June 15, 2016

Comments of GE Transportation on California Air Resources Board's Draft Technology Assessment for Freight Locomotives Submitted June 15, 2016

GE Transportation ("GET") respectfully offers the following comments on the Draft Technology Assessment for Freight Locomotives released by the California Air Resource Board ("ARB") on April 26, 2016 ("Draft Technology Assessment"). As a global digital industrial leader and manufacturer of technologically advanced, diesel-electric heavy-haul locomotives, GET understands the importance of California and national air quality and energy efficiency goals. GET appreciates ARB's proposed recommendations in its Draft Technology Assessment to pursue the next generation of emissions standards at a national level, as well as ARB's acknowledgement of certain technology and other challenges. The comments provided herein focus on GET's perspective in developing the first freight locomotive to be certified to the U.S. Environmental Protection Agency ("U.S. EPA") Tier 4 standards, as well as the technical feasibility, cost, and environmental considerations for further technology advancements needed to meet any new emissions standards for new or remanufactured locomotives.

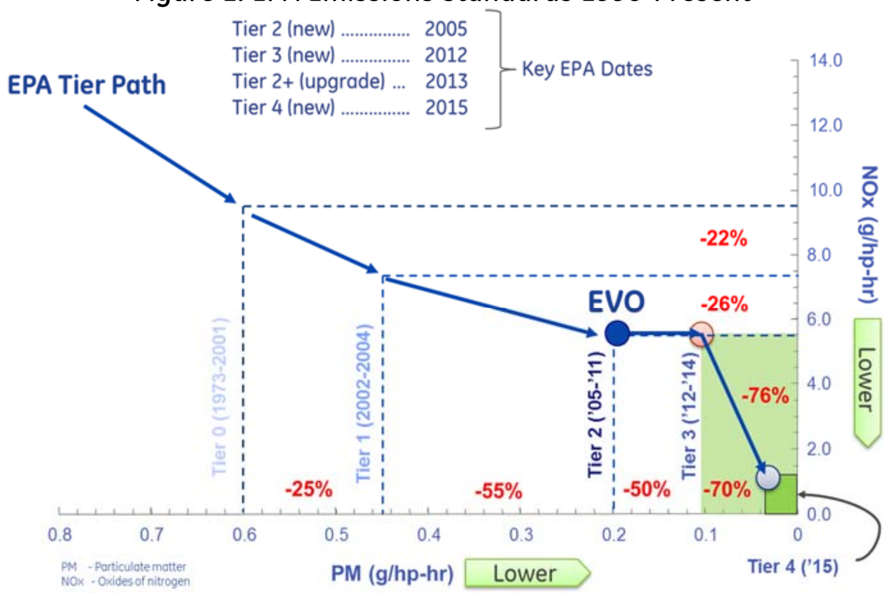
In addition to fuller evaluation of advanced technology requirements, there are potential opportunities for network and digital solutions across the entire freight logistics system – including rail – to meet emissions and climate goals. The greatest potential for emissions reductions is not modification of command-and-control hardware on the locomotive itself, but rather, the power of digital solutions to realize system efficiencies across the entire rail ecosystem. For these reasons, GET is investing in digital, smart, and fuel-efficient solutions for the rail ecosystem – beyond locomotives – to help its customers optimize networks, minimize downtime, reduce operating costs and fuel use, and realize significant emissions reductions. GET looks forward to continuing this discussion about overall approaches to air quality and energy efficiency goals with other members of the rail industry and policymakers, including ARB and U.S. EPA.

I. Evolution of EPA's Locomotive Emissions Standards

As ARB's Draft Technology Assessment notes, emissions from locomotives are regulated by the U.S. EPA, and the standards have become significantly more stringent over the last 20 years. These standards focus on emissions of nitrogen oxides ("NOx") and particulate matter ("PM").[1] The first set of U.S. EPA emissions standards (promulgated in 1998) required that, beginning in the year 2000, new locomotives meet the Tier 0 NOx standard of 9.5 grams per brake horsepower per hour ("g/bhp-hr") and a PM standard of 0.60 g/bhp-hr. Today's Tier 4 emissions standards require new locomotives to meet a NOx standard of 1.3 g/bhp-hr and a PM standard of 0.03 g/bhp-hr. The figure below (also indicating the introduction of GE's first Evolution series locomotive in 2005) shows the increased stringency of locomotive emissions standards over time.

[1] U.S. EPA also regulates Carbon Monoxide ("CO") and Hydrocarbons ("HC"); however, the primary focus of EPA and ARB's regulatory efforts are the control of NOx and PM emissions.

