



Element 1

Powering Innovation

A solution for extended H₂ supply for high power mobility applications

The 8th FC International Meeting 2020

第8回国際交流会

David S.W. Lim, PhD
Element 1 Corp, VP, Asia



Scalable.
Reliable.
Affordable.

www.e1na.com



Element 1 Corp

Overview

Scalable, Reliable, and Affordable H₂ Generation

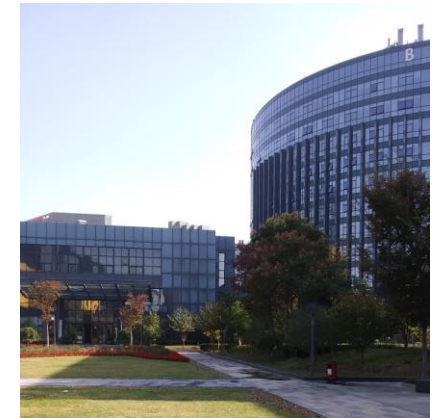
- e1 is the global leader in developing small-scale advanced H₂ generation systems supporting the fuel cell industry
- e1 offers solutions for both stationary and mobile fuel cell systems
 - Extensive IP portfolio
 - Track record of commercial success
- **Business model is licensing and Joint Venture**
- The company maintains world-class product development and testing facilities in Bend, Oregon, with a subsidiary in Jiaxing, China



Scalable.
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e1 N.A. Bend, Oregon USA



e1 China, Jiaxing



Management Team



Dr. Dave Edlund Ph.D., Founder & CEO

- 30 years experience developing fuel reformers and H₂ purifiers
- 100 H₂ generator and fuel cell patents. Co-founder of IdaTech, LLC (later sold to Ballard Fuel Cell Systems)

Robert Schluter, Founder & President

- 20 years business operations, sales and marketing experience
- Founder of Pangaea Technology Resources



Greg Haugen, CFO

- VP Finance and Administration for Advanced Power Technology, Inc.
- Helped lead successful IPO of APT in 2000. Extensive M&A experience
- Public accounting experience with KPMG



David S.W. Lim Ph.D., Vice President Asia

- 15 years experience in H₂ and fuel cell industry with collaborations with Ballard, IdaTech, and other industrial players
- Former CTO and co-founder of Pfemtoquest LLC



Koji Hoshi, Dir. Of Engineering

- 15 years of fuel reformer and fuel system engineering experience
- Formerly Sr. System Engineer for Ballard Fuel Cell Systems





What is a Hydrogen Generator?

Examples

A completely self-contained machine that converts feedstock to purified H₂

- **Electrolyzer** (water split by electricity into H₂ and oxygen)
 - High CapEx and OpEx
 - 55 kWhrs electricity → 1 kg H₂ (US\$8.25 at \$0.15/kWhr)
- **Natural gas reformer** (methane plus water reacted to make H₂)
 - High CapEx, only possible where there is good NG pipeline infrastructure
- **Methanol Reformer** (methanol plus water reacted to make H₂)
 - Lowest CapEx, no supporting infrastructure required
 - 6.3 kg methanol → 1 kg H₂ (US\$3.15 at US\$500/ton methanol)
- **Methanol mixed with water** is feedstock for e1 H₂ generators
 - 33% of product H₂ is derived from water
 - $\text{CH}_3\text{OH} + \text{H}_2\text{O} \rightarrow \text{CO}_2 + 3\text{H}_2$
 - Cost of produced H₂ about US\$4 to US\$5/kg
 - Compressed H₂ at fueling stations in California sells for up to US\$16/kg

Uniquely suited for making hydrogen on-board a vehicle



e1 Markets & Products

Scalable, High Value Solutions at an Affordable Cost



Critical Infrastructure

Reliable and cost-effective fuel reformers supporting telecom and other critical infrastructure

S-Series

L-Series



FCEV H₂ Refueling Stations

Scalable fuel reformers supporting fleet FCEV refueling stations and material handling

L-Series



Mobile H₂ Generation

Mobile (on-board) fuel reformers for bus, truck, tram and marine fuel cell solutions

M-Series



Solving “The Hydrogen Challenge”

