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Methanol Institute Comments to Senate Bill 1383 Workshop

Additional submitted attachment is included below.

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California Energy Commission, California Public Utilities Commission, and California Air Resources Board Joint Workshop on Renewable Gas Under Senate Bill 1383.

Comments of the Methanol Institute

For decades, California has led the nation in addressing climate change, energy efficiency, fuel diversification and clean air. California Senate Bill 1383 carries on this tradition in requiring a short-lived climate pollutant strategy developed to achieve a reduction in the statewide emissions of methane by 40 percent, hydrofluorocarbon gases by 40 percent and anthropogenic black carbon by 50 percent below 2013 levels by 2030. The Energy Commission is charged with identifying cost-effective strategies to achieve those goals by considering priority end uses of renewable gas, including biomethane and biogas.

As the trade association for the global methanol industry, the Methanol Institute (MI) welcomes this opportunity to provide our comments on this important workshop. As detailed below, methanol's use as a fuel offers a host of environmental benefits, including reduced HC, NOx, SOx and Particulate Matter emissions, and coupled with the GHG benefits when using bio-methanol sourced from renewable gas, the benefits would be transformative for California and a key component of the drive to address climate change and improve air quality. Based on current commercial experience in various gasoline markets outside the U.S., MI believes that producing and blending bio-methanol from renewable gas is the lowest cost pathway for introducing renewable gas energy into California's transportation energy supply (as well as the U.S. markets). As one supporting example, methanol made from natural gas is commonly blended in gasoline (typically M15) for conventional (unmodified) vehicles where it has been successfully and widely used in a number of China Provinces since as early as 2004 (13+ years). The continued expanding use of Methanol blends (that are properly blended to gasoline quality standards with corrosion additives and co-solvents) in China markets are technically demonstrating that they can be used in vehicles manufactured over the past 20+ years. As another supporting example, BioMCN in Europe has been commercially (economically) producing bio-methanol made from renewable gas (bio-methane) in their existing methanol capacity for the past four years which is then blended into European gasoline along with ethanol for fueling conventional vehicles for use in meeting the EU Bio-fuel directive targets. These two commercial operations demonstrate that methanol derived from renewable gas is a very viable and low cost pathway for introducing renewable energy into the existing vehicle fuel supply system which does not require large and risky investments (usually government subsidized) into developing new supply infrastructure as well as new vehicle fleets for other alternative fuel options being considered (such as CNG vehicles).

In addition to currently replacing some existing fossil based gasoline, Bio-methanol can be used as a partial diesel fuel substitute used for fueling cars, heavy-duty trucks, buses, and marine vessels with some minor engine modification. Methanol also is a convenient liquid hydrogen carrier fuel for fuel cell technologies that can be utilized for passenger and freight movement. Current bio-methanol production technologies today can produce economical low- and ultra-low carbon emissions fuels in line with Senate Bill 1383's goals. Since bio-methanol derived from renewable gas is already being commercially practiced as a viable, low-cost pathway to conventional vehicle fuel supplies which does not require large upfront investments (or subsidies) for new fuel infrastructure and new alternative fuel vehicle fleets, it would appear to be in California's interest to therefore include this pathway in their future renewable fuel considerations. Even though other global markets have already demonstrated there are no significant technical or economic barriers to commercially blending methanol into gasoline supplies for conventional vehicles, there are some 'regulatory' hurdles that would have to be removed or satisfied to allow methanol blending to participate in the U.S. gasoline supply as it already does in other global markets. In these following comments, we hope to briefly reintroduce methanol to California's fuel policy discussion, and set the stage for continuing dialogue and engagement.

Methanol and Light-Duty Vehicles

When blended into gasoline supplies for today's conventional vehicles, methanol provides the highest amount of octane per unit of supplied energy, and the energy is supplied from non-petroleum energy sources for economically (without subsidies) reducing dependency on crude oil imports. However, for developing next generation fuel/engine systems for vehicles, Methanol's fuel properties provide certain key advantages with respect to vehicle engine efficiency. Past pioneering innovations by Lotus Engineering and EPA have led to important insights on the potential for ultra-high efficiency methanol engines, including the potential to exceed the efficiency of even diesel engines. Research in the US, China, Australia, Israel and the EU continues to build on this foundation. Methanol production and engine optimization research is underway at various US and EU universities, including, the Massachusetts Institute of Technology, Bath University in the UK, the University of Ghent and the DTU, the Technical University of Denmark. Fuel blending research, development and commercialization focused on Gasoline Ethanol Methanol (GEM) blends is also underway in Australia, by Coogee Chemicals in association with ProDrive and Orbital, through the testing of GEM vehicles including a 2013 Toyota Camry Altise and a 2012 Ford Mondeo Zetec.

