Appendix K – Discussion on NOx Emissions from Heavy-Duty Hybrids and Rationale for Setting no NOx increase and Minimum AER

NOx Emissions from Heavy-duty Hybrids

Heavy-duty hybrid vehicles generally have better fuel economy compared to their equivalent conventional counterparts, and hence have lower fuel consumption. Since less fossil-based fuel is combusted, the amount of CO2 emitted is also proportionately reduced since the correlation between the amount of fuel combusted and CO2 emissions is well established.

While the case for GHG emission benefits of heavy-duty hybrid vehicles is relatively straightforward, NOx emission reduction benefits are much less definitive, as previously discussed. If the hybrid system is well designed and integrated, NOx emissions from a hybrid vehicle can be lower compared to an equivalent conventional vehicle. This is shown in a study comparing a series hybrid-electric bus where the hybrid bus consistently had lower per-mile NOx emissions compared to a similar conventional bus (Kittelson et al., 2015). However, other studies show either inconclusive NOx benefits (CalHEAT, 2013), or higher NOx emissions levels compared to the conventional vehicles (NREL, 2015).

The foregoing discussions suggest the need to approach the issue of NOx emissions from hybrid vehicles cautiously. To address the potential NOx emission increases for heavy-duty hybrid vehicles, the proposed amendments require that manufacturers of heavy-duty PHEVs perform emissions testing to demonstrate the PHEVs do not have elevated NOx emissions compared to an equivalent conventional vehicle.

It is to be noted that the proposed Phase 2 GHG ATC provisions are only applicable to PHEVs, which are more likely to be series or series/parallel designs, whereas, the hybrid vehicles tested in the NREL study were all of parallel designs. Since the combustion engine in a series hybrid system is most likely being used as a generator to charge the battery pack(s), it can be designed to operate in the most efficient engine operating regimes. Because the combustion engine, when being used in this manner, will be exposed to much less transient fluctuations, engine control algorithms could be designed with narrower latitude to minimize NOx emissions. Thus, a series hybrid drive system, as discussed, has some inherent advantages pertaining to the transient characteristics of the combustion engine which could potentially lead to lower NOx emission levels compared to a parallel hybrid drive system. Nevertheless, the potential for elevated NOx emissions from PHEVs is still present due to the CO2/NOx trade-off and NOx aftertreatment system optimization challenges with the integration of the hybrid powertrain.

K-1

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Rationale Supporting the Proposed Solution

Staff’s proposal would encourage manufacturers to further develop well-integrated hybrid technologies, while also ensuring that any PHEVs that generate emission credits by taking advantage of this provision would not emit excess NOx emissions. Note that the proposed CA Phase 2 GHG regulations do not claim any NOx emission benefits since the “no NOx increase” provision would simply prevent excess NOx emissions over what is already accounted for by other existing regulations.

The proposed requirement of requiring the PHEVs to also demonstrate AER has a two-fold purpose: (1) to align with the requirements of CARB’s incentive programs, particularly those requirements in the HVIP where a 35-mile AER range is required to receive funding (CARB, 2017e), and (2) to support CARB’s zero-emission vision for heavy-duty vehicles (CARB, 2016e). Advances in energy storage technologies and electric drives would assist with the progression toward a greater level of electrification and provide synergistic benefits for zero and near-zero heavy-duty vehicle technologies. Heavy-duty hybrids directly benefit the advancement of innovative clean technologies and remain an important part of CARB’s technology roadmap to transform the heavy-duty on-road fleet into one utilizing zero and near-zero emission technologies to meet air quality and climate change goals.

During workshops and consultation meetings with industry, primarily with EMA and representatives of EMA’s affiliated companies, EMA stated their opposition to both the proposed limit on no NOx emissions increase and proposed AER provisions. EMA indicated that the additional requirements were either unwarranted, in the case of the no NOx emission increase provision, or technologically unachievable, in the case of the original proposal of 35-mile AER starting with 2021 MY PHEVs.

Staff’s proposal would align with the federal Phase 2 GHG regulations with respect to stringency, structure, and timing. However, staff’s proposal also includes additional conditions to qualify for ATCs to protect the air quality benefits of California’s regulatory and incentive programs. Note that U.S. EPA has stated that the stringency of the Phase 2 GHG standards was determined without consideration of any advanced technology. In addition, the proposed requirements for PHEVs align with requirements in other CARB programs, such as the no NOx emission increase and the 35-mile AER requirements of the HVIP program. Staff believes, given the allowance for PHEVs to generate GHG credits, which are increased by the 3.5 multiplier, to offset emissions from other vehicles not in compliance with the Phase 2 GHG emission standards, it is not in the public interest to ignore the potential negative impact of higher NOx emissions.

Even though a 35-mile AER in class 8 applications is potentially feasible in the near future and a demonstration program for PHEVs in drayage operation is currently
underway with a goal of demonstrating at least a 35-mile AER (CARB, 2016f), this technology is not commercially available currently. Kenworth and Volvo are participating in this demonstration project. The Kenworth trucks will use a low-NOx CNG genset system with a 35 to 100 kW-hr battery pack and is projected to provide an AER of 50 miles. The Volvo trucks will be PHEVs with a reduced size diesel main engine. The battery pack installed on these trucks is projected to have at least a 30-mile AER.

Currently, lighter heavy-duty hybrids with 20-mile AER or greater are either commercially available or have been demonstrated. Electric Vehicles International offers a plug-in series hybrid utility truck (16,500 pounds – 19,500 pounds GVWR) that is capable of achieving 40-mile AER (EVI-USA, 2017). Efficient Drivetrains, Inc. has a plug-in hybrid drivetrain in a Freightliner chassis utility truck capable of more than 25-mile AER (Worktruckonline, 2017). Pacific Gas & Electric currently operates a plug-in electric hybrid class-6 flatbed truck with a 50-mile AER (Worktruckonline, 2017a).

To account for the technological issue raised by EMA, but to also remain consistent with our goal of supporting the requirements of CARB incentive programs, staff have revised the initial proposal and are now proposing a phased in approach of requiring increasingly longer AER over time, starting with, for slow-charge PHEVs, a 10-mile AER requirement in 2021, increasing to a 20-mile AER requirement in 2024 and, finally, a 35-mile AER requirement in 2027, as shown in Table K-1.

<table>
<thead>
<tr>
<th>Vehicle Model Year</th>
<th>AER (miles)</th>
<th>ATC Multiplier</th>
</tr>
</thead>
<tbody>
<tr>
<td>Slow-Charge(1)</td>
<td>Fast-Charge(2)</td>
<td></td>
</tr>
<tr>
<td>2017 – 2020</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>2021 – 2023</td>
<td>10+</td>
<td>10+</td>
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<td>2024 – 2026</td>
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<td>15+</td>
</tr>
<tr>
<td>2027+</td>
<td>35+</td>
<td>20+</td>
</tr>
</tbody>
</table>

Notes:
(1) Slow-charge refers to Level 1 and Level 2 chargers with electrical circuit rated up to 240 volts AC, up to 80 amps, and 19.2 kilowatts.
(2) Fast-charge compatible PHEVs must: 1) be capable of charging from 15 percent state-of-charge to 85 percent state-of-charge within one-half hour (0.5hr); and 2) demonstrate that typical operating time is at least 8 times (8x) typical charging time (i.e., a vehicle must be capable of operating for 8 minutes for each minute of charge time).
(3) If the PHEV AER is less than that specified in the AER column for the respective vehicle MY, an ATC multiplier of 1.5 would be applicable if the PHEV demonstrates no NOx increase compared to an equivalent conventional vehicle.