The Case for Hydrogen Generation from Methanol

- Fuel cell solutions are being commercialized in the HD vehicle and marine industry
- HD vehicle and marine fuel cell systems require new hydrogen solutions to crack “The Hydrogen Challenge”
- Lowering hydrogen’s total cost per kilogram at the point of use is key to adoption of fuel cell power solutions
 - The best delivered liquid hydrogen can do is \$6 kg
- Compressed hydrogen solutions *limit* fuel cell deployment
 - Limited space is available for very large hydrogen storage solutions
 - Supporting energy systems add cost and weight at the point of use

Methanol-generated H₂
Provides the Lowest Total
Cost of Hydrogen

e1’s on Vessel Hydrogen Generation
Technology Solves “The Hydrogen Challenge”





Why On-board H₂ Generation?

Think in Terms of kW-hours

<1 kWhr

Hundreds of kWhrs

>1 MWhr

kW-hours = kW x hours = power x distance (time between refueling)

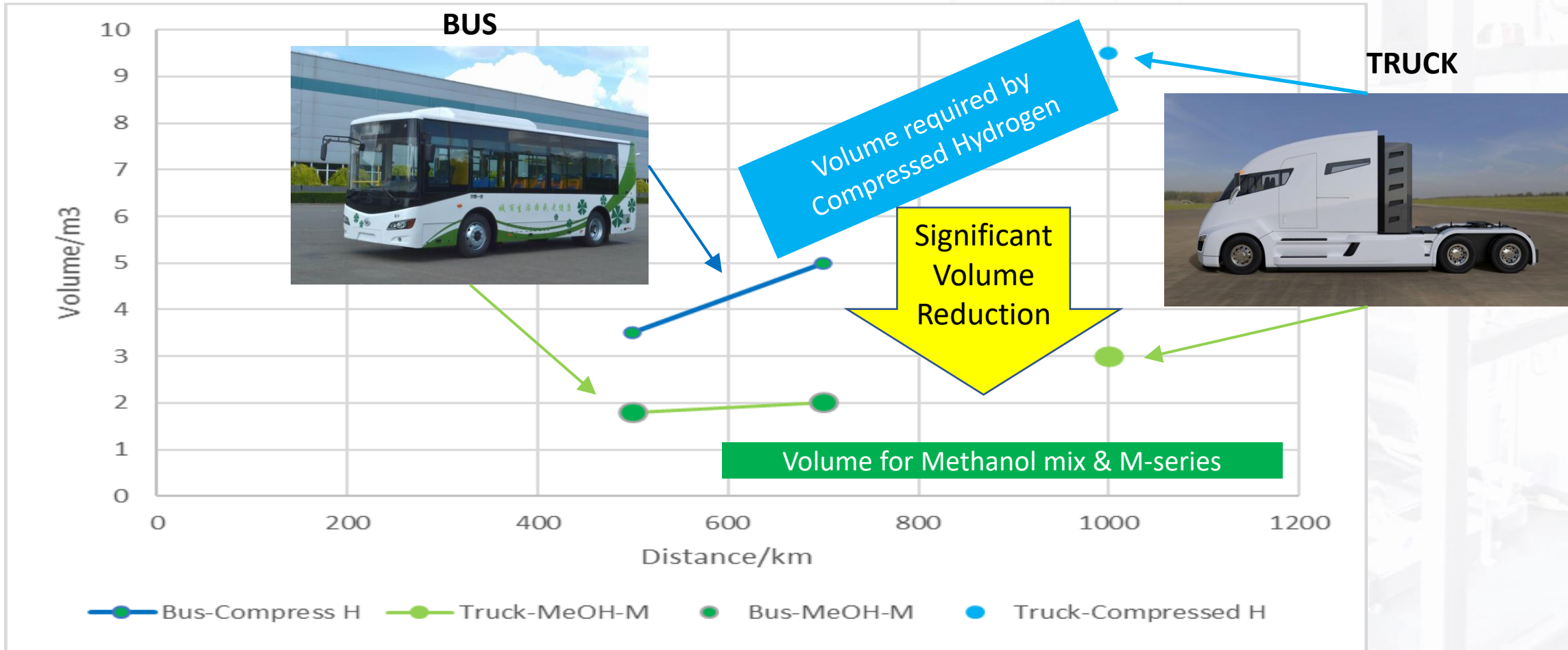
Battery

Fuel Cell





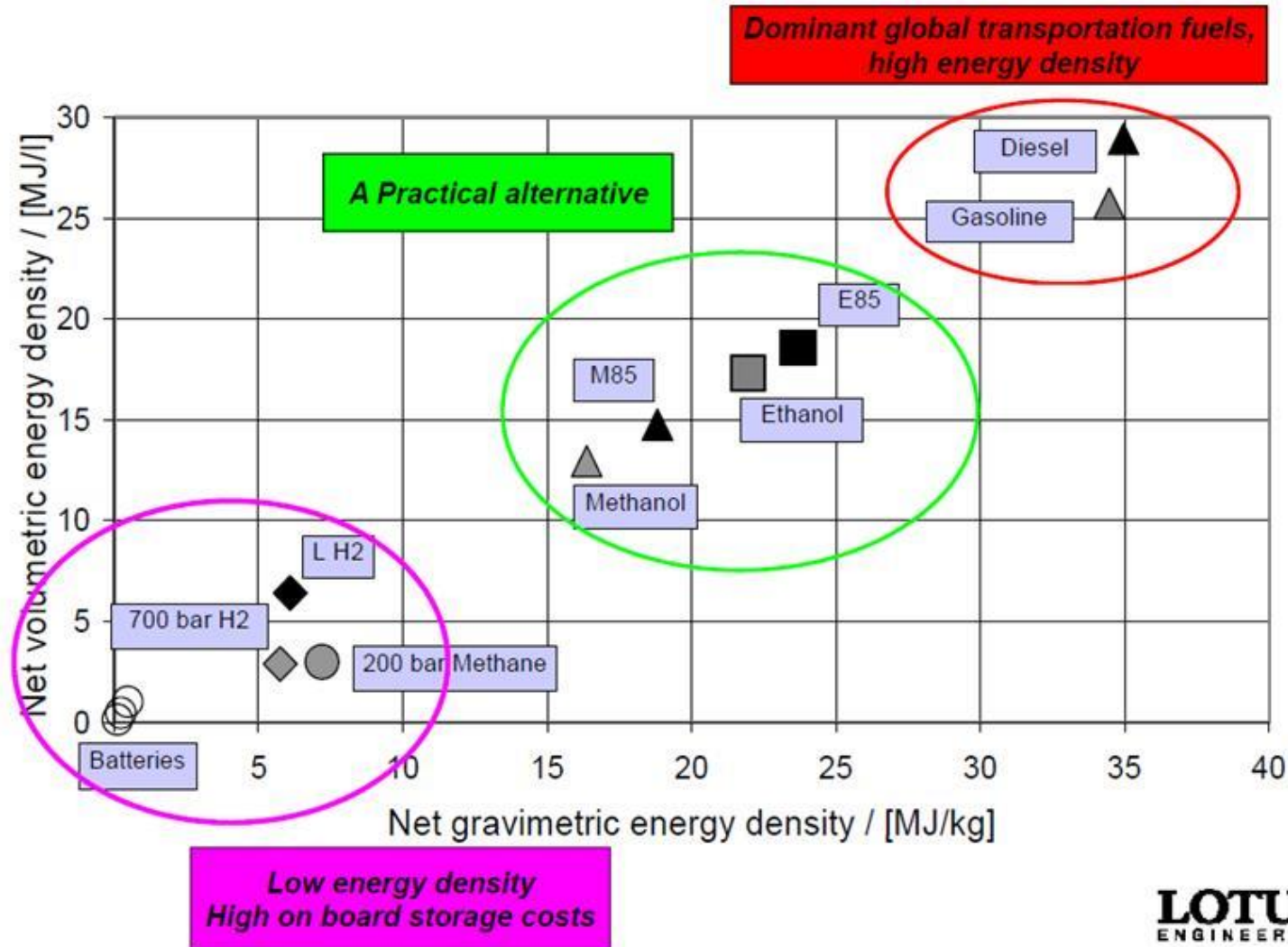
The Hydrogen Challenges of HD FCV





Methanol: A Very Practical Liquid Fuel

Methanol has Four Times the Energy Density of 700 bar Gas H₂



Methanol:

