PEM FUEL CELL TECHNOLOGY
Key Research Needs and Approaches

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UTC POWER MARKET FOCUS

Transportation Fuel Cells

On-Site Power Solutions

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FUEL CELL RESEARCH NEEDS

Look at early markets differently

	Early Market	Automotive
Performance	<u>Stationary CHP</u> System electrical efficiency Heat utilization	Optimize hybridization Broaden operating window Low metal loading
Durability	<u>Stationary CHP</u> 40-80,000 hr components - seals, membranes Water management Robust systems <u>Fleet vehicles</u> Cyclic conditions Environmental contaminants Field – lab reconciliation (demo) Defined accelerated tests (demo)	Cyclic conditions Environmental contaminants Water management Reliable freeze start up
Cost	<u>Stationary CHP/DG, Fleet Vehicles</u> System simplification (demo) Relaxed specifications (demo) Supply base confidence (demo)	System simplification Relaxed specifications Low metal loading High volume manufacturing Supply base competition

Early markets can…
Understand key operational attributes
Establish supply chains

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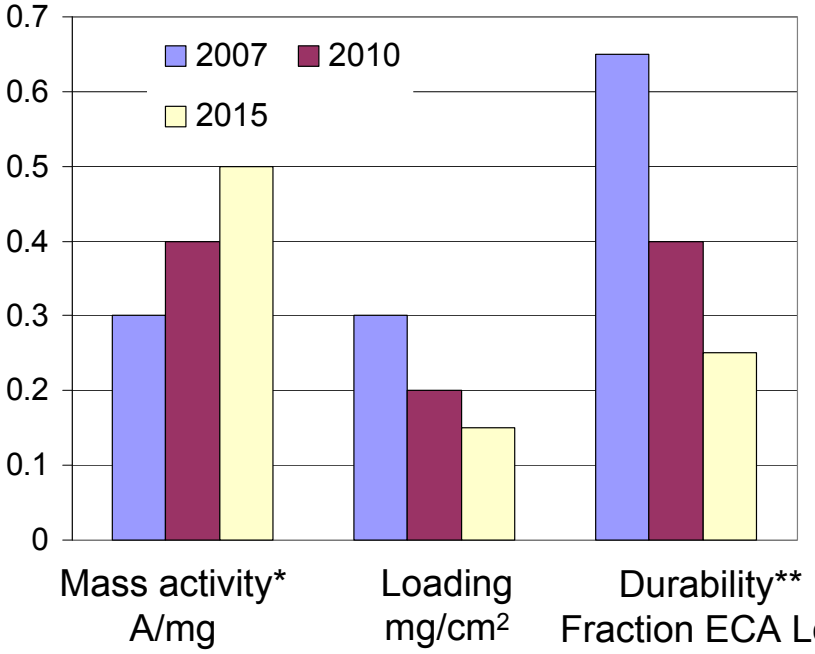
FUEL CELL RESEARCH NEEDS

Catalysts

- Good progress is being made in the area of Pt-based catalysts
- DOE 2010 activity, loading and durability goals appear achievable
- The upcoming RFP should target 0.10 g PGM/kW with 2010 performance and durability goals
- Assessment in a catalyst layer format is critical to ensure transport performance isn't sacrificed

Projected Improvements 2007-2015



2020

Support synergies
Crystal structure specific
Advanced core shell structures

Non precious metal catalysts
Non carbon supports

2015

Improved dispersed alloy catalysts
Core shell structures
Molecular modeling insights

2010

* Half cell test (RDE) in 0.1 M $HClO_4$, O_2 saturated, RT
** Half cell test (RDE) in 0.1 M $HClO_4$, O_2 saturated, RT, 20k cycles 1.2V-0.65 V

