June 14, 2016

Re: General Comments and Observations on Draft Freight Locomotive Technology Assessment

VeRail Technologies, Inc. is pleased to submit its comments in regard ARB's Draft Technology Assessment on Freight Locomotives. We have noted the page numbers in the Technology Assessment and the particular comments or data we are addressing.

We strongly support ARB's goals to reduce locomotive emissions substantially from current EPA Tier 4 levels to Tier 4+ (at least 70% below Tier 4), near-zero, and zero-emission track-miles levels. Please see our attached information on these upcoming locomotives and technologies.

Sincerely,

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Page I-8

Tractive Effort (TE): GE's improvements in tractive effort can allow 600 ES44C4s, with alternating current (AC) to displace up to 800 older direct current (DC) locomotives and to save more than 70 million gallons of fuel annually. (Bachand, 2007a, Bachand, 2007b; Cotey, 2009)

The question now arises as to whether the fuel savings numbers presented will also apply to Tier 4 locomotives. The latest Tier 4 locomotives from both GE and EMD use large amounts of exhaust gas recirculation (EGR). EGR is known to have adverse effects on engine efficiency. No known published data on current Tier 4 line haul locomotive efficiency is known, but it may be that the fuel savings, and thus GHG reduction, etc. may not be as good for Tier 4 locomotives as it is for the previous generations of non-EGR equipped Tier 2 and Tier 3 line haul locomotives.

Page III-3 Table III-2: Older Conventional vs Genset Switch Locomotive Specifications

VeRail submits that the "Engine Horsepower" number submitted for the EMD GP38-2 is actually incorrect for comparison purposes to the NRE 3-Engine Genset locomotive. The GP38-2 is shown as 2,000 HP and the NRE locomotive is shown as 2,100 HP. While the number for the NRE locomotive is correct (three 700 HP Cummins QSK19 engines = 2,100 BHP engine horsepower), the 2,000 HP shown for the GP38-2 is actually Traction Horsepower (THP) not engine Brake Horsepower (BHP). The EMD GP38-2's EMD 16-645E engine actually produces 2,137 BHP (Report LA-023 AAR Locomotive Emissions Testing 2006 Final Report). The reason for the seeming discrepancy is that EMD rates its locomotives by their traction horsepower (horsepower actually available to the traction motors only) whereas other manufacturers, such as NRE, rate their locomotive's horsepower as the actual overall BHP available from the engine(s). In addition to the THP, the EMD engine must also produce horsepower to power the cooling fans, traction motor blower, air compressor, and low voltage equipment. In order to still have 2,000 HP available for traction, the engine itself must produce about 15% more horsepower at the flywheel. Thus VeRail suggests that the table be amended to reflect a true comparison of BHP for both locomotives, not THP for EMD and BHP for NRE.

Page III-3 Table III-2: Older Conventional vs Genset Switch Locomotive Specifications

VeRail submits that the "Locomotive Starting Tractive Effort (STE)" number for the NRE locomotive should be modified to show the STE for both the 4-axle and 6-axle versions of these locomotives. The information in the table entitled "Locomotive Weight (pounds)" clearly shows the weight difference between the 4-axle 3GS21B locomotive and the 6-axle 3GS21C locomotive, but the Tractive Effort only lists the STE for one locomotive model. According to published NRE specification brochures the 80,000 pounds noted would be for the NRE 4-axle 3GS21B, while the 6-axle NRE 3GS21C produces 136,500 pounds of STE.

The 61,000 pound STE number noted for the EMD GP38-2 is also misleading. EMD listed the STE for a GP38 (not GP38-2) weighing 244,800 pounds as 61,000 pounds. Since STE is linked directly to overall locomotive weight, EMD shows that a heavier GP38AC weighing the 268,000 pounds as the NRE 3GS21B locomotive would produce almost 67,000 pounds of tractive effort. Both the GP38 and GP38AC were limited to about a 25% adhesion rate for STE. With the advent of the EMD Dash-2 series (e.g. the GP38-2), EMD introduced a new wheel-slip control system that increased the adhesion rate. While VeRail is not aware of an EMD published actual number for STE for the GP38-2, EMD brochures showing tractive effort curves indicate that the actual STE for a GP38-2 was in the 70,000 to 80,000 pound range. According to published data, much of the BNSF GP38-2 fleet weighs approximately 262,000 pounds, and the average weight of a UP GP38-2 is about 268,000 pounds. Based on these numbers VeRail suggests that the comparison STE for the GP38-2 be changed to 67,000 pounds to better reflect the current California BNSF and UP fleets.