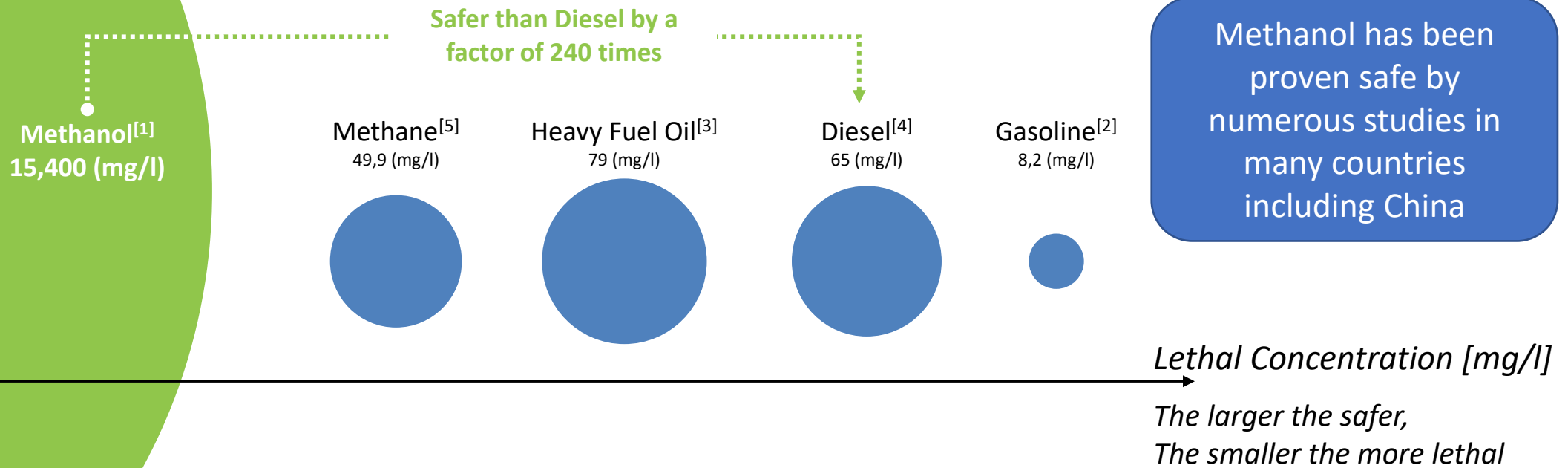
- Good energy density
- Liquid fuel = easily manageable
- Very accessible



Safer for the Environment

LC50, LC = LETHAL CONCENTRATION

Concentration in water, at which half the marine population died within the specified test duration



Methanol has been proven safe by numerous studies in many countries including China

