Next Generation Heavy-Duty Natural Gas Engines Fueled by Renewable Natural Gas

Frequently Asked Questions

Gladstein, Neandross & Associates (GNA) published a comprehensive whitepaper in May 2016 titled, “Game Changer: Next Generation Heavy-Duty Natural Gas Engines Fueled by Renewable Natural Gas,” on behalf of a number of public and private sector sponsors—including Agility Fuel Systems, the American Gas Association, the California Natural Gas Vehicle Partnership, Clean Energy, Pacific Gas & Electric Company, the South Coast Air Quality Management District and the Southern California Gas Company. The whitepaper details how the union of ultra-low NOx heavy-duty natural gas vehicles (NGVs) and ultra-low carbon renewable natural gas (RNG) blends can uniquely, immediately, and economically help transform America’s heavy-duty transportation system, reduce petroleum dependency, improve ambient air quality, and address climate change. This document addresses some of the most common questions asked about the analysis and results of the whitepaper.

1. Is there enough RNG available to really make this a viable strategy at scale?

According to the California Air Resources Board (CARB), nearly 70 million diesel gallon equivalents (DGE) per year of RNG are currently being dispensed to power NGVs in California. While this is already considered “scale” production, it’s only a small percentage of the total diesel consumed in California’s transportation sector (about 3.5 billion gallons per year). A recent technical study[1] prepared by the University of California-Davis on behalf of CARB and the California Environmental Protection Agency (CalEPA) concluded that more than 21 percent of California’s existing on-road diesel fuel market could be displaced by “commercially competitive” RNG. This is enough RNG to exclusively fuel approximately 31 percent of all Class 8 heavy-duty on-road trucks operating in California. The study focuses on current market conditions, and does not consider the RNG-production potential under more-favorable market conditions, and/or drawing upon RNG feedstocks beyond California’s borders. CARB recently assessed the larger picture of “technically recoverable” RNG feedstock from in-state resources. CARB concluded that “California generates enough organic waste and biogas each year to produce 2.4 billion gallons of transportation fuels, enough to replace ¾ of all diesel used by California vehicles.”[2] In sum, it is very clear that California’s supply of RNG is fully adequate to help the State aggressively deploy large numbers of near-zero-emission NGVs fueled by this ultra-low-carbon, domestic and renewable fuel source.

The rest of the nation also has diverse and plentiful raw feedstock resources for making RNG. Studies from a range of reputable sources estimate that sufficient feedstock exists in the U.S. today to produce enough RNG to displace *tens of billions* of diesel gallons. This means that very large percentages of our nation’s current diesel use for on-road HDV goods movement can be powered by ultra-low-carbon RNG fuel.

2. Aren’t “zero-emission” battery-electric trucks much cleaner?

Actually, recent analysis indicates that—even in “clean-grid” states like California—HDVs powered by near-zero-emission natural gas engines (certified to 0.02 g/bhp-hr) have tailpipe nitrogen oxide (NOx) emissions that are comparable to—or possibly lower than—the amount of NOx emitted to produce electricity used to charge similar heavy-duty BEVs. This is due to the relatively high NOx emissions rates from a portion of the existing power plant mix—particularly in regions that rely heavily on coal-based electricity generation. The Game Changer analysis also considered certain potential 2030 scenarios under which grid mixes in these regions will become cleaner, such as the federal Clean Power Plan[3] and California’s Renewable Portfolio Standard. Even under a 30 percent renewable generation portfolio, it was found that heavy-duty engines certified to 0.02 g/bhp-hr NOx (i.e., CWI’s natural gas ISL G NZ) compare very favorably to heavy-duty BEVs for extremely low NOx emissions. (Details are provided in Section 13 of the Game Changer White Paper.)

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[1] Jaffe, A; The Feasibility of Renewable Natural Gas as a Large-Scale, Low Carbon Substitute, prepared for the California Air Resources Board and the California Protection Agency, June 2016, https://www.arb.ca.gov/research/apr/past/13-307.pdf

[2] California Air Resources Board, “California Biofuels Cap & Trade Initiative,” April 29, 2015, https://www.arb.ca.gov/lists/com-attach/135-slcpdraftstrategy-ws-AXlGY1M1Ul4AdVQw.pdf.

