in Slide 10 of the In-Use Emissions deck (Day 1 of the workshop). Recent in-use emissions testing programs at the University of California–Riverside and West Virginia University have documented order-of-magnitude-higher NOx emissions at low load for 2010-compliant diesel trucks, compared to their design levels and in-use NOx emissions from 2010-compliant natural gas trucks. We recommend being more clear that today's dedicated natural gas engines for heavy-duty applications do not require SCR for NOx control, and are achieving low NOx levels as designed in real-world operation.

- The conclusion on Slide 12 that LNG locomotives and OGVs "may provide benefits, with reduced methane leakage" is in need of expansion. LNG engines have strong potential to provide major NOx and PM reductions (including black carbon) compared to diesel engines. This includes direct-injection LNG engines using diesel fumigation, which can maintain diesel-equivalent efficiency / tailpipe CO2 emissions. Like other natural gas applications (and various transportation fuel pathways), full fuel cycle GHG implications will depend on reduced methane leakage.

Thank you for the opportunity to submit these comments regarding the Technology and Fuels Assessment workshops. Please contact me or any of the principals at GNA if you require additional information.

Sincerely,

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