



Moving Towards Commercialization as the 1st Carbon-Negative, Compression-Ignition Fuel

October 12, 2017

Dairy and Livestock Subgroup #2:
Fostering Markets for Digester Projects

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International DME Association



International DME Association



VOLVO



ISUZU



AYGAZ



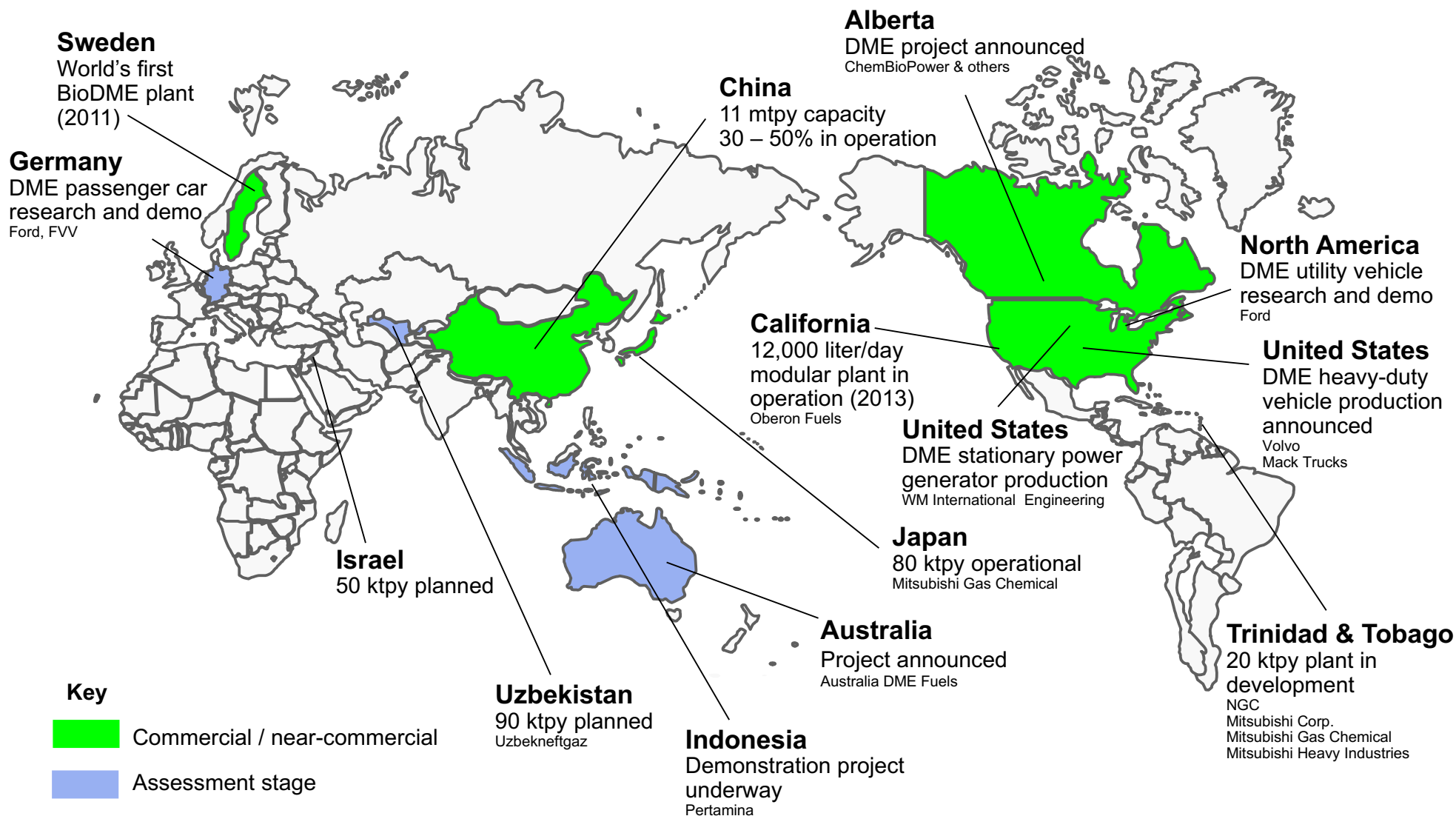
DME
PT. DUTA MAKSIMA ENERGI



DME Around the World



International DME Association



A close-up photograph of a black and white cow with yellow ear tags, looking directly at the camera. The cow is in a green field, and another cow is visible in the background. The text is overlaid on the image.