VeRail also suggests that that the STE number for the NRE locomotives be shown as follows to parallel the table listing for the weight of the NRE locomotives and better reflect the STE for both the 4-axle and 6-axle versions of the NRE locomotives:

80,000 (4 axle)
136,500 (6 axle)

Page III-5 Table III-3: Comparison of Tractive Effort for U.S. Freight Diesel-Electric Locomotives

Paralleling the comments above on locomotive weights and STE in Table III-2, Table III-3 compares a 4-axle EMD GP38-2 to a 6-axle NRE 3GS21C. This is an apples-to-oranges comparison as the expected STE and CTE of a 6-axle locomotive will always be expected to be about 50% higher than a 4-axle locomotive due to the 50% additional weight that can be carried on a 6-axle locomotive and the 50% additional traction motors (six traction motors vs. four traction) on the locomotive. VeRail recommends that the comparison shown in the table be between a 268,000 pound 4-axle EMD GP38-2 and a 268,000 pound 4-axle NRE 3GS21B. In that case the numbers per both EMD and NRE publications and presentations would be more as follows:

Type of Locomotive	STE (lbs. force)	CTE (lbs. force)	Weight (Pounds)	Horsepower
Switcher Locomotives: 1970’s or Gensets (2007-Present)				
EMD GP38-2 (1972-1987)	67,000	54,700	268,000	2,000 THP
NREC Genset (3GS21B) (2007-2014)	84,366	46,044	268,000	2,100 BHP

Page III-8 Locomotive Useful Life

Historically, the North American Class I railroads have purchased virtually all of the locomotives freshly manufactured, with Class I railroads average life about 30 years. However, as the freshly manufactured locomotives lifetimes exceed twenty years, the locomotives can be cascaded down from interstate line haul service to Class I railroad regional hauler or switch (yard) locomotive service. Interstate line haul locomotives begin to gradually transition to regional and local service after about 15 to 20 years.

A few freight locomotives that first serviced Class I railroads, and then serviced shortline railroads, have recorded total useful lives of up to 50 years or more.

VeRail believes that the above two paragraphs need major clarification to give an idea of the actual state of locomotives today.

First, while it was true in the past that "**locomotives can be cascaded down from interstate line haul service to Class I railroad regional hauler or switch (yard) locomotive service**", this is not the case anymore. Most locomotives needed for short line, yard, and local service would be classified as either low horsepower or medium horsepower units. Since the introduction of the 6-axle GE Dash 40-C in 1987 and the 6-axle EMD SD70 in 1993, the nation's Class I line haul fleet has turned to 4,000 horsepower or higher 6-axle locomotives. Since the introduction of Tier 2 locomotives (EMD SD70M-2 and SD70ACe, GE ES44DC and ES44AC) in 2003, the horsepower standard for line haul locomotives has risen 10% to 4,300 to 4,400 horsepower. This means that for almost the last 30 years EMD and GE have not manufactured a locomotive that can reasonably "locomotives can be cascaded down from interstate line haul service to Class I railroad regional hauler or switch (yard) locomotive service", let alone used by today's short line railroads.

The most common locomotives in use today for short line and switch (yard) service are between 1,500 and 2,000 traction horsepower (e.g. the EMD SW1500 switcher, and EMD GP38-2 road switcher). Some railroads also make use of medium horsepower locomotives such as the 3,000 HP EMD 4-axle GP40-2 and 6-axle SD40-2, or even the 3,500 HP 4-axle EMD GP50. BNSF has been using 3,800 HP EMD GP60 and GP60M (built in 1990) locomotives in switch service in California for a number of years.

The key is that the number of 4-axle low and medium horsepower locomotives available to "cascade" to other operations or railroads has virtually disappeared. Most recently UP has begun to divest itself of most of its 1,500 HP switchers (models SW1500 and MP15DC/AC built from 1966 to 1984), but as can be seen from their build dates, these locomotives range from 32 years to 50 years in age!

This also calls into question the comment that "a few freight locomotives… have recorded useful lives of up to 50 years or more." In reality, there is a huge number of locomotives in this 50 year age range (or that will hit 50 within the next 10 years). Most of these are currently in switch service or on short lines, but it is these locomotives that are being used in the major metropolitan areas that have the worst air quality issues. As an example of the low horsepower and medium horsepower locomotives in most use today, the following gives an idea of models and ages:

Manufacturer	Model	Horsepower	Production	Age in 2016
4-Axle Low to Medium Horsepower Locomotives				
EMD	SW1000	1,000	1966-72	44-50 years
EMD	SW1500	1,500	1966-1974	42-50 years
EMD	MP15DC	1,500	1974-1980	36-42 years
EMD	MP15AC	1,500	1975-1984	32-41 years
EMD	GP15-1/15AC/15T	1,500	1976-1983	33-40 years
EMD	GP38/38AC/38-2	2,000	1966-1986	30-50 years
EMD	GP40/40-2	3,000	1965-1986	30-51 years
EMD	GP50	3,500	1980-1985	31-35 years
EMD	GP60	3,800	1985-1994	22-31 years
6-Axle Low to Medium Horsepower Locomotives				
EMD	SD40/40-2	3,000	1966-1986	30-50 years

Note also in the above table that if 30 years was considered a "normal" life for a locomotive, only the EMD GP60 would be within this normal lifespan. This clearly demonstrates the need for a new generation of clean low and medium horsepower locomotives utilizing the latest Tier 4+, near-zero, and zero emissions technologies.