[3] The U.S. Supreme Court decision to halt enforcement of the national Clean Power Plan, combined with the Trump administration’s pro-coal stance, have cast significant uncertainty about the ability to achieve 30 percent renewable energy generation by the 2030 timeframe.

This extraordinary ultra-low-NOx accomplishment by today's heavy-duty natural gas engine technology has been recognized by key State agencies. In the words of the California Energy Commission:

Natural gas engines and emission control technologies that achieve the CARB optional low oxides of nitrogen (NOX) emission standard are now commercially available, and, when combined with biomethane fuel, can reduce the life-cycle emissions of medium- and heavy-duty vehicles to levels near or equal to those of zero-emission electric vehicles.[4]

3. Won't investment in natural gas trucks and infrastructure just delay the onset of the inevitable electric truck future?

California needs rapid, large-scale deployment for *any and all* heavy-duty truck types that can provide zero-emission or near-zero-emission levels. Air quality regulators have strongly recognized that early deployment of such HDVs is the key to meeting federally mandated, health-based ambient air quality standards by 2023. CARB rightfully seeks to accelerate commercial deployment of electric trucks, and other zero-emission vehicle (ZEVs) technologies. However, it has also recognized that major commercialization for heavy-duty ZEVs (i.e., hundreds of thousands of units) **will not be feasible before 2030.** In the most challenging HDV applications such as long-haul trucking, CARB's assessment is that battery-electric trucks will not be commercially feasible for "the next several decades."[5] Conversely, CARB has noted that large-scale, near-term deployments of near-zero-emission natural gas trucks in heavy-duty goods movement applications are both technically and economically feasible. Significantly, CARB found that this "will provide the largest health benefit of any single new strategy" under consideration by California for the foreseeable future.

Simply put, to help restore healthy air, California must take advantage of this unique opportunity to rapidly deploy large numbers of commercially available heavy-duty NGVs using RNG.

It is also important to note that today's investments in RNG (production and end use) go well beyond their importance to support large-scale deployments of ultra-clean heavy-duty NGVs. These investments also help directly support a future with lower-carbon generation of electricity for the power grid, and production of hydrogen for fuel cells. In other words, expanded development and use of RNG for NGVs is fully synergistic with commercializing electric and fuel cell vehicles of the future that can become truly "zero emitting" on a full-fuel-cycle basis.

4. Today's advanced diesel engines are certified to very low emission levels, and also achieve excellent efficiency. Why do we even need natural gas engines to get emission benefits? With ultra-low NOx diesel engines just around the corner, shouldn't we just wait?

The timeframe is very uncertain for heavy-duty diesel engines to achieve the needed near-zero NOx emission levels. So far, no diesel engine has been certified below the existing federal heavy-duty engine NOx standard (0.2 g/bhp-hr). Diesel emissions continue to improve, but to achieve the near-zero NOx level (90 percent lower than the standard)—already achieved by natural gas engine technology—engine manufacturers still face significant engineering challenges. In particular, there are tough tradeoffs to resolve when seeking to achieve near-zero NOx emissions while also meeting new federal GHG and efficiency requirements. If and when manufacturers can simultaneously achieve both, near-zero-emission heavy-duty engines (using renewable diesel) will be a welcome addition to California's HDV market and the State's efforts to achieve clean air. However, as noted above, early deployment of the cleanest available heavy-duty truck technologies is the key to meeting California's urgent air quality challenges.

In fact, local air quality officials at the South Coast Air Quality Management District (SCAQMD), and the San Joaquin Valley Air Pollution Control District (SJVAPCD) have developed urgent plans to dramatically reduce NOx from heavy-heavy-duty trucks (HHDTs) in their air basins, where HHDTs are the number one NOx source. Both agencies have strongly advocated for promulgation of a national heavy-duty engine NOx standard at 0.02 g/bhp-hr, with full recognition that only natural gas engine technology has achieved this near-zero level of NOx emissions.