Figure 1. EPA Emissions Standards 1998-Present



GET supports ARB's view that any future generation of emissions standards (presumably "Tier 5" standards) for new and remanufactured locomotives be considered by U.S. EPA as required by Section 209 of the Clean Air Act. GET further appreciates ARB's efforts to assess the technology opportunities available to further reduce locomotive emissions. GE notes, however, that a variety of challenges – primarily technical feasibility, cost, and environmental – must be overcome to achieve the NOx and PM emissions levels contemplated by ARB's suggested Tier 5 standards. Figure 1 demonstrates that, as emissions standards become ever more stringent and approach near-zero, fewer opportunities exist to obtain emissions reductions solely from modifications to the engine and locomotive. Thus, more innovative approaches need to be evaluated by policymakers, and those approaches may not solely take the form of "g/bhp-hr" standards.

II. PERSPECTIVES FROM GET'S U.S. EPA CERTIFIED TIER 4 COMPLIANT LOCOMOTIVE

Achieving further emissions reductions on new locomotives beyond Tier 4 emissions standards presents challenges and tradeoffs related to technical feasibility, cost, and environmental benefits. In developing the first U.S. EPA certified Tier 4 compliant freight locomotive, GET met these challenges at substantial expense and tradeoffs, but such factors will be even more important in developing any potential Tier 5 compliant locomotive.

By way of background, GET shipped its first U.S. EPA certified Tier 4 technology locomotive in July 2015, culminating over 8 years of engineering, design, testing and validation representing a total investment of more than $200 million. Fundamental design changes necessary to meet Tier 4 performance requirements included the introduction of Exhaust Gas Recirculation ("EGR"), a larger cooling system, and control system enhancements for real-time EGR and NOx emissions control. These modifications resulted in a longer, taller and heavier locomotive by 16 inches in length, 2 inches in height, and 8,000 pounds in mass. Supporting GET's service introduction of Tier 4 locomotives, continual component and system improvements are necessary to implement critical refinements and to ensure the most safe, reliable, and efficient product available for GET's railroad customers.

III. FUTURE TECHNOLOGY CONSIDERATIONS

GET's experience with engineering and manufacturing a Tier 4 compliant locomotive offers key insights in considering the development of future technological advancements to further reduce locomotive emissions. GET's comments below offer observations associated with the technical feasibility, cost, and environmental tradeoffs related to ARB's assessment of both compact aftertreatment and hybrid battery technologies. These tradeoffs and challenges are presented with the addition of new technologies on both new and remanufactured locomotives.

A. Compact Aftertreatment Systems

1. Technical Feasibility

The potential addition of a "compact aftertreatment system"[2] on new or remanufactured locomotives must resolve both height and weight constraints due to fixed locomotive packaging requirements and address the possible adverse impact on performance. The Tier 4 compliant locomotive is already at the Association of American Railroads ("AAR") Plate L limit[3] for height. The addition of aftertreatment would likely increase the locomotive height, such that Plate L could not be met without a significant redesign of the engine, platform and cab structures. Similarly, the weight of the locomotive is a significant concern, as the Tier 4 locomotive is at a maximum weight to ensure bridge loadings across the country are not breached. Specifically, a GET Tier 4 certified locomotive weighs approximately 432,000 pounds. Any technology added to the locomotive will push its weight beyond current limits and require compromises in operability, operating range due to fuel capacity, and performance. Accordingly, in order to ensure continued safe and reliable locomotive operation for GET's railroad customers, maintaining locomotive size and weight limits with the addition of an aftertreatment system would require significant redesign across the locomotive with commensurate cost. GET anticipates even more strain on locomotive packaging requirements as the AAR adopts Plate M. Furthermore, any new technology added to the locomotive (such as an aftertreatment system) creates potential concerns with locomotive reliability. As an example of performance requirements meriting further investigation, the implications of using aftertreatment systems in certain environments with extreme heat or cold or in long or successive tunnels should be better understood.

2. Cost

Any evaluation of costs for installation of aftertreatment systems on freight locomotives needs to also account for other changes to the locomotive necessary to accommodate the addition of a compact aftertreatment system. These design, engineering and manufacturing changes must address the length, height and weight constraints already present on Tier 4 compliant locomotives. In addition, other engine control, wiring, and system changes needed will drive further costs. From an operational perspective, all life cycle costs for use of aftertreatment technology should be evaluated. In addition to the cost of the urea solution, other operational costs include the production and distribution of the urea solution throughout the rail system, creation of additional infrastructure to store and handle the urea solution at all or a majority of railroad fueling points, additional operator

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[2] A "compact aftertreatment system" is described by ARB in its Draft Technology Assessment as a one-ton combined SCR and DOC system. See ARB Technology Assessment at V-4 (Draft April 2016).
[3] See American Association of Railroads ("AAR") Standard S-5510, Plate L – Locomotive Diagram for Interchange Service.

training, and scheduled maintenance and cleanings of SCR systems, as well as periodic replacement of these systems.