Page III-9 of the technical assessment states: "The national locomotive replacement rate from 1996 to 2004 (767 units per year) indicates a fleet turnover rate of the U.S. Class I railroad fleet (25,000 units) of about 30 years." As can be seen from the table above, this clearly does not apply to low and medium horsepower locomotives.

<u>Page IV-6</u>

As of August 2015, ARB staff believes GE went into full scale commercial production of Tier 4 interstate line haul locomotives by the fall/winter of 2015. As of January 2016, ARB staff believes up to 350 commercial Tier 4 units were delivered to four Class I railroads during calendar year 2015.

According to a presentation on locomotive emissions at the American Short Line and Regional Railroad Association (ASLRRA) national conference held in April 2016,Tier 4 line haul locomotive orders and deliveries were as follows:

Class I Tier 4 Locomotive Fleet and Orders 2015-2016:

- BNSF – 236 Tier 4 GE ET44C4
- CN – 121 Tier 4 GE ET44AC
- CSX – 225 Tier 4 GE ET44AC
- NS – 47 Tier 4 GE ET44AC
- UP – 279 Tier 4
    - 200 GE ET44AC
    - 65 EMD SD70ACe-T4
    - 14 Railpower RP20BD Tier 4 (1800 HP)

Page IV-7

compressed natural gas (CNG) only has about a quarter of the energy of diesel fuel.

The introduction of 5,000 psi high pressure compressed natural gas storage has changed the outlook for storing enough CNG on a locomotive dramatically. Using 5,000 psi CNG well over 1,000 DGE of CNG can be stored on a low or medium horsepower locomotive. Based on a projected 10,000 to 50,000 gallon per year consumption for a switch (yard) locomotive (TA page I-7), a locomotive equipped with 5,000 psi CNG tanks have to refuel at most only once per week, perhaps only once every two weeks. A medium horsepower locomotive consuming 25,000 to 100,000 gallons per year (TA page I-6)would only have to refuel twice per week and perhaps only once every two weeks. Considering servicing schedules for these types of locomotives, refueling on these intervals would not be at all egregious or even necessarily different from current refueling schedules.

Page IV-11

IHB also expects to reduce its annual diesel consumption by about one million gallons, or about 32,000 gallons per locomotive.

Based on published data from the IHB RFP, the 1,500 HP EMD SW1500's being converted to dual fuel only use an average of about 28,000 gallons of diesel per year. The engines specified are targeted to reach about a 50% average diesel substitution rate. Therefore the annual diesel consumption reduction on the 21 converted SW1500's would be about 14,000 gallons each, or just shy of 300,000 gallons per year.

Page IV-13

IHB planned to convert 31 of its 46 switcher locomotives to CNG-diesel dual fuel operation, funded primarily by a Congestion Mitigation and Air Quality (CMAQ) grant. (Indiana Harbor Belt, 2014; Piellisch, 2013b) As of early 2014, IHB expected to have the first converted locomotive by the second quarter of 2015. (Stagl, 2014a). No updated data are available.

As of June 2016 the first two SW1500 switcher locomotive conversions were projected to be completed by November of 2016, with the remaining 19 locomotives to be converted through 2019 or earlier.

Page IV-14

On page IV-14 the BNSF and UP LNG locomotive projects using converted dual fuel EMD SD70ACe and GE ES44AC locomotives is reviewed. Florida East Coast (FEC) is also currently running dual fuel GE ES44C4 locomotives and considering a conversion of their entire fleet. It is recommended that ARB include information on the FEC dual fuel locomotive program in the technical assessment.

Page IV-14

Spark-ignition technologies have a lower compression ratio, resulting in lower performance in torque and thermal efficiency. Therefore, it is most likely that natural gas locomotives will be built using dual-fuel engines with compression ignition (Vantuono, 2013), especially for line haul locomotives.

VeRail has developed its own spark ignited natural gas engine for locomotives. It is projected that the efficiency of these engines, designed and calibrated specifically for locomotive application will closely match the performance and efficiency of the diesel engines they are designed to replace. The key is in designing an engine specifically for locomotive application and duty cycles, rather than trying to retrofit an existing on-road engine designed and calibrated for on-road vehicle use.