Methanol and bio-methanol offer a significant opportunity to comply with the full scope of California's regulatory requirements, through the optimized use of high octane methanol compatible vehicles, and through the introduction of renewable gas derived methanol, and renewable methanol from waste CO_2 and renewable power generation as well as biomass gasification. Methanol's properties yield a broad range of environmental and emission reduction benefits, such as the following:

- Inherently lower NOx and PM due to its low temperature combustion properties;
- A lack of carbon-carbon bonds which results in inherently ultra-low particulate emissions;
- In-use "fail-safe" characteristics with high margins of in-use catalyst performance, in contrast to diesel engine complex selective catalytic reduction (SCR) and Lean NOx Trap (LNT) with very narrow or non-existent margins of compliance (e.g., VW worse case);
- Potential for ultra-low well-to-wheel GHG emissions from the use of renewable methanol;
- High thermal efficiency due to the use of higher compression ratio enabled by methanol's high octane, which can be leveraged by engine downsizing;
- Ultra-low knock limit due to its high octane and latent heat properties, further enhancing turbo-charged high compression DI technology;
- Higher power and greater engine down-sizing potential than gasoline technology;
- Higher torque and power response for a given engine size, due to its faster flame propagation coupled to its high octane value;

- Strong synergy and reinforcement of hybridization and electric drive train utilization in electric and fuel cell vehicles;
- Low incremental cost of flexible fuel technology capable of running on gasoline-ethanol-methanol (GEM) blends;
- In-use emissions confidence for consumers, regulators and OEMs that, unlike "clean diesel's" complexity and reliance on consumer behavior to maintain system compliance, methanol engine out emissions are far lower than diesel engine out emissions and more amenable to less complex emission system design.

Methanol and Heavy-Duty Vehicles

According to the California Air Resources Board's April 2016 report "Draft – Supporting Information for Technology Assessments: Truck and Bus Sector Description," the class 2b-8 commercial heavy-duty truck population in the state is nearly 1.5 million vehicles. Heavy-duty trucks are responsible for nearly 33% of NOx emissions, 26% of PM2.5 emissions, and 8% of GHG based statewide emission sources. Since many of these trucks will continue to operate on the state's streets and highways for the next 20 years, it is critically important to address this large legacy fleet as well as exploring options for new vehicle technologies.

Alcohol fuels – methanol and ethanol – are ideally suited for spark ignition (SI) engines because of their high octane number (low tendency to knock). However, they are not very well suited for compression ignition (CI) engines which require high cetane numbers. There are, however, CI engine technologies that do utilize alcohol fuels and can achieve diesel fuel efficiencies or better. This includes a range of dual fuel approaches that can: (1) inject a mixture of diesel and alcohol fuel directly into the combustion cylinder; (2) separately inject diesel and alcohol fuel directly into the cylinder; and (3) employ so-called "fumigation" where alcohol fuels are injected into the intake and diesel directly into the cylinder with this homogeneous alcohol-air mixture then ignited by a pilot injection of diesel. Ignition improvers can also be added to methanol to enhance combustion, a topic being address by Avocet Solutions and others. Another option is to simply add spark ignition to a heavy-duty engine which then runs on alcohol fuels, an approach typically taken with CNG and LNG heavy-duty vehicles. Particularly for the dual fuel options, there is no need to make changes "inside" the engine, you simply add a common fuel rail system and purpose-designed injectors. Therefore, with both the dual fuel CI and alcohol SI engines, you can deploy conversion "kits" that can allow the legacy fleet to dramatically cut its diesel fuel usage and resulting emissions.

In addition to the GHG benefits of using renewable bio-methanol, using methanol as a diesel fuel substitute in CI and SI engines for heavy-duty trucks provides a range of benefits depending on substitution ratios for both the legacy fleet and new trucks including: (1) reducing NOx emissions by as much as 70%; (2) as the methanol molecule contains no carbon-to-carbon bonds (CH3OH), particulate matter emissions can be dramatically reduced; (3) methanol also contains no sulfur, so SOx emissions can be lowered.

For more information, visit our web site at www.methanolfuels.org.

Methanol Marine Fuels

There is increasing international pressure, as well as California focus, on marine vessel emissions. Under the International Maritime Organization, Emission Control Areas (ECA's) have been established to regulate both sulfur and NOx emissions. The California Air Resources Board has also adopted regulations which govern the fuel sulfur and other operational aspects of Ocean-Going Vessels operating within the state's waters and its 24 nautical mile U.S. boundary. These regulations, which go beyond the IMO regulations, are designed to reduce PM and NOx emissions to very stringent levels, as well as SOx emissions from ocean-going vessels. The state's OGV Fuel Regulation provides an exemption for "alternative fuels," and methanol is included in the definition of alternative fuels in the rule.

