

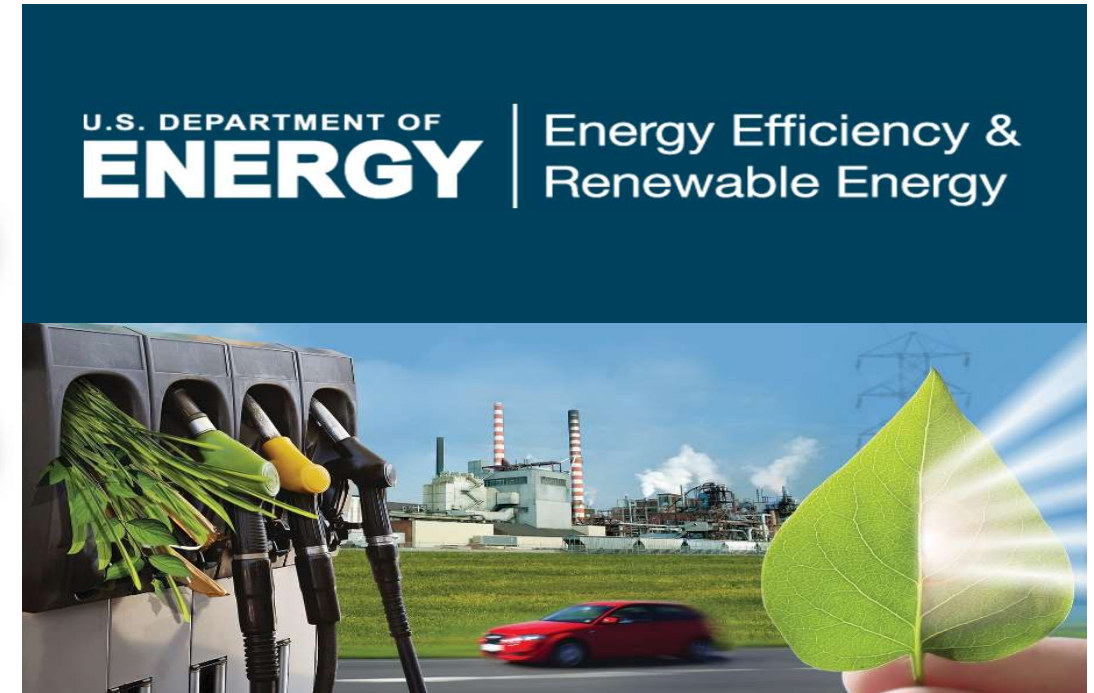
DME as a Renewable Hydrogen Carrier: Innovative Approach to Renewable Hydrogen Production

DOE project award #: TCF-21-24944

6-8 June 2022

DOE Hydrogen Program
2022 Annual Merit Review and Peer Evaluation Meeting

AMR Project ID #: ST242



Troy A. Semelsberger (PI)



This presentation does not contain any proprietary, confidential, or otherwise restricted information

Project Goals and Objectives

Ultimate Goal

Commercialize Oberon's renewable dimethyl ether (rDME™) as a hydrogen carrier supplying fuel-cell grade hydrogen and as a means of storing and transporting hydrogen on a global scale

Project Objectives

- Design, build, and demonstrate integrated DME-SR process using LANL's novel dual-catalyst bed to produce 25 kilograms of fuel-cell grade hydrogen per day (end-of-project TRL = 6-7)
- Validate hydrogen quality through fuel-cell performance testing
- Provide full documentation to Oberon related to design, bill-of-materials, and performance of integrated DME-SR prototype for Oberon's Phase 4 commercialization plan

Overview

Timeline and Budget

- Project Start Date: 05 April 2022
- Project End Date: 05 April 2025
- Total Project Budget: \$3M
 - DOE Share: \$1.5M
 - Cost Share: \$1.5M
 - DOE Funds Spent*: \$0
 - Cost Share Funds Spent*: \$0