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FUEL CELL RESEARCH NEEDS

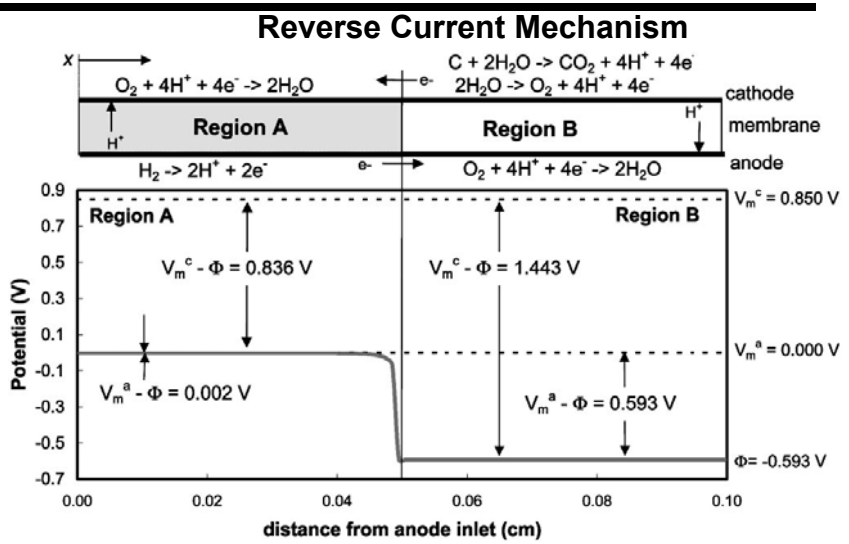
Catalyst supports

Modified carbon supports (graphitized or surface-modified) with potential control sufficient in the near to medium term

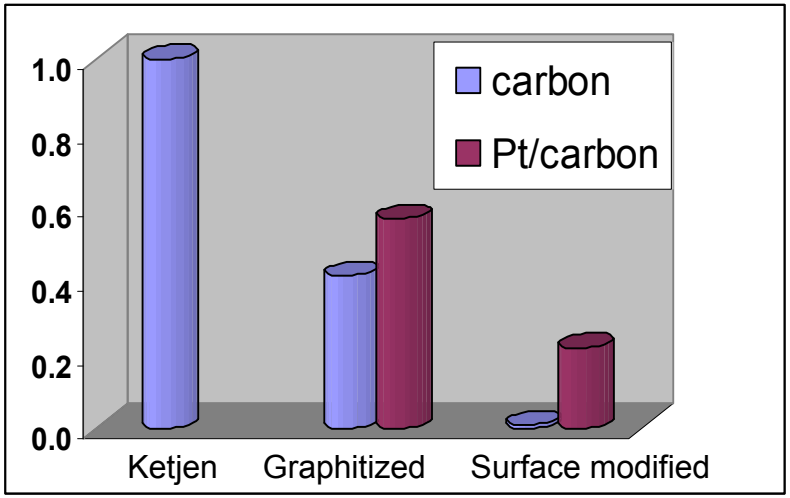
- Stabilized carbons known to offer ~ 3x reduction in corrosion rates
- Potential control reduces corrosion rates by 2-4 orders of magnitude

Longer term to meet increased durability requirements and more stringent operating conditions, new non corroding supports may be required

Fuel cell OEM's need to demonstrate satisfactory performance and durability with commercially-available alternative supports



"A Reverse-Current Decay Mechanism for Fuel Cells", C. A. Reiser, L. Bregoli, T. W. Patterson, J. S. Yi, J. D. Yang, M. L. Perry, and T. D. Jarvi, *Electrochemical and Solid State Letters*, 8 (2005) A273.



Normalized Corrosion Rates at 1.4V_{RHE} in 0.5M H_2SO_4 at 60C.