California's need for <u>new</u> heavy-duty engines that achieve very low emissions during laboratory (certification) testing is only part of the story. It's also essential that HDVs maintain these emission levels during real-world operation, as thousands of miles are accumulated. Recently, two of the nation's leading testing laboratories (West Virginia University and the University of California, Riverside) conducted emissions testing of "in-use" heavy-duty trucks with late-model natural gas and diesel engines. These tests

[4] California Energy Commission, <u>2017-2018 Investment Plan Update for the Alternative and Renewable Fuel and Vehicle Technology Program</u>, Draft Staff Report, October 2016
[5] See for example CARB's "Draft Technology Assessment: Medium and Heavy-Duty Battery Electric Trucks and Buses," October 2015.

showed that heavy-duty natural gas engines generally emit NOx well below their certification level during in-use operation, across all types of duty cycles and driving conditions.[6] Conversely, based on a body of test data,[7] CARB has found that 2010-compliant heavy-duty diesel engines with advanced emissions controls can exhibit NOx "control challenges" during in-use operation in low temperature, low speed duty cycles (such as are common in large metropolitan regions). In fact, a January 2017 CARB report[8] found that in-use diesel trucks can emit NOx at levels up to nine times (9x) higher than their U.S. EPA 2010 certification level when operating in low speed applications (such as port drayage and other similar urban commercial applications).

5. If it requires onboard storage of a high-pressure gaseous fuel to achieve emissions benefits, why not use compressed hydrogen to power fuel cells (this will achieve zero emissions)?

Hydrogen fuel cell vehicles (FCV) have clear long-term potential to power heavy-duty trucks that will achieve zero direct-vehicle emissions. Like battery-electric "ZEVs," FCVs have significant "upstream" emissions, and are not necessarily lower emitting than heavy-duty NGVs on a "full-fuel-cycle" basis. As CARB has recently noted, heavy-duty FCVs exist only in very early stages of development and demonstration (e.g., Toyota is testing such a prototype vehicle). On the fueling infrastructure side, CARB expects approximately 50 hydrogen stations to be opened in California by mid-2017. Notably, "almost all these stations will not be compatible with medium- or heavy-duty vehicles."[9] In sum, the timeframe for heavy-duty FCVs—especially in Class 8 trucking applications—is currently uncertain.

It's important to note that the ongoing advancement of heavy-duty NGV technology actually helps the commercial viability of heavy-duty FCVs. This is because natural gas and hydrogen are stored on HDVs using similar fuel tank technology, which is often made by the same manufacturers. For example, the same tank manufacturer making advancements with lighter, lower-cost on-board CNG tanks may also be working on similar compressed hydrogen tanks for proof-of-concept heavy-duty FCVs and pre-commercial light-duty FCVs. In other words—similar to the case where there is positive synergy between RNG production and generation of cleaner electricity and hydrogen—development of advanced on-board fuel storage for heavy-duty NGVs helps to advance a future where heavy-duty fuel cell vehicles can meet the rigorous performance requirements of California's vast goods movement trucking system.

6. Aren't NOx emissions just a California problem?

No. NOx is the primary constituent of two major air quality problems: 1) ground-level ozone and 2) fine particulate matter ($PM_{2.5}$). Ozone and $PM_{2.5}$ are major, pervasive health problems throughout the United States, and across the world. In America, an estimated 241 counties do not meet federal ambient air quality standards for ozone. These air quality "nonattainment" counties are dispersed throughout California and all over the U.S., including nearly the entire northeastern seaboard, from Virginia to Massachusetts. It has been estimated that approximately 200,000 premature deaths occur in the U.S. each year, due to combustion-related air pollution primarily associated with transportation sources.[10]

Globally, the World Health Organization (WHO) estimates that millions of people die prematurely each year from ozone and $PM_{2.5}$ air pollution. In fact, WHO has labeled urban air pollution to be "the largest single environmental health risk we face today," noting that many of the world's largest cities are headed towards public health emergencies that will entail "horrible future costs to society."[11]

7. Only one company makes an NZ engine and it has limited power. Can we really use NZ engines in enough trucking applications to matter?