Both CARB and local air quality management districts such as the South Coast Air Quality Management District have placed a high priority on reducing port-related emissions, which continue to present one of the most serious air quality and public health challenges. For the marine sector, stringent rules are already in place, and additional measures are under development in a variety of source categories, including harbor craft, ocean going vessel fuel use, ocean going vessel on-shore power, and ocean going speed restrictions. Additionally, a desired shift to freight transport on inland waterways, can shift burdens from the on-road segment to shipping. Methanol use in marine engines offers a significant means of supporting the implementation of both IMO and CARB requirements. Methanol use in marine engine applications would also provide significant SOx, NOx, and PM benefits. Recent testing by major marine engine manufacturers and "in-vessel" performance shows the methanol reduces emissions of SOx by 99%, NOx by up to 60%, and PM by 95%. Such dramatic gains, coupled with the GHG benefits of using renewable bio-methanol fuel can be transformative for the air quality of California's ports and inland waterways

A May 2016 study by the European Commission's Joint Research Centre on "*Alternative Fuels for Marine and Inlands Waterway Transport*" concludes that methanol and LNG are the most promising alternative fuels for shipping. A report prepared for the Methanol Institute by FCBI Energy on *"Methanol as a Marine Fuel"* concludes that methanol's use as a marine fuel provides shippers and port facilities with an affordable option for compliance with tightening emission requirements. Further, produced from a wide range of feedstocks – including a variety of renewable pathways such as renewable gas – methanol provides a "future proof" solution to sustainable shipping.

For more information, visit our web site at: http://www.methanol.org/marine-fuel/

Methanol as a Hydrogen Carrier Fuel for Freight

Methanol is also being used in fuel cell applications as a high density source of hydrogen for PEM fuel cells, and in direct methanol fuel cells such as technology commercialized by California-based Oorja Fuel Cells for freight material handling equipment. In Denmark, Serenegy is using methanol-based fuel cells as a range extender for light-duty plug-in electric vehicles. Commercial methanol availability for fleet trials in Denmark is being provided by "OK," the country's largest independent fuel retailer. As a frame of reference, a commercial methanol refueling station would offer significant capital cost savings compared to its hydrogen refueling station counterpart. A methanol station capable of refueling a large scale fleet of thousands of methanol fuel cell vehicles would have a throughput capacity of over 1,000 kg-equivalent per hour of hydrogen, comparable to gasoline, and cost less than 0.5% of the capital cost of a gaseous or cryogenic H_2 station with the same fuel throughput capacity. To put this into further perspective, 50 MW of power would be needed to produce 1,000 kg/hour of H_2 through on-site water electrolysis.

Methanol fuel cell vehicles, such as those being commercialized by Serenergy, therefore offer a significant path to realizing the GHG reductions called for by Senate Bill 1383; such a path would avoid the long recharge times associated with battery electric vehicles while avoiding the vast capital requirements inherent in any serious, large scale transition to a hydrogen refueling infrastructure capable of gasoline-equivalent station throughput. In addition, methanol fuel cells could be used as auxiliary power units for the "hotel load" of class 8 long-haul trucks, for powering transport refrigeration units used for cold storage, and even for cold ironing of marine vessels in place of shore power.

For more information, visit our web site at: http://www.methanol.org/fuel-cells/

Methanol Production – Renewable Pathways

Recent advances in methanol production in the form of renewable methanol from CO_2 feedstock coupled to renewable power generation have demonstrated that renewable methanol can play a major role in addressing the need for sustainable ultra-low carbon fuels. Ultimately, a transition may be feasible from oil refining to an industrial base dedicated to ultra-low carbon liquid fuels from renewable gas and the capture and conversion of CO_2 and renewable hydrogen or the remote gasification of biomass, including municipal solid waste and other non-food feedstocks. This could provide a supportive path for California to entirely divorce from petroleum based fuels, as envisioned by Nobel Prize Laureate George Olah and his colleagues at the University of Southern California in their seminal book *"Beyond Oil and Gas: The Methanol Economy."* Once such an industrial base is in place, it would enable the direct de-carbonization of the atmosphere.

The industrial scale production of ultra-low carbon intensity renewable methanol is already underway in Iceland, Netherlands, and Canada. For example, in Iceland, Carbon Recycling International is capturing and reacting CO_2 from geothermal power generation with renewable hydrogen produced via electrolysis into renewable methanol. In the Netherlands, BioMCN converts biogas into advanced second generation bio-methanol. Renewable Methanol from the CRI facility has been independently reviewed by the International Sustainability and Carbon Certification protocol and has been assigned a well-to-wheels carbon intensity of less than 10 grams of CO2-e per MJ.

In Canada, bio-methanol can be produced from municipal solid waste feedstocks by Enerkem. Enerkem's Alberta Biofuels facility in Edmonton has the capacity to convert 100,000 dry tons of MSW into 43 million liters per year of methanol, as well as other biofuel products such ethanol. Their plant will bring Edmonton's recycling rate from 60% to 90%.

Furthermore, if renewable methanol is coupled to ultra-efficient combustion, and thus a higher Energy Economy Ratio (i.e., EER values defined by CARB), and then applied to a Plug-in Hybrid Electric Vehicle (PHEV) platform, a strong synergy could be enabled such that up to an 80% GHG emission reduction could be achieved without necessitating the 100% complete electrification through the total replacement of liquid fuels with electricity.

For more information, visit: http://www.methanol.org/

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