“...significantly expand the number of livestock digester projects in California...”

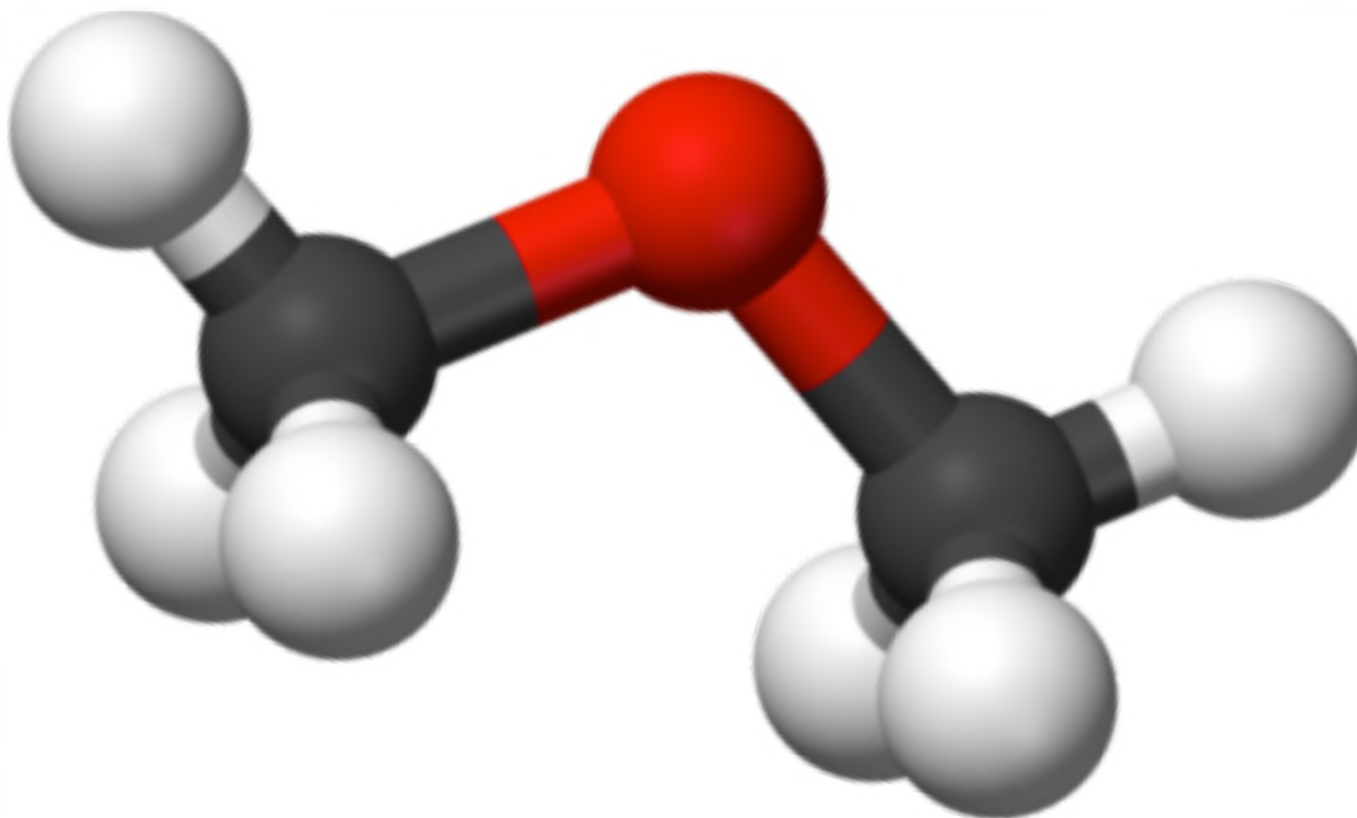
“...identify both commercial ready and emerging technologies and approaches...”