It is true that (as of mid-2017) only one company (Cummins Westport, Inc.) currently has certified a natural gas engine (the CWI ISL G NZ) to a near-zero-emission NOx level. The CWI ISL G NZ engine is offered with horsepower and torque ratings that range from 250 to 320 HP and 660 to 1,000 lb-ft, respectively. It is available for HDV applications that include buses (transit, shuttle, school) and

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[6] Johnson, Jiang, Yang, "Ultra-Low NOx Natural Gas Vehicle Evaluation – ISL G NZ," November 2016, http://www.cert.ucr.edu/research/efr/2016%20CWI%20LowNOx%20NG_Finalv06.pdf.
[7] For example, see In-Use Emissions Testing and Demonstration of Retrofit Technology for Control of On-Road Heavy-Duty Engines, accessible online at http://www.arb.ca.gov/lists/com-attach/35-techfuel-report-ws-BmdcLIciAjAHYIM7.pdf.
[8] Yoon, Collins, Misra, Herner, Carter, Sax, "High In-Use NOx Emissions From Heavy-Duty Diesel Trucks Equipped with SCR Systems and Their Impact on Air Quality Planning in California," October 26, 2016.
[9] California Air Resources Board, "Draft Technology Assessment: Medium- and Heavy-Duty Fuel Cell Electric Vehicles," November 2015, https://www.arb.ca.gov/msprog/tech/techreport/fc_tech_report.pdf.
[10] Caiazzo, Ashok, Waiz, Yim and Barrett, "Air Pollution and Early Deaths in the United States," Atmospheric Environment, Volume 79, November 2013, accessed online at http://www.sciencedirect.com/science/article/pii/S1352231013004548.
[11] Statement by Dr.Maria Neira, World Health Organization Director for Public Health, Environmental and Social Determinants of Health, PHE e-News, May 2015, http://www.who.int/phe/news/may2015/en/.

return-to-base trucking (refuse, goods movement).[12] Thus, the ISL G NZ provides an immediately available near-zero-emission alternative for many important HDV applications, especially those that operate in highly urban environments that have the worst air quality (high ambient-air levels of ozone and air toxics).

An important new and larger "NZ" engine will be commercially introduced and available for purchase by Q4 2017. CWI's 400 horsepower ISX12 G engine is a 12-liter natural gas engine designed for various heavy-heavy-duty vehicle (Class 8) uses. This workhorse engine provides up to 400 HP and 1450 lb-ft of torque, making it well suited for regional-haul truck/tractor, vocational, and refuse applications. The ISX12 G natural gas engine is currently certified to the existing federal NOx standard of 0.2 g/bhp-hr. However, CWI is working to certify and commercialize the 90 percent lower-emitting NZ version in the coming year. The result will be that HHDT applications – Class 8 trucks that consume very large volumes of diesel and contribute the highest NOx emissions – can soon be powered by near-zero-NOx natural gas engines. Like all natural gas engines, this emerging ISX12 G NZ engine will be able to use RNG instead of fossil natural gas, to provide "deep" GHG reductions due to carbon intensity ratings for commercially available RNG that range from 75 to 125 percent lower than conventional diesel fuel. Moreover, CARB is now developing a renewable CNG pathway from livestock manure that offers a carbon intensity rating *400 percent lower* than baseline California diesel fuel.[13]

Additionally, CWI has already received certification of its ISB6.7 G natural gas engine to meet CARB's Optional Low NOx Emissions standards. This heavy-duty natural gas engine emits NOx at 50 percent below the current EPA / CARB limit of 0.2 g/bhp-hr. Like the ISL G NZ engine, the ISB6.7 G engine meets EPA's 2017 GHG emission requirements. This engine platform is widely available by OEMs for midrange trucks, vocational trucks and mid-size bus (school and shuttle) applications.[14]

Finally, CWI's landmark introductions of three different ultra-low-NOx heavy-duty natural gas engines are believed to be just the beginning of this important market. Other heavy-duty engine OEMs are also working to develop, certify and commercialize their own natural gas engines at "NZ" NOx levels. Announcements of certifications and associated commercialization plans for such engines are believed to be imminent.

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[12] Cummins Westport Inc., ISL G NZ Press Release, October 13, 2016, http://www.cumminswestport.com/press-releases/2016/cummins-westport-begins-production-of-isl-g-near-zero-natural-gas-engine.
[13] California Air Resources Board, "Fossil & Renewable Natural Gas in the LCFS," presentation for the Public Working Meeting for Stakeholder Groups, April 17· 2017.
[14] Cummins Westport Inc., accessed online February 22, 2017, http://www.cumminswestport.com/models/isb6.7-g.