Powertrain Electrification and Fuel Cell R&D

Power of Choice

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H2@Scale End Use Applications for Truck
Cummins Powers a Broad Range of Applications with Diverse Requirements

- The world’s largest independent engine manufacturer
- Global manufacturing
- Broadest and most capable distribution and customer support network
- Powering more types of equipment in more markets than any other engine company

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<th>Common Requirements</th>
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CHANGING GROWTH DRIVERS

NEW TECHNOLOGIES
SUSTAINABILITY
EMISSIONS REGULATIONS
ENERGY PRICES & AVAILABILITY
GLOBALIZATION
Commercial Vehicle Applications
“Powertrain of Choice”
Benefits of PEM Fuel Cells

- Zero carbon, zero emissions (compared to conventional fuels)
- High energy density (compared to battery)
- Quick refueling (compared to battery)
- Improving performance & durability
- Immediate startup (compared to SOFC)
- Transient response (compared to SOFC)
- Improving cost of operation
Key Drivers for Adoption of Technology

TECHNOLOGY
- Efficiency
- Durability
- Cold start
- Transient response

INFRASTRUCTURE
- Public refueling stations
- Pipeline
- Hydrogen by-product from industries

COST
- PEMFC ($/kW)
- Hydrogen fuel ($/kg)
- On-board storage system
- Refueling station

REGULATIONS
- Zero emission zones
- Government funding
- Incentives

Customer Cost of Operation
At today’s price of hydrogen (~$10/kg) and PEMFC system ($1000/kW), total cost of operation (TCO) are not justified.

At DOE targets ($50/kW and $2-3 kg/H2), TCO could be better than EV.

Key elements in ecosystem
1. Electricity / Natural Gas price
2. Electrolysis / SMR equipment
3. H2 & O2 distribution
4. PEMFC system & on-board storage
# Building Capabilities Across the Value Chain

## CELLS & MATERIALS
- Materials
- Cells

## MODULE COMPONENTS
- Stack
- Fuel cell controller
- Air handling
- Thermal management

## SYSTEM COMPONENTS
- H₂
- O₂
- Fuel cell module
- Battery pack
- Motor generator
- Controls
- Power electronics

## SYSTEM INTEGRATION & AGGREGATION
- Integrated powertrain system
- On-board storage

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