“...identification of potential impacts, benefits, and barrier to scaling up projects...”

DME is a Renewable Gas



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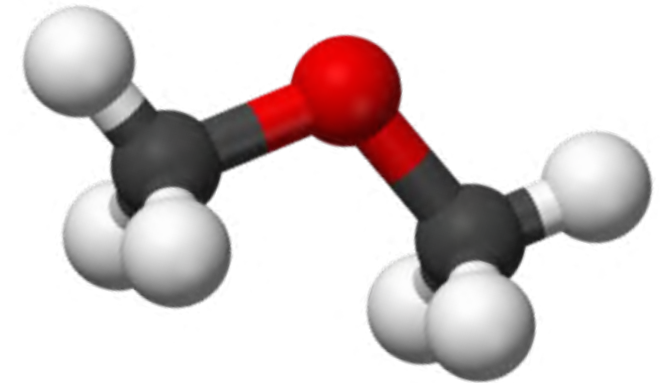
Dimethyl Ether (DME)



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- **Simple Fuel**

- Clean burning, no soot generated
- Made from various methane sources



- **Simple Infrastructure**

- LPG-like Handling (cylinders/tank, only change seal)

- **Simple Engine**

- Diesel-like performance, less after treatment
- Efficiency & torque of diesel engine with no soot produced

DME is a Renewable Gas



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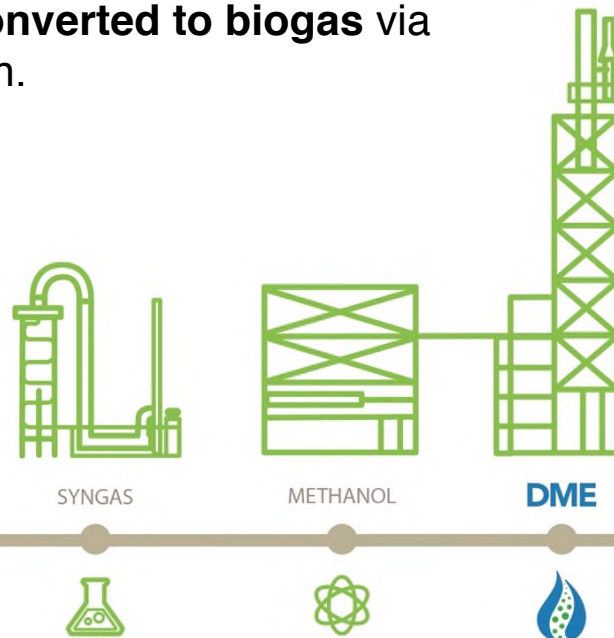
1 Dairy manure, agricultural waste, and food waste are converted to biogas via anaerobic digestion.



BIOGAS



NATURAL GAS + CO₂



AGRICULTURE



TRANSPORTATION



CONSTRUCTION

2 Biogas is converted to DME via the Oberon 3-step process, resulting in a fuel with an estimated carbon intensity of -237. Both the CH₄ and CO₂ in biogas is converted to DME. No CO₂ scrubbing.

3 DME based on renewable feedstocks offers a 68-101% GHG reduction, combusts with NO soot/PM, and is an excellent, clean-burning, diesel replacement. Initial Applications: Heavy-duty trucking

DME Environmental Benefits



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- Biogas-based, Oberon DME qualifies for EPA D-3 & D-5 RINs
- 68% GHG reduction

SAE INTERNATIONAL
 2016-01-0208
 Published 07/2016
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Well-to-Wheels Emissions of Greenhouse Gases and Air Pollutants of Dimethyl Ether from Natural Gas and Renewable Feedstocks in Comparison with Petroleum Gasoline and Diesel in the United States and Europe