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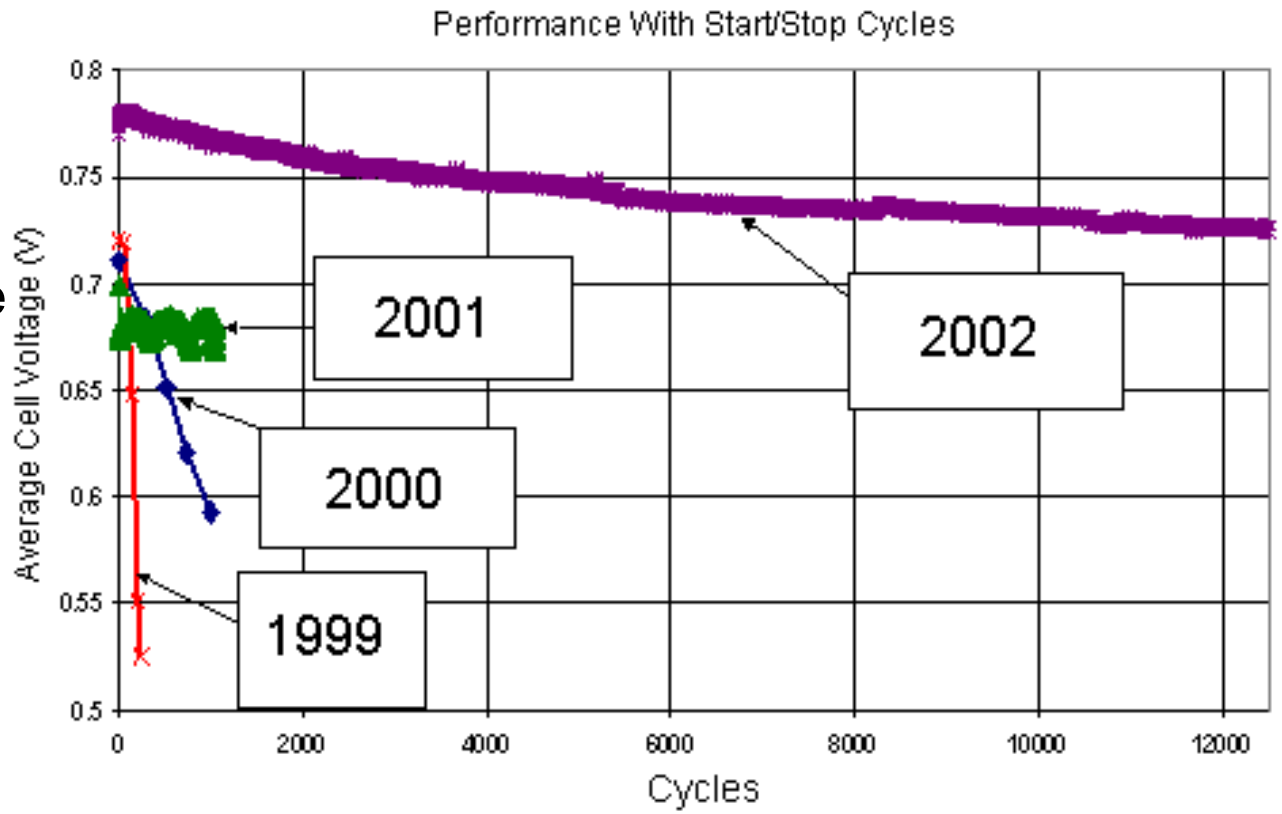
FUEL CELL RESEARCH NEEDS

Potential control has major impact on decay

Understanding basic mechanism enables rapid progress

New materials can be used in addition to potential control

Some related U.S. patents
6,777,115 (2004)
6,821,668 (2004)
6,838,199 (2005)
6,887,599 (2005)
6,913,845 (2005)
6,924,056 (2005)
6,991,864 (2006)



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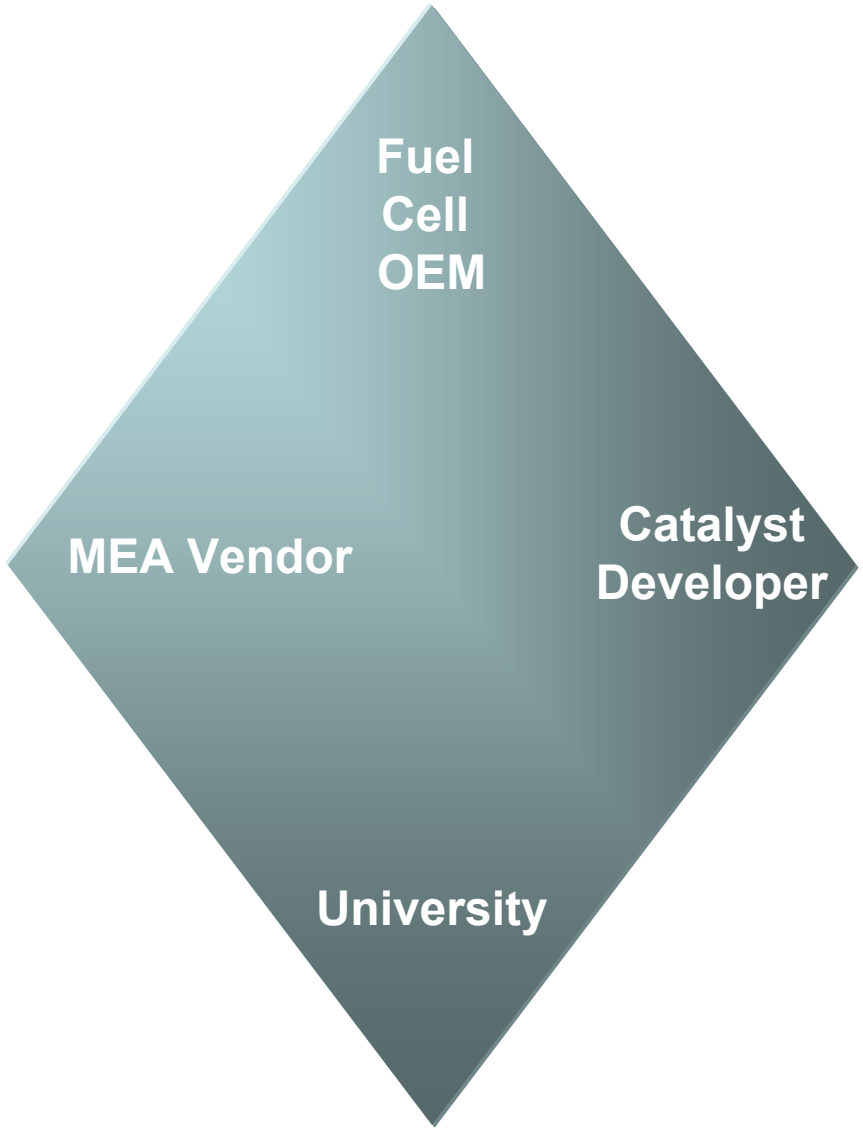
FUEL CELL RESEARCH NEEDS