Page IV-14

The railroad companies are focused on natural gas as a locomotive fuel because of its potentially favorable economics as compared with diesel fuel. However, no emission reductions are anticipated with natural gas beyond the locomotives' certified emission levels (Tier 0 to Tier 3) for existing line haul locomotives.

While this may be true of existing line haul dual fuel conversions, it is not true of VeRail's natural gas conversions for low and medium horsepower locomotives. VeRail's dual fuel natural gas locomotives are designed to meet ARB's Tier 4+ locomotive emissions targets and VeRail's 100% natural gas locomotives are designed to be near-zero emissions vehicles.

Page V-1

Staff also believes aftertreatment-equipped locomotives could be augmented with on-board batteries to provide an additional 10-25 percent reduction in diesel fuel consumption and GHG emissions.

VeRail seriously questions the ability to augment even today's Tier 4 line haul locomotives with batteries, let alone a next-generation Tier 4 locomotive that includes SCR NOx reduction. The current GE Tier 4 locomotive required a frame stretch and changes to the hood and cooling system. The new Tier 4 locomotive from EMD has also required major changes to the locomotive, including a new lighter-weight 6-axle truck. This is needed to not only make room for the new Tier 4 equipment but to also keep the locomotives within required weight ranges. There therefore appears to be not only little to no room to add batteries to these locomotives, but it is also questionable whether or not the weight of the current locomotives can be reduced enough to allow the addition of batteries without exceeding current weight limits. When GE introduced it hybrid demonstrator based on their Tier 2 ES44AC locomotive, they stated that one of their most difficult tasks was reducing the weight of the base ES44AC locomotive in order to add the batteries (see Figure V-2: GECX 2010 Battery Pack found on page V-5 of the Technical Assessment). Today's Tier 4 GE ET44AC locomotives are actually longer and heavier than GE's Tier 2 and Tier 3 ES44AC on which battery hybrid locomotive GECX 2010 was based.

If additional aftertreatment systems such as SCR are added to the locomotive, weight will need to be re-allocated for these systems before the batteries can even be considered. On page V-3 of the Technical Assessment ARB staff states: "These aftertreatment systems, on a freight interstate line haul locomotive, could possibly be 8 to 10 tons or more in weight and up to 900 cubic feet in size." Adding the additional weight penalty of the aftertreatment, VeRail believes that this brings into question the ability to add batteries as well.

Pages VI-4 and VI-5: RP Green Goat Hybrid Switch (Yard) Locomotive

After discussing this hybrid locomotive technology, the Technical Assessment states: "**This technology could reduce fuel consumption by up to 80 percent or more, saving up to $120,000 in fuel costs annually.**"

VeRail believes that this statement needs to be clarified since the Green Goat technology uses an on-board generator to recharge the batteries. The amount of horsepower-hours actually expended by a switch locomotive do not change based on the source of electric power, whether that be directly from a diesel generator, directly from a natural gas generator, via an onboard battery system, or via an external electric catenary source. For a hybrid which gets the majority of its power from an onboard power source the onboard generator will have to produce the same amount of horsepower-hours over the course of the day, it is just that this power load on the generator can "leveled" through the use of the battery system. To do a given amount of work in a railroad yard will require the same amount of horsepower-hours, it is only the efficiency of the power source that will change this equation. So unless plug-in hybrid technology is used, VeRail does not see how the fuel consumption of a hybrid locomotive can be reduced by 80 percent simply by adding batteries and going with a smaller (e.g. <300 hp) diesel generator.

Page VIII-4: Operational Considerations

An isolated freight electrification system in California could create a number of challenges for UP and BNSF operations on the North American freight rail system including:

- **Maintenance of two separate types of locomotive technologies – all-electric in California and diesel-electric for the rest of North American freight rail system; and**
- **Delays in operations by having to stop freight trains at an exchange point, just outside the South Coast Air Basin or California border, to switch all-electric to diesel-electric operations (these delays could take anywhere from 2 to 6 hours, depending on the configurations of the trains, and based on price and time, could potentially lead to a mode shift to trucks or ships).**

VeRail feels that in fairness to other technologies presented in the Technical Assessment or that have been proposed to ARB, it should be noted that the operational considerations regarding switching out one set of locomotives for another could be applied to other technologies as well, such a battery tenders that need to be switched in and out of the train, near-zero emissions natural gas locomotives, or even SCR equipped Tier 4+ straight diesel locomotives that would not be operated outside of the South Coast Air Basin or California border.

VeRail encourages ARB and the railroads to consider innovative ways to utilize an area-specific fleet of Tier 4+, near-zero, and/or zero emissions locomotive in conjunction with a train's existing locomotive consist that will power the train outside the South Coast Air Basin or California border. The key is to find the right combination of the lowest emission output with the least disruptive operating practice in order to move line haul freight operations to the next level of emissions reduction.