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ABSTRACT
 Dimethyl ether (DME) is an alternative to diesel fuel for use in compression-ignition engines with modified fuel systems and offers potential advantages of efficiency improvements and emission reductions. DME can be produced from natural gas (NG) or from renewable feedstocks such as landfill gas (LFG) or renewable natural gas from various waste streams (RNG), or any other biomass. This study investigates the well-to-wheels (WTW) energy use and emissions of five DME production pathways as compared with those of petroleum gasoline and diesel using the Greenhouse gases, Regulated Emissions, and Energy use in Transportation (GREET) model developed at Argonne National Laboratory (ANL). The five DME pathways include 1) fossil NG with large-scale DME plant, 2) natural gas from fossil NG with large-scale plant for both methanol and DME (separately), 3) LFG with small-scale DME plant, 4) manure-based biogas with small-scale DME plant, and 5) combined from black liquor production with small-scale DME plant. This study analyzes DME production and use in the U.S. and Europe, and in two vehicle classes (light and heavy duty vehicles [LDV and HDV]). The WTW results show significant reductions in fossil fuel consumption and greenhouse gas (GHG) emissions by DME compared to gasoline and diesel. DME is produced from fossil NG-based DME produced in large-scale DME plant petroleum diesel dies.

CITATION: Lee, U., Han, J., Wang, M., Ward, J. et al., "Well-to-Wheels Use and Renewable Feedstocks in Comparison with Petroleum Gasoline and Diesel in the United States and Europe," SAE Technical Paper 2016-01-0208, 2016, doi:10.4271/2016-01-0208.

Argonne NATIONAL LABORATORY

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
 WASHINGTON, D.C. 20460

AUG 17 2016

OFFICE OF AIR AND RADIATION

Rebecca Boudreux, Ph.D.
 President
 Oberon Fuels, Inc.
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 La Jolla, California 92037

Dear Dr. Boudreux:

You petitioned the Agency on behalf of Oberon Fuels, Inc. ("Oberon") to approve a pathway for the generation of cellulosic and/or advanced biofuel feed RINs under the renewable fuel standard ("RFS") program for the production of a renewable diesel substitute, dimethyl ether ("DME"), made from waste-derived biogas. Oberon's biogas-to-DME process uses electricity purchased from the grid and available onsite waste-derived biogas for process energy and approved waste-derived biogas from onsite and offsite sources as the feedstock to produce DME using a novel three-step production process (the "Oberon process").

Through the petition process described under 40 CFR 80.1416, Oberon submitted data to the EPA to perform a lifecycle GHG analysis of the Oberon pathways. This analysis involved a straightforward application of the same methodology and of (75 FR 14676) and the July 2014 RFS rule modeling completed for previous rules in the RFS program.

The attached document "Oberon Fuels Regulatory Program" describes the data submitted by Oberon for the determination of the lifecycle greenhouse gas emissions of the Oberon pathways.

Based on our assessment, renewable DME treatment facility digesters, agricultural digester components of biomass process qualify under the Clean Air Act for cellulosic components of biomass process. Biogas from waste digester processes that the Oberon pathways qualifies for advanced must meet the definitional requirements as appropriate, be made from renewable biomass pursuant to 80.1426(e)(1)(i) and (1)(ii) if

- In 2016, Argonne updated DME GREET Model
- DME = 85-101% GHG reduction (waste biomass, landfill gas, animal & organic waste)

Why Bother Converting to DME?

Compression Ignites, No Spark Plugs



Why Convert to DME?



Power & Torque of a Diesel Engine

Photo Credit: Ron Jautz © 2017

Why Convert to DME?

Breaks Open the HD Trucking Market



Why Convert to DME?



Diesel-like Performance, Propane-like Handling

DME Engine Development



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Diesel-like Performance, LPG-like Handling

DME fuel pump at ENN service station (Shanghai)



BioDME Project

Partners include
TOTAL, Preem, Delphi,
ETC, Chemrec, &
Haldor Topsoe



上汽集团
SAIC MOTOR

NAVISTAR[®]



Moving Towards Commercialization



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2015

Ford building world's first DME-powered passenger car for on-road testing.



2017

Ford developing world's first DME engine for full-size pickup trucks. Development of the 6.7 liter engine, for use in the popular F-250, F-350, and F-450, is underway.



NYC Department of Sanitation (DSNY) first Mack customer in the world to test a DME-powered Mack truck. (Photo Ron Jautz © 2017)

Moving Towards Commercialization



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- Aftermarket conversions moving forward
- Enable the conversion of 100% diesel vehicles to run on both DME and diesel
- Initial studies indicate 30-60% diesel displacement
- Advanced testing phase of conversion technologies used in the European market, adapted for DME use



What is next for DME?