Catalyst, electrode and MEA teaming construct

Non corroding catalyst and electrode structures need special attention due to sensitivity of performance on operating conditions and cell design

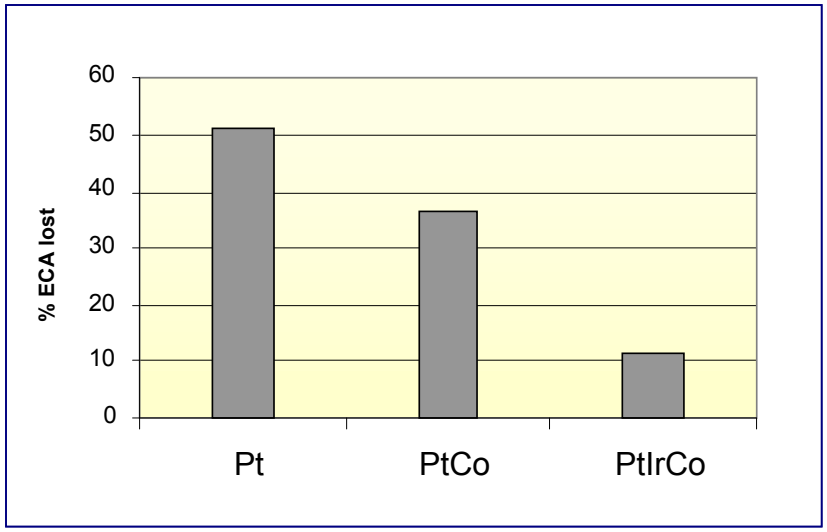
Recommend teaming arrangement to include fuel cell OEM to investigate design and operation sensitivity

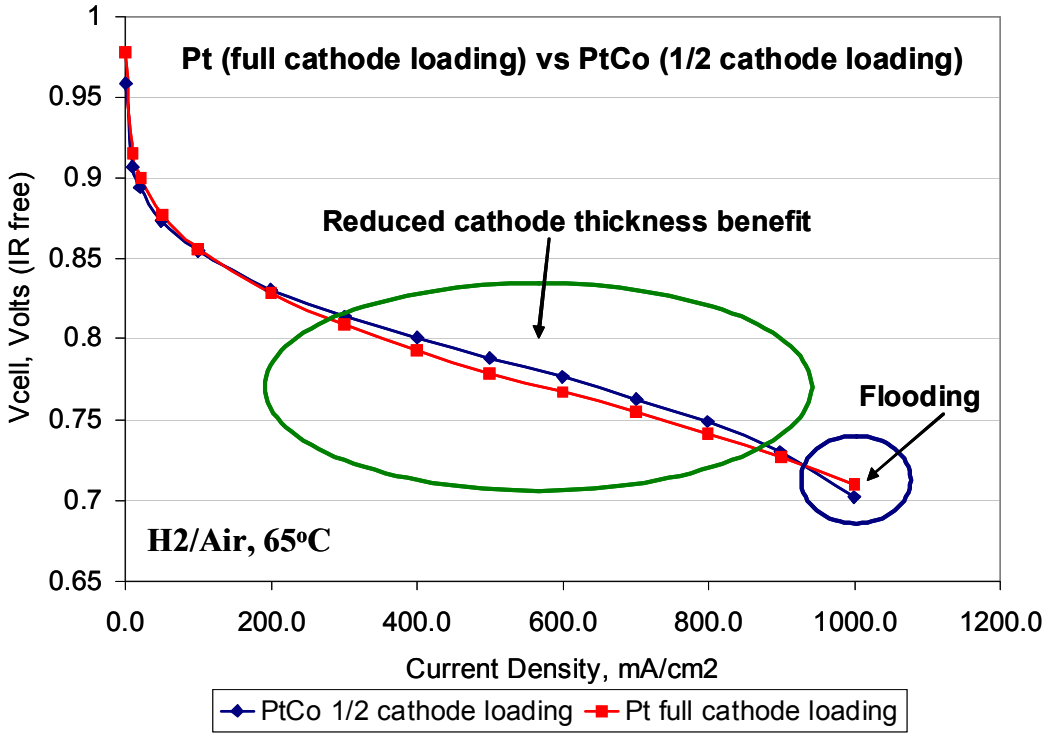
Universities should investigate fundamentals of the materials being considered



