AHEAD ENERGY

Fuel Cells Fueled by Alternative Fuels

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James Grieve, Introduction

- Chief Scientist, Delphi Automotive Systems (retired 2016)
  - engines, fuel cells, hybrid vehicle systems, emission controls, alternative fuels

- CTO, MicroEra Power (licensing spin-out)
  - high efficiency DG, supporting the renewable intensive grid
  - SOFC/ICE combined cycle systems (natural gas, NH3 etc.)

- Chairman, AHEAD Energy, 501(c)(3)
  - owns a test facility in Rochester, NY – in transition to a multi-user site for commercialization of fuel cell and related systems using low carbon fuels
  - promotes the use of low carbon fuels in concert with renewables.

- Board member, NH3 Fuel Association

SOFC, 3 products - each with high efficiency

Fuel in

Electricity

Hydrogen

Heat

SOFC, as a fuel flexible fuel cell

- External Reforming (Gasoline, Diesel, Jet Fuel, Propane, Ethanol)

vs.

- Internal Reforming (LNG, methanol, NH3)
  - Steam vs. Dry vs. Mixed (recycle) Reforming
  - Internal Reforming issues (NH3 substantially avoids these):
    - Coking of anode
    - Excessive endotherm anode inlet

- Big differences in internal reforming capability between different stack developers – Delphi had good results
- But, long term issues need evaluation (40,000 hours not 400 hours)
  - Robustness/durability impact
  - Coking, coarsening, delamination etc.

SOFC optimized for intended fuel?

- Diesel Engines and Diesel Fuels are highly co-optimized
- Gasoline Engines and Gasoline Fuels are highly co-optimized

- SOFC optimized for LNG may be different than for NH3 or methanol…
  - Stack Materials
  - Operating temperature
  - O/C ratio
  - Reforming Process
  - Fuel Utilization

- Extensive long term testing needed to optimize and understand severity factors. Many stacks needed to account for variability.

- Difference between “works in the lab” and “fieldable product” is HUGE!!!

Example: Reforming Process Options

- Process modeling (spreadsheet) to calculate Carbon Activity for Methane Cracking, Boudouard and CO Reduction reactions:

Fuel: Methane

Reforming: Internal

	Carbon formation limit (COR)
Case 1: 40% anode recycle	749 °C
Case 2: Steam reforming S/C=2	693 °C

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Clean Energy Commercialization Center

285 Metro Park, Rochester, NY 14623

A low-cost, open-source facility for performance and durability testing of fuel cell related components and systems

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History and Current Status:

- **R&D site built by General Motors and updated by Delphi**
- **Proximity to three Universities:** University of Rochester, Rochester Institute of Technology, and Monroe Community College
- **6 explosion-proof labs, 24/7 monitoring, gas storage and supply, Uninterrupted Power Supply, premium HVAC, fire suppression and exhaust systems lab-by-lab, oil free compressed air, deionized water**
- **Office space, loading docks, assembly/light manufacturing**
- **Owner: AHEAD Energy, 501(c)(3), in transition to a user managed facility**
- **USD $7-$10 million replacement cost for building and contents**

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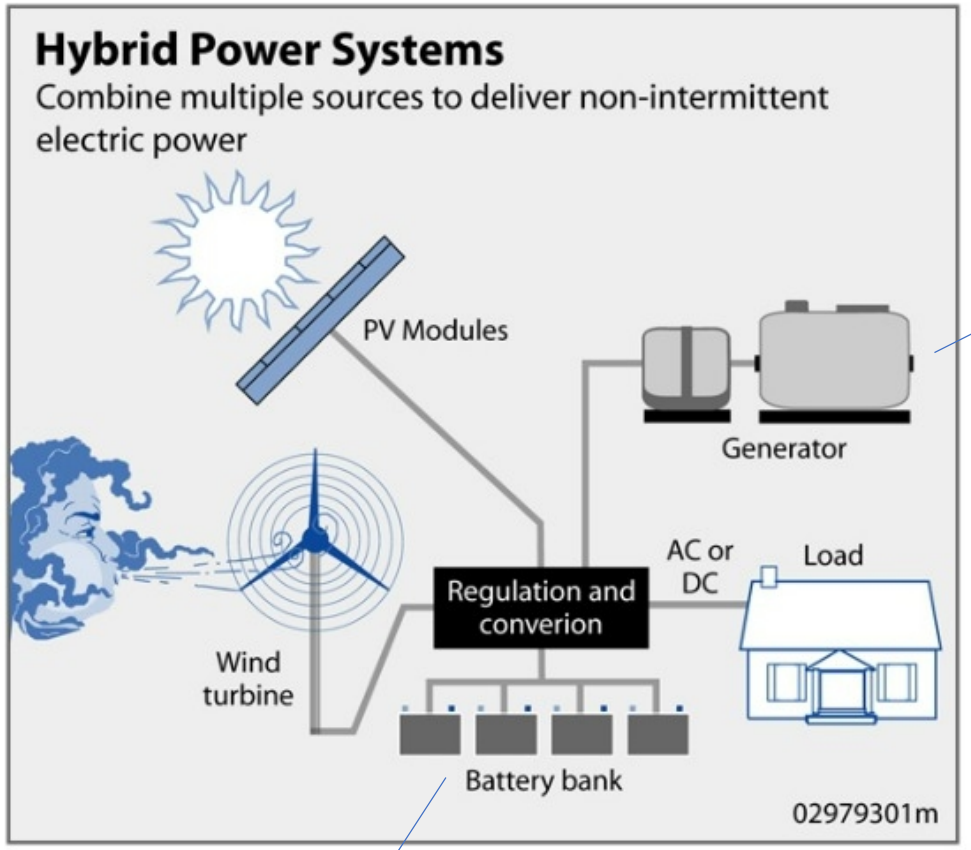
Clean Energy Commercialization Center

- Tech to Market integration and validation
- Shared Infrastructure fits “Consortium Approach” and CRADA model which Dr. Satyapal discussed.

Renewable Hybrid Systems



SOFC/ICE approach brings many advantages:

- Very high efficiency at light load (SOFC-only)
- High efficiency at mid load (SOFC/ICE, ultra-lean)
- Good efficiency at high load (ICE dominant, stoich)

- Fuel flexibility (natural gas, biogas, methanol, NH3)

- Extremely low emissions (H2 assisted starts)
- No cold starts

- 24/7/365 SOFC Direct Current microgrid (supporting PV and batteries)

- ICE is dynamic, used for high value functions like Back-Up, Demand Response and Peak Shaving

Safe/ultra-robust energy storage:
Lead Carbon? Ice Storage? Nickel Iron?

SOFC Internal Combustion Engine Hybrid

Showing co-products of SOFC: Electricity, Hydrogen and Heat

microEra Power
DISTRIBUTED GENERATION SOLUTIONS