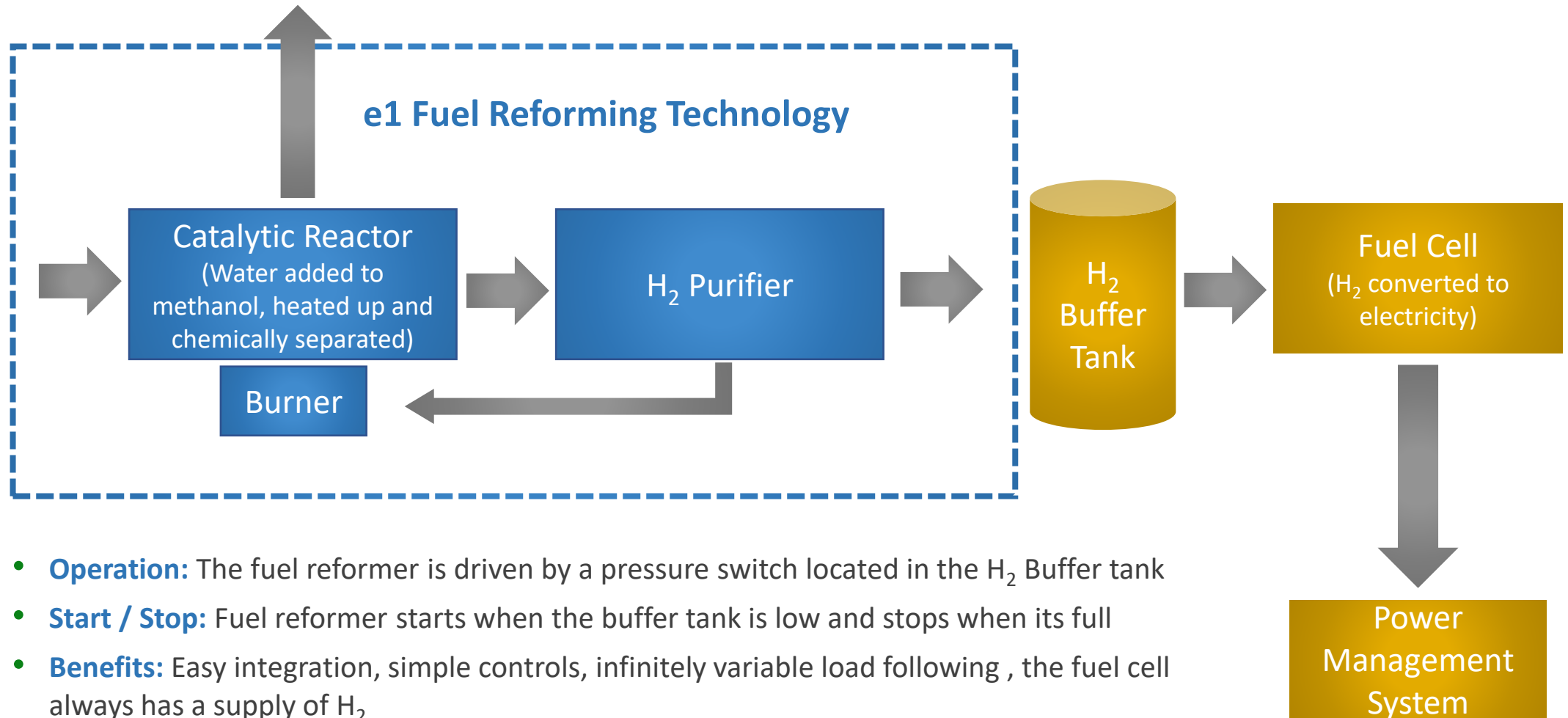
[1] ECHA, European Chemicals Agency, registration dossier Methanol
[2] Petrobras/Statoil ASA, Safety Data Sheet, ECHA registration dossier Gasoline
[3] GKG/ A/S Dansk Shell, Safety Data Sheet
[4] ECHA, European Chemicals Agency, registration dossier Diesel
[5] ECHA, European Chemicals Agency, registration dossier Methane
Additional Source: Meyer-Werft

Courtesy of the Methanol Institute



e1 Methanol Fuel Reformer

Simple Operation



Scalable.
Reliable.
Affordable.



Hydrogen Purification Membrane

Enables Use of Low-Temperature PEM Fuel Cells

Overview

- e1's membrane purifier was designed to enable use of **low-temperature PEM fuel cells**
- **Operation:** Passive process works by pressure differential
- **Product H₂:** ≈99.99% with <0.2 ppm CO and <0.2 ppm CO₂

Key Advantages

- **Lowest initial cost of equipment**
- **Quiet and simple operation:** No moving parts
- **High reliability and long lifetime:** engineered for > 20,000 operating hours
- **Easy integration:** no valves, absorbents, or complicated controls

Developed over 30 years, e1's membrane purifier is the **Key** to low cost H₂ generators