3. Environmental Benefits and Tradeoffs

More detailed evaluation of estimated emissions reductions is needed to fully consider technological challenges present in certain aftertreatment systems. For instance, selective reduction catalyst ("SCR") will not be active at lower temperatures and engine speeds meaning that NOx reduction will not occur at Idle, Notch 1, or Notch 2. Also, the effectiveness of a Particulate Matter (PM) filter and Diesel Oxidization Catalyst (DOC) merits further evaluation, as it is highly dependent on the composition of the PM, ambient conditions, in-use aging of filter substrate, and catalyst aging. ARB's assessment of PM filters and DOC is mostly based on the PM output from a 2-stroke engine, which produces a higher relative percentage/quantity of soluble organic fractions as compared to a 4-stroke engine (used on all Tier 4 locomotives). PM composition from a 4-stroke engine is mostly dry carbon (i.e., soot). Therefore, a DOC and PM filter system on a T4 locomotive is likely to realize a different reduction in PM emissions. Furthermore, the demonstrations referred to in ARB's Draft Technology Assessment were conducted using lower horsepower engines with greater PM emissions (on a brake-specific PM basis). The use of aftertreatment systems on a Tier 4 Evolution Series engine may yield different results. Additionally, these demonstrations did not consider the possible reduction in effectiveness of the aftertreatment systems resulting from natural aging and in-use deterioration.

Lastly, it is important to keep in mind that any new equipment added to the locomotive creates tradeoffs with respect to locomotive reliability, fuel efficiency and emissions reductions. Evaluation of emissions reductions from aftertreatment systems must consider and include the emissions generated by the system itself and not just the emissions reduced on the locomotive. Specifically, the production, transport and maintenance of the aftertreatment system produces emissions that to some extent offset the emissions reduction benefits on the locomotive itself. Additionally, the additional weight of a compact aftertreatment system reduces engine performance and decreases fuel efficiency. These reductions in efficiency need to be offset in order to meet the emissions levels in any proposed Tier 5 emissions standards.

B. Hybrid Battery Technology

With respect to ARB's assessment of a hybrid technology to significantly reduce emissions and fuel use, GET notes that development of hybrid technology for locomotives is still in its infancy and costly. For instance, the GECX 2010 hybrid locomotive, referred to in the Draft Technology Assessment, utilized a battery system that was only one-quarter of the size of the long-term vision required to achieve a ten percent (10%) fuel savings. Therefore, while the GECX 2010 hybrid locomotive demonstrated the technical feasibility of a hybrid locomotive, it did not demonstrate the capability to realize a 10% fuel savings.

Other considerations need further evaluation when assessing the effectiveness of a hybrid locomotive. As mentioned above, the Tier 4 locomotive is already at maximum weight, and a battery system adds considerable weight to the locomotive. At 432,000 pounds, any technology added to the GET Tier 4 certified locomotive will push the locomotive beyond current weight limits and require compromises in operability, operating range due to fuel capacity, and performance. Furthermore, the cost of a hybrid locomotive yielding a 10-25% fuel savings should be further evaluated. A hybrid system with 10-25% fuel savings capability at current battery prices would result in costs greater than ARB's $750,000 estimate. Battery degradation and life cycle also deserve more robust modeling to accurately evaluate the life cycle cost for battery systems.

IV. Digital Solutions for the Future

As a technology leader in advanced manufacturing, including the locomotive industry, GET is focused on digital, smart, and fuel-efficient solutions for its customers to connect the entire rail ecosystem. These digital solutions offer opportunities to minimize downtime, reduce fuel use and other operating costs, and deliver significant emissions reductions. Two such GET products already deployed on locomotives in California are Distributed Power and Trip Optimizer. LOCOTROL Distributed Power is a control and communication system that enables coordinated braking and traction power distribution between lead and remote locomotives – for faster stopping times and shorter stopping distances. Trip Optimizer is a smart, automated cruise control system that uses data to take into account route topology and conditions and make a fuel-efficient plan, realizing an average of 10 percent fuel savings.

When evaluating advanced technologies, policymakers should consider the range of options available to improve efficiencies within the rail ecosystem to reduce emissions and increase energy efficiency. This is an unprecedented time of innovation for digital industrial solutions, and policymakers should take these initiatives into account when considering various approaches to achieve air quality and energy efficiency goals. GET continues to invest in digital solutions beyond the locomotive to optimize rail network performance, and believes that these advancements have the greatest potential for emission reductions at reasonable cost in the shortest time frame.

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GET appreciates this opportunity to comment on ARB's Draft Technology Assessment and thanks the Board for its consideration. If you have any questions regarding these comments, please contact Jennifer Shea at jennifer.shea@ge.com or Shannon Broome at sbroome@hunton.com.