* As of ~03/01/2022

Partners

- Project Lead: LANL
 - Troy A. Semelsberger (PI, LANL)
- Co-PI(s):
 - Rod Borup (Co-PI, LANL),
 - Wendy Merkin (Co-PI, Oberon Fuels)
- Partner organization: Oberon Fuels

Team

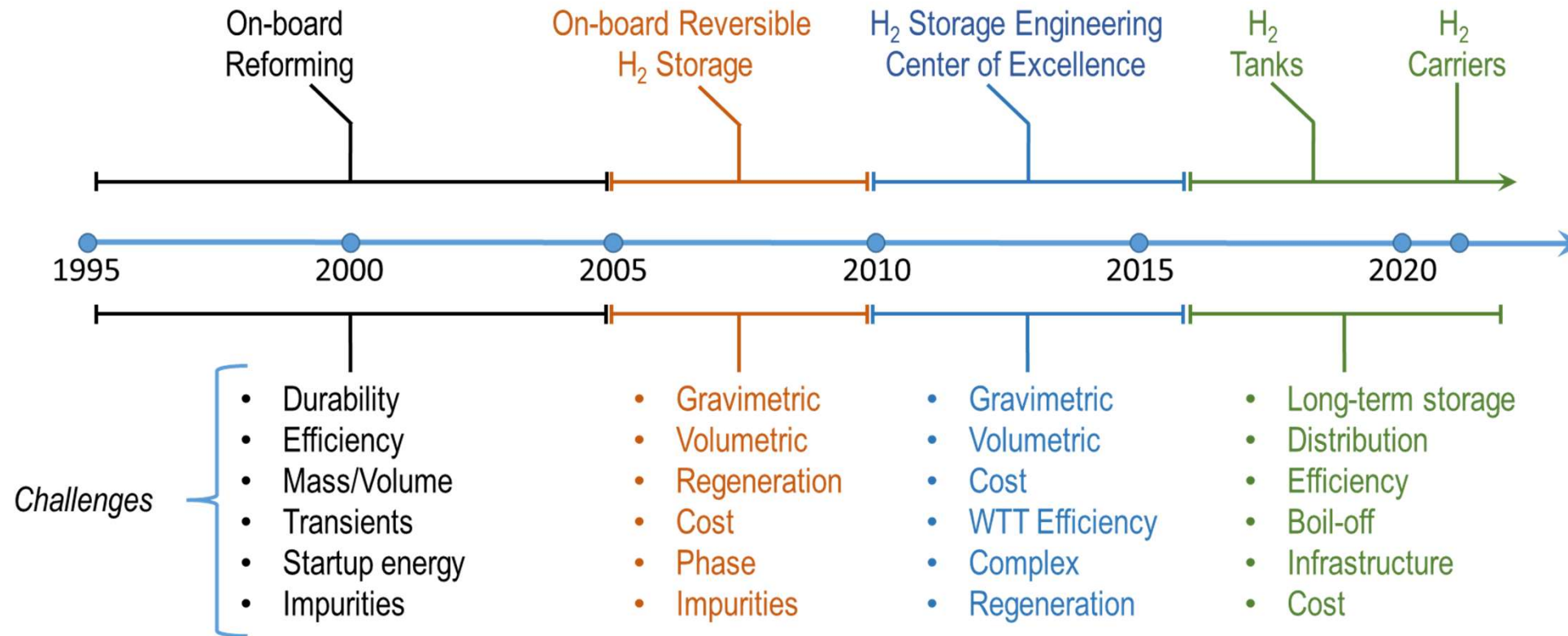


Rebecca Boudreaux, Ph.D., President & CEO
Cinch Munson, VP of Commercial Development
David Mann, VP of Regulatory & Gov't Affairs
Wendy Merkin, Director of Site Development
Elliott Hicks, Chief Operating Officer



Troy A. Semelsberger, Ph.D.
Rod Borup, Ph.D.
Mike Heidlage, Ph.D.
Jose Tafoya
Steve Stringer (Tech Transfer)

Relevance/Potential Impact



To meet the goals of the H₂@Scale initiative, safe, efficient, and low-cost transport and bulk storage of hydrogen is of critical importance.