Purification module array

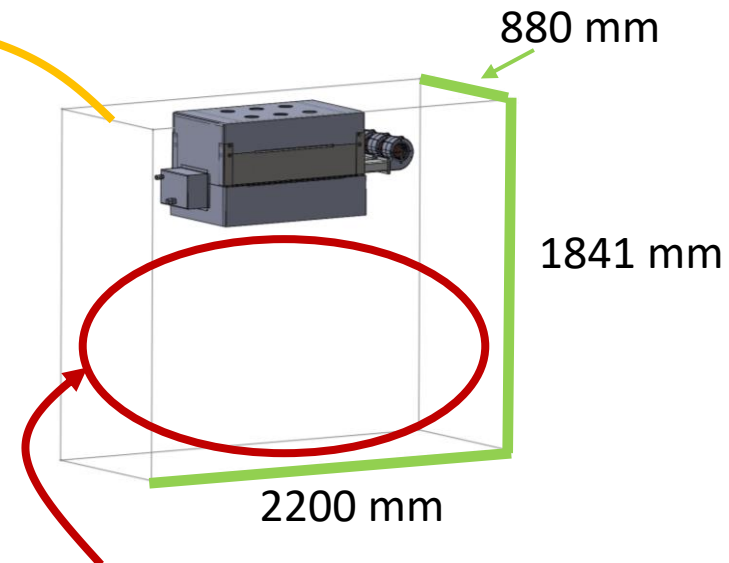
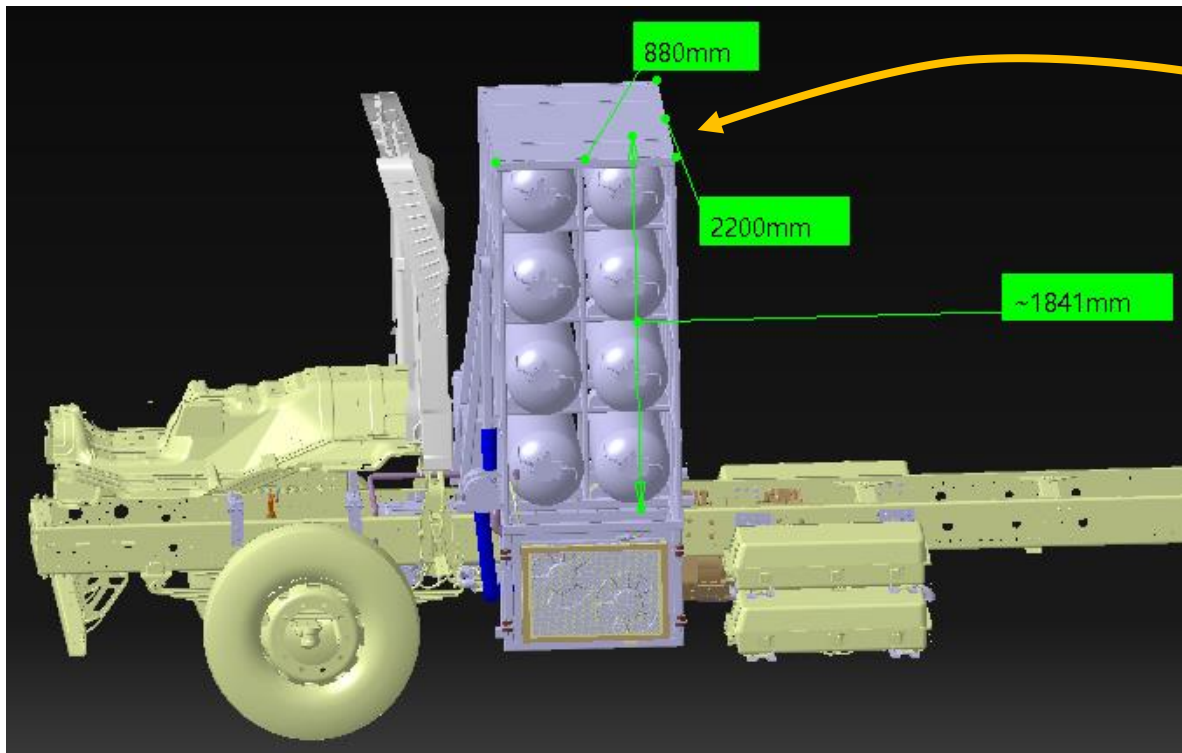


M-Series is Small in Size

Fits in Location Previously Used for Cylinders of Hydrogen

M-Series + methanol/water gives *5x range* of compressed H₂ in same space on vehicle

Light-Duty Delivery Truck, 40 kW FCM



Space for 2,200 L methanol/water tank (equiv. to 190 kg H₂)
Sufficient for **67 hours operation** at full power (40 kW)
(only **13 hours operation** using compressed hydrogen)



M-Series Methanol to H₂ Generator (Mobile)

On-Board H₂ Generation for *HD Transportation*

Overview

- **M-Series:** Designed to compressed H₂ to support mobile fuel cell propulsion solutions
- **Feedstock:** Methanol & DI water feedstock
- **H₂ Production:** Can scale to support from 30 kW to 300 kW
- **Product H₂:** ≈ 99.99% with <0.2 ppm CO and <0.2 ppm CO₂
- **Target Uses:** HD Trucks, buses, trains and marine vessels