FUEL CELL RESEARCH NEEDS

MEA optimization should focus on new materials





Advanced alloys for cyclic stability improvement

MEA optimization to mitigate flooding

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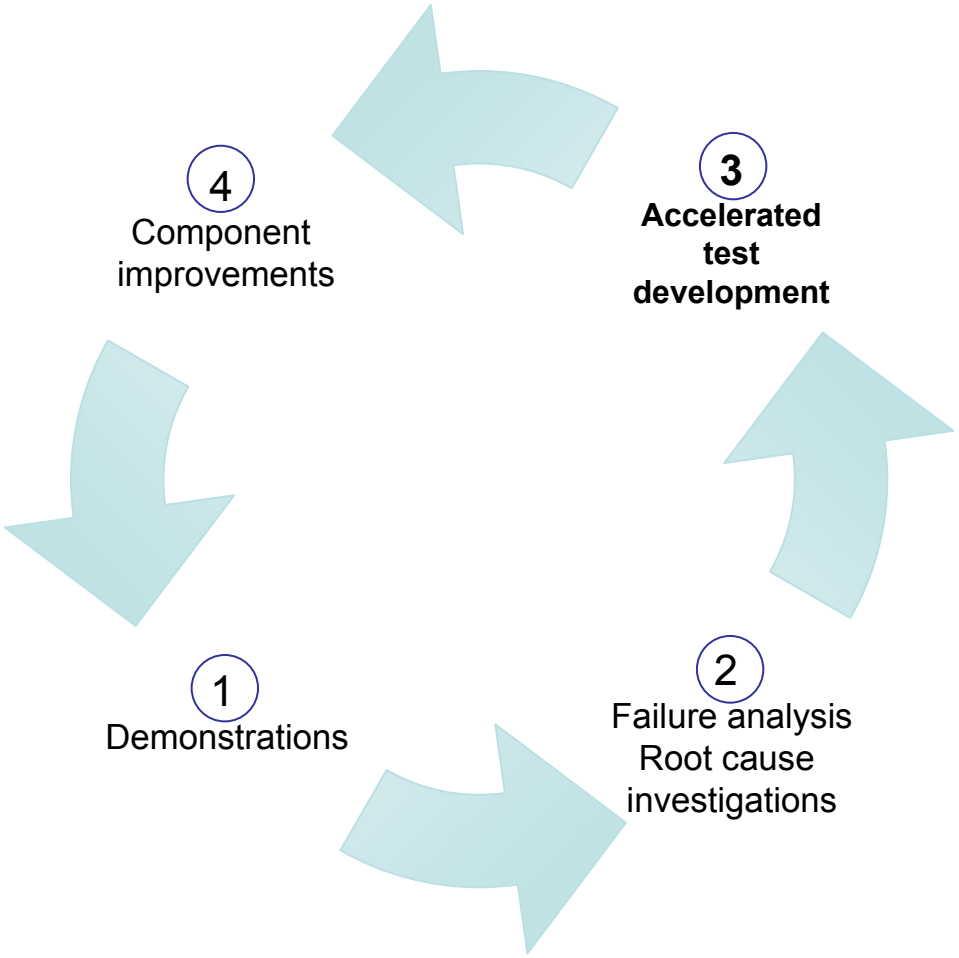
FUEL CELL RESEARCH NEEDS

Accelerated tests must link to failure modes

Important gap in current PEM understanding

Accelerated tests need to be derived from failure modes during real life operation

In addition, testing emulating service conditions should also be conducted to probe unknown failure modes



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FUEL CELL RESEARCH NEEDS

Demonstrations can identify failure modes