DOE EERE

¿Can we do better than just another H₂ carrier?

Relevance/Potential Impact

H₂ Carriers and Alternative Fuels must address:

1. Availability
2. Economics
3. Acceptability
4. Environmental & Emissions
5. Technology
6. Versatility
7. National Security



DME fueled buses



DME fueled HD trucking



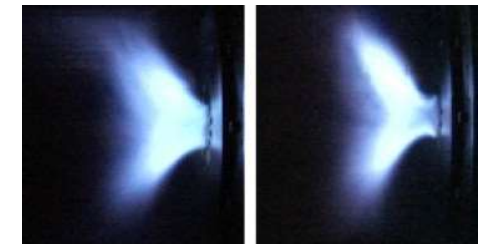
DME used as a H2 carrier



DME used as heating & cooking fuel



DME used for DME-Propane blends



(a) DME flame

(b) Methane flame

DME used as a turbine fuel

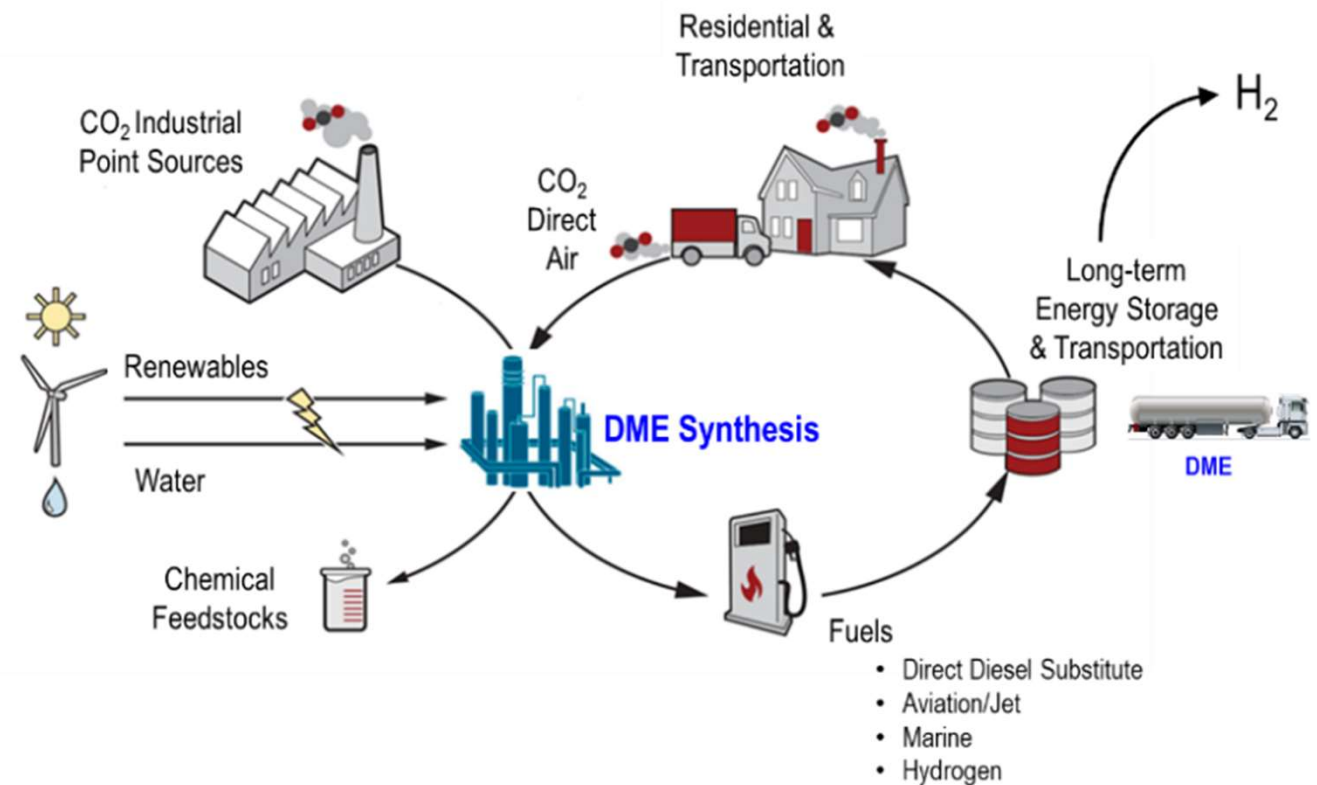
¿Is DME the missing link to the Hydrogen Economy?