Key Advantages

- **Vibration Resistant:** Designed for transportation applications
- **Operation:** Designed for cyclic and variable operation
- **Compact Design:** Occupies significantly less space than compressed H₂ storage solutions
- **Lifetime:** Designed for greater than 20,000-hour lifetime (H₂ production)
- **Manufacturing:** Under e1 manufacturing license



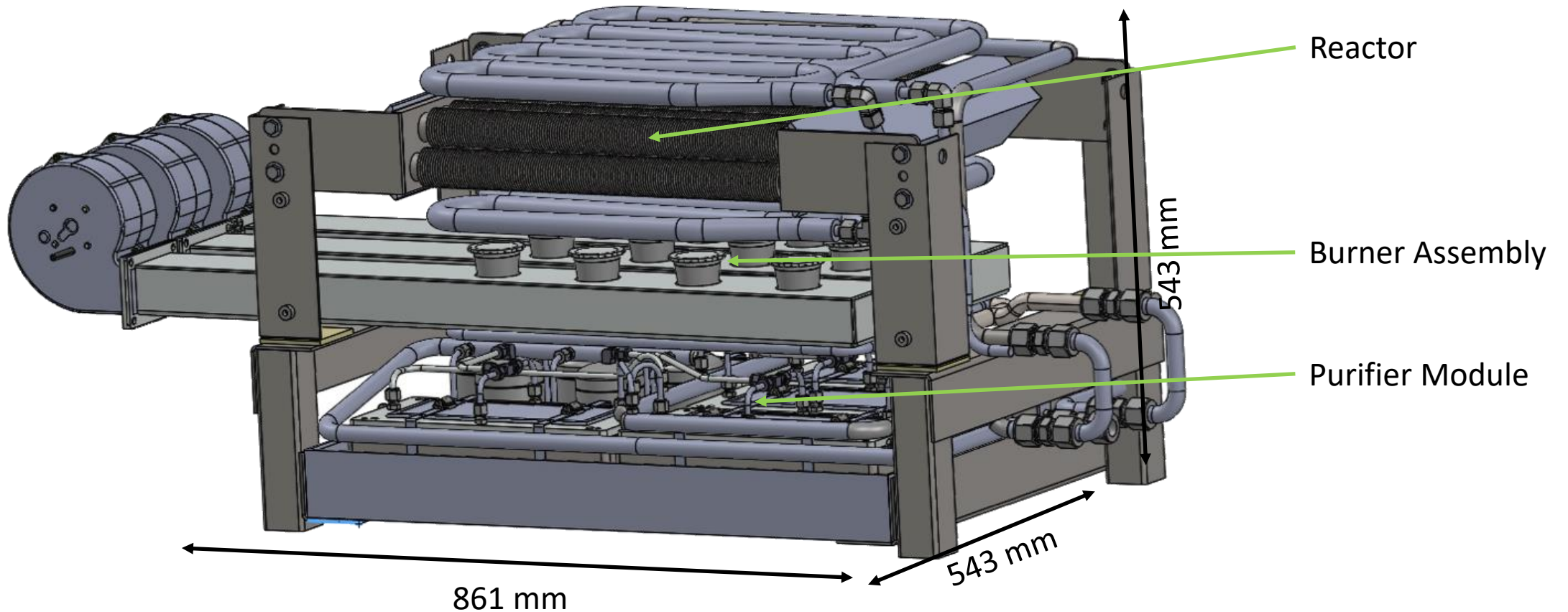
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M-Series Methanol to H₂ Generator

Better Than Compressed H₂

- Sized for 40 kW fuel cell module (model M40)
- Very small size—**only 0.25 m³**