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DME100

100 DME vehicles on the road in 2018-2019

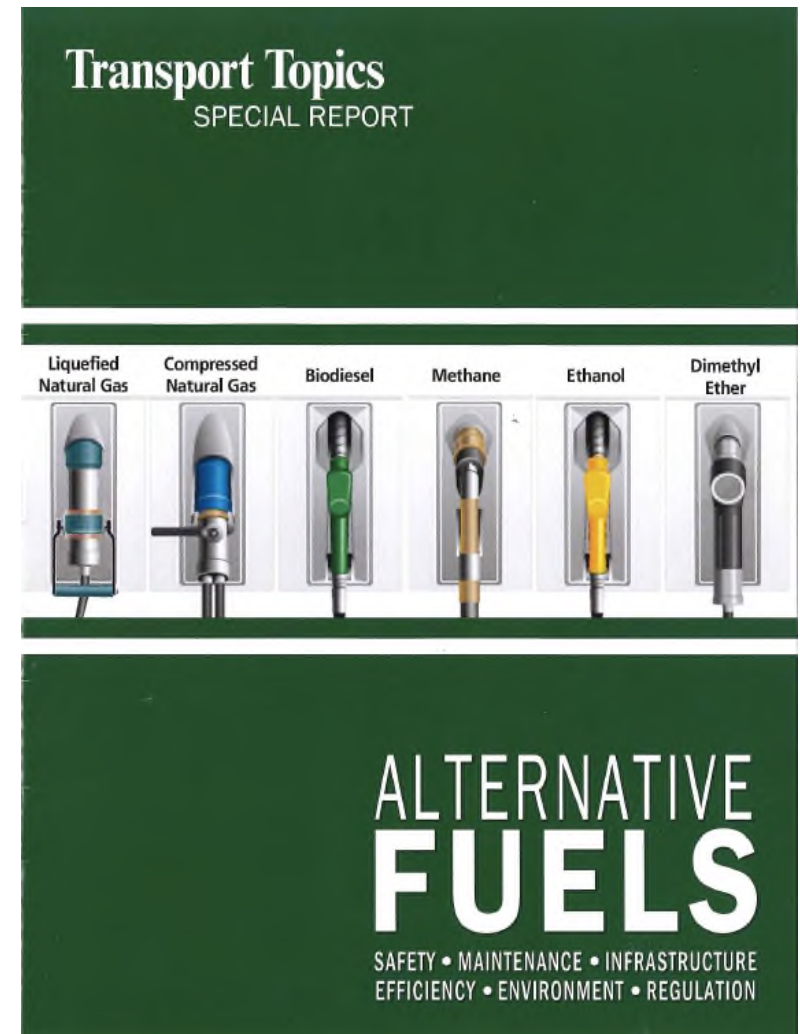
- **DME** known to be a clean-burning, low-carbon diesel replacement 20+ years. *Technical hurdles are no longer an issue.*
- **Remaining questions are:**
 - How do we scale the DME supply chain economically?
 - Do DME's economics and favorable properties lead to customer demand for the fuel?

Where do we go from here?



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- **Collaborative Projects** for biogas-based fuel production
 - Better understand the economics and applicability of each fuel-type to the CA dairy industry in particular
 - Shared fueling infrastructure
 - Shared alternative-fuel maintenance facilities
 - Determine additional synergies among technology solutions





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International DME Association
DME: 21st Century Energy



DME Regulations



International DME Association



ASTM Intl. Specification

Published 2014
ASTM D7901-14b
DME as a fuel



ISO Standard

Published 2015 as
ISO 16861:2015
DME as a fuel



Legal Fuel in CA

CDFA modified CA Code of Regulations to allow the legal sale of DME as a fuel effective January 1, 2015.



Tier 1 Report

As part of Multimedia Assessment process, CARB published DME Tier 1 report February 2015. Evaluated DME effects on air, soil, and water.



RINS Eligible

Renewable Fuel Standard (RFS) Pathway Approved