Relevance/Potential Impact

Oberon-LANL CRADA addresses the long-term storage and distribution problem with hydrogen

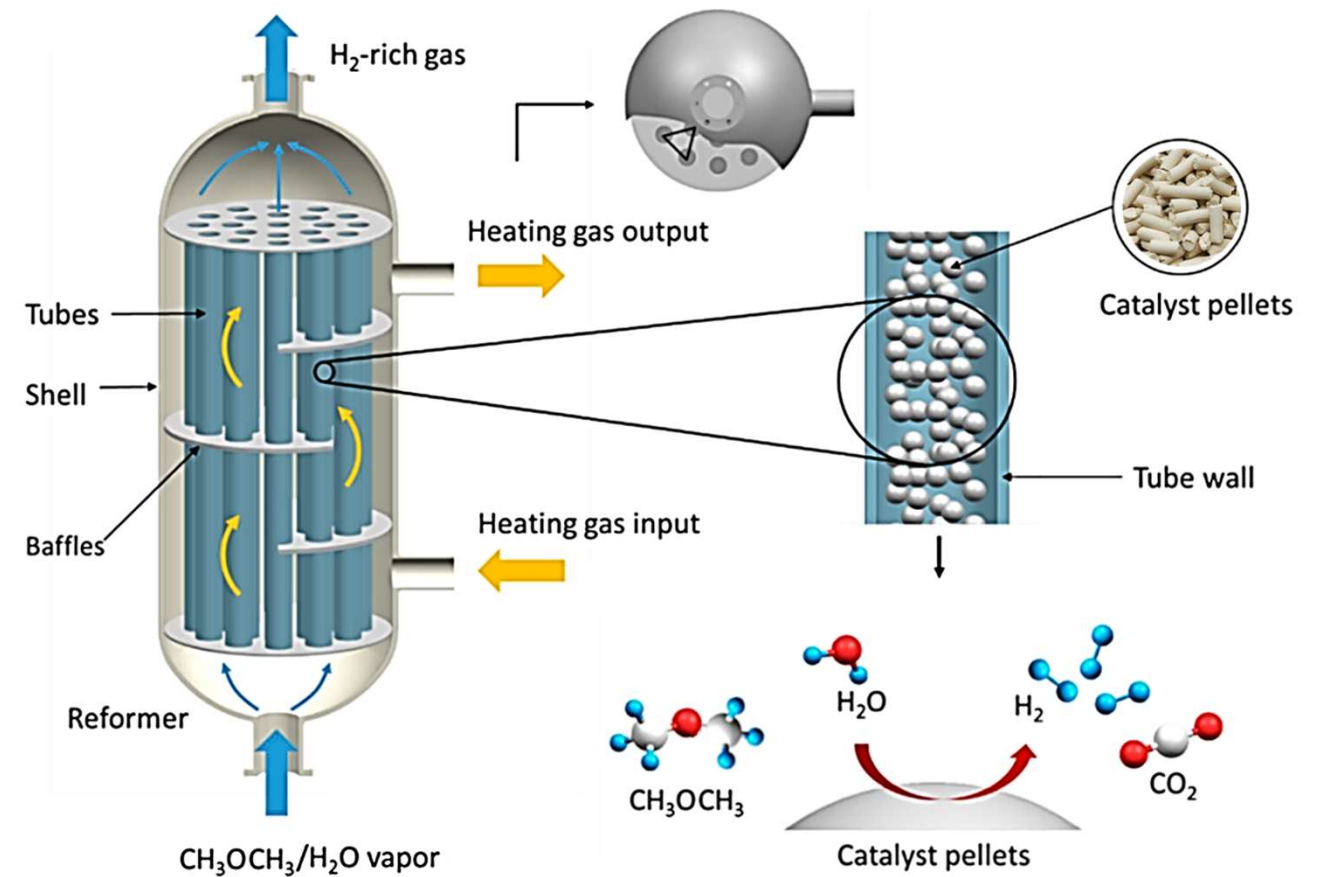
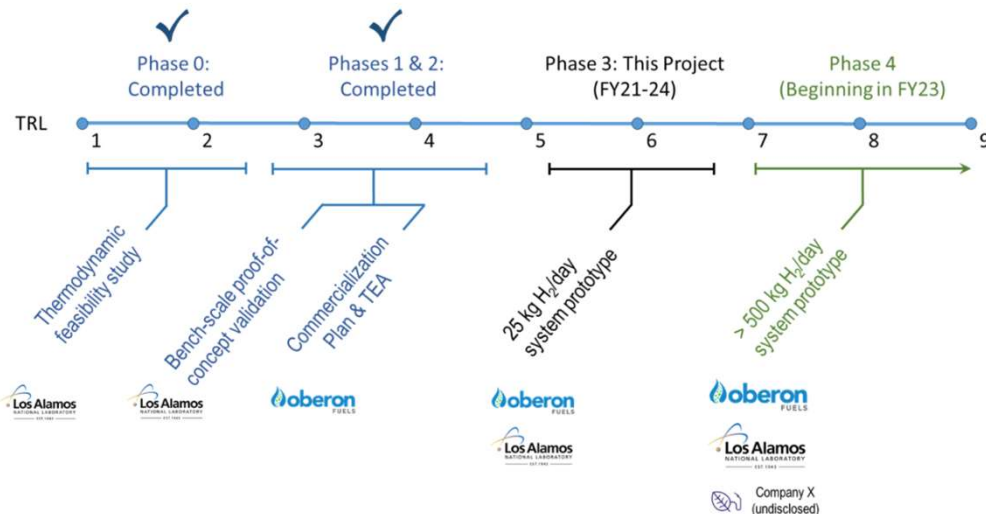
Impact:

- ✓ Broadens the end-use cases of DME
- ✓ Provides the foundation for further scale-up to 500+ kg H₂/day
- ✓ Accelerates decarbonizing multiple market sectors
- ✓ Provides a gateway to the hydrogen economy
- ✓ Accelerates light- and heavy-duty fuel cell deployment



Approach

1. Design scaled-up reactor using LANL's catalyst to produce 25 kg H₂/day
2. Build prototype reactor
3. Demonstrate 25 kg H₂/day
4. Provide data and insights for scale-up to 500 kg H₂/day
5. Deploy commercial units delivering fuel-cell grade hydrogen to FCEV (Phase 4)



Accomplishments

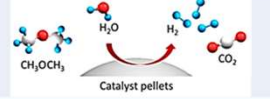





1. TCF Kick-off meeting held 5 April 2022
 - Team consensus on path forward
2. Initial lab preparation is underway to site reactor system at TA-46, Bldg 16, Rm 5B
3. Identified major components for reactor system
4. Initiated conversation to site Oberon's rDME tanks

Tech Transfer/Marketability

Innovative next generation technologies for the economic viability and commercialization of fuel-cell grade hydrogen from DME

Continued Success:

- ✓ ***Facilitate and collaborate with Oberon Fuels and Company X to further scale-up and demonstrate DME-SR technologies***
- ✓ ***Direct DME synthesis via CO₂ reduction***
- ✓ ***DME upgrading to marine and aviation fuel***

DME Alternative Fuel			
Industry	Graphical Representation	Commercially Demonstrated	Focus of this Study
Hydrogen		✗	✓
Turbine Fuel		✓	✗
Diesel Fuel Substitute		✓	✗
Aerosol Propellant		✓	✗
Heating & Cooking Fuel		✓	✗
DME-Propane Blends		✓	✗