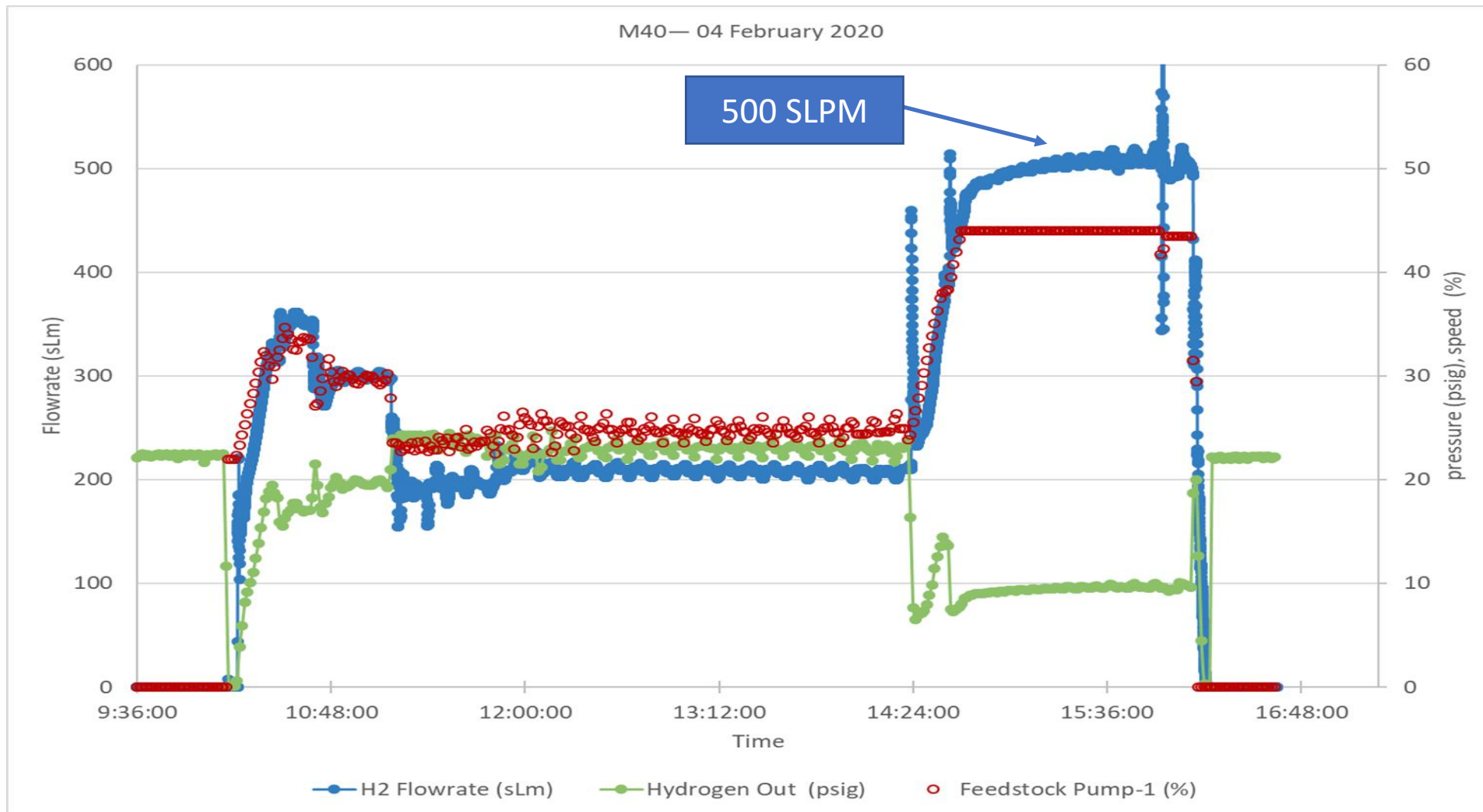
M-40 Assembly

Supports 40kW FCM – MD Truck





M-40 Operations





Mobile H₂ Generator (for HD vehicle & Marine)

Key Advantages

→ **Occupies smaller space (HD vehicle & marine) compared to compressed H₂**

- Result is greater driving range between fueling

→ **Attractive Economics**

- Very low CapEx and OpEx, produce H₂ for \$3 to \$5 per kg

→ **Minimal Maintenance**

- Simple, routine servicing every 12 months

→ **Scalable**

- Support 30 kW to MW fuel cells

→ **Simple / Familiar Feedstock Storage**

- No stored high-pressure H₂ required, improved safety
- No requirement to invest in gaseous H₂ fueling infrastructure

Extreme cold
weather operation
available with
methanol



Accelerates the Adoption of Fuel Cell HD vehicle/Marine Transportation



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The End

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