July 6, 2016

California Sustainable Freight Action Plan
Discussion Draft

Comments of the Methanol Institute

For decades, California has led the nation in addressing climate change, energy efficiency, fuel diversification and clean air. Recent initiatives by California Governor Jerry Brown seek to build on this heritage by establishing a goal of replacing 50 percent of petroleum fuel use with most ambitious greenhouse gas (GHG) emission standards, advanced clean car regulations, zero emission mandates and low carbon fuel standard. The Governor's Executive Order B-32-15 prioritizing California's transition to a more efficient and less polluting transport system is a critical step in this legacy.

As the trade association for the global methanol industry, the Methanol Institute welcomes this opportunity to provide our comments on the discussion draft of the California Sustainable Freight Action Plan. As central theme of this plan is the need to enter into strategic partnerships, and developing well-planned investments around the deployment of new technologies. As we noted in recent meetings with staff for the California Air Resources Board and the California Energy Commission, we believe that methanol can play an important role in fulfilling the goals of this Action Plan.

As a diesel fuel substitute, methanol can be used to fuel heavy-duty trucks, buses, and marine vessels. Methanol also is a convenient liquid hydrogen carrier fuel for fuel cell technologies that can be utilized for freight movement. While most methanol is produced from the steam reformation of abundant US natural gas, there is a wide range of renewable feedstocks and methanol production technologies today that can produce economical low- and ultra-low carbon emissions fuels in line with the Action Plan's goals of continuing to support California's economy. In these comments, we hope to briefly reintroduce methanol to California's fuel policy discussion within the context of sustainable freight and set the stage for continuing dialogue and engagement.

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.

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; and (4) methanol's lower carbon intensity and higher brake thermal efficiency can also lead to CO2 benefits, especially when substituting diesel with renewable methanol.

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 using commercially ready 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 – methanol provides a "future proof" solution to sustainable shipping.

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

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 Protonics 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 ultimate sustainable mobility challenge laid out by California; such a path would avoid sacrificing 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: www.methanol.org/Energy/Fuel-Cells.aspx

Methanol Production – Domestic Natural Gas and 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. In the initial stages of a transition to methanol compatible vehicle technology, the use of abundant US natural gas would add significantly to California's energy security, fuel diversity and economic growth. Ultimately, a transition may be feasible from oil refining to an industrial base dedicated to ultra-low carbon liquid fuels from 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.

All of these benefits are of central relevance to sustainable fright for attaining and maintaining strict air quality standards as well as GHG emission reduction goals.

The methanol supply resource base is especially robust, in the face of growing supplies of low-cost natural gas. A large scale introduction of methanol heavy-duty vehicles and marine vessels could easily be served by growing methanol production capacity, particularly in North America. Utilization of the nation's growing natural gas supply base for methanol production and use in the US would materially enhance the nation's fuel diversity. With the decline in natural gas pricing, since 2012 we've seen the addition of approximately 5 million metric tons (1.7 billion gallons) of methanol capacity restarted or built in the US. Methanol also can be produced from captured methane emissions which would otherwise be flared at remote oil production sites. The methanol industry has a history of providing excess production capacity to serve its core markets, and the transportation market would not be an exception to that practice. According to IHS, global methanol production capacity is 113 million metric tons per year or 37.6 billion gallons of methanol annually.

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.

In Canada, bio-methanol is being 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%.

Renewable methanol is fully miscible with conventional methanol and offers a highly scalable renewable liquid fuel pathway without the risk of indirect land use change, fertilizer overuse, and top soil erosion risks associated with conventional corn ethanol. 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.

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.

It is also instructive to compare the underlying energy efficiency of Power-to-Liquid (PtL) technology with Power-to-Gas technology, as both have a key role to play in utilizing stranded or underutilized renewable power capacity. Analysis performed by the Center for Solar Energy and Hydrogen Research (ZSW) in Stuttgart, Germany suggests that the PtL technology, similar to that utilized by CRI, is 10% more efficient than PtG technology used in such projects as the Audi EtoGas program.

For more information, visit: www.methanol.org/Methanol-Basics/The-Methanol-Industry.aspx

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