Collaboration and Coordination

Collaboration

Partner		Roles
DOE HFTO		Sponsorship, guidance, support
Oberon Fuels		rDME supplier, TEA/LCA outlooks, Phase 4 Coordination
LANL		Project lead, design, build, demonstrate prototype reactor, reporting

Coordination

- ✓ *Planning, Assessing, Mitigating, & Solving*
 - *Constant team engagement with biweekly meetings*
 - *Clear, well-defined milestones and objectives*
- ✓ *Face-to-Face Meetings (F2F)*
 - *HFTO quarterly and annual F2F meetings*
 - *HFTO Peer Review*
 - *Participate in at least four F2F TCF project meetings during the 36-month project*

Milestones

Fiscal Year	Due Date	Milestone Name/Description	Criteria	Type
FY22	Q3-FY22 (June 2022)	LANL (M1): Finalize 50% design package for rDME-SR reactor scaled to 25 kg H ₂ /day	Month 3	Milestone
	Q4-FY22 (Sept 2022)	LANL (M2): <ul style="list-style-type: none"> • Finalize 50% design package for integrated system scaled to 25 kg H₂/day production rates • Order off-the-shelf BOP components (i.e, valves, tubing, fittings, mass flow controllers, etc..) 	Month 6	Milestone
FY23	Q1-FY23 (Dec 2022)	LANL(M3): <ul style="list-style-type: none"> • Finalize 100% design package for rDME-SR reactor scaled to 25 kg H₂/day • Order fabrication of rDME-SR reactor 	Month 9	Milestone
	Q2-FY23 (Mar 2023)	LANL (M4): <ul style="list-style-type: none"> • Finalize 100% design package integrating rDME-SR reactor with hydrogen purification for 25 kg H₂/day • Order remaining off-the-shelf components to complete construction of integrated system 	Month 12	Milestone
	Q3-FY23 (June 2023)	Oberon (M): <ul style="list-style-type: none"> • Deliver required DME for demonstration to LANL 	Month 15	Milestone
	Q4-FY23 (Sept 2023)	LANL (M5): Field verification and commissioning	Month 18	Milestone
FY24	Q1-FY24 (Dec 2023)	LANL (M6): Demonstrate hydrogen production rates of 12.5 kg H ₂ /day with full gas phase analysis of product stream	Month 24	Milestone
	Q2-FY24 (Sept 2024)	LANL (M7): <ul style="list-style-type: none"> • Demonstrate hydrogen production rates of 25 kg H₂/day with full gas phase analysis of product stream • Verify and document hydrogen purity with HCD 	Month 30	Milestone
FY25	Q1-FY25 (Dec 2024)	LANL (M8): <ul style="list-style-type: none"> • Validate and document fuel cell performance using rDME-SR hydrogen • Document catalyst durability for continuous hydrogen operation 	Month 33	Milestone
	Q2-FY25 (Mar 2025)	LANL (M9) Deliver final report documenting rDME-SR performance and hydrogen quality to Oberon	Month 36	Milestone

FY22 Future Work

Fiscal Year	Due Date	Milestone Name/Description	Criteria	Type
FY22	Q3-FY22 (June 2022)	LANL (M1): Finalize 50% design package for rDME-SR reactor scaled to 25 kg H2/day	Month 3	Milestone
	Q4-FY22 (Sept 2022)	LANL (M2): <ul style="list-style-type: none">• Finalize 50% design package for integrated system scaled to 25 kg H2/day production rates• Order off-the-shelf BOP components (i.e, valves, tubing, fittings, mass flow controllers, etc..)	Month 6	Milestone

Summary

- 1. LANL-Oberon TCF Kick-off meeting held 5 April 2022**
 - *Attendees: LANL, DOE, and Oberon Fuels*
- 2. NDA fully executed**
- 3. Team consensus on milestones, deliverables, and time table**
- 4. Biweekly coordination meetings scheduled for project duration**
- 5. LANL lab preparation underway to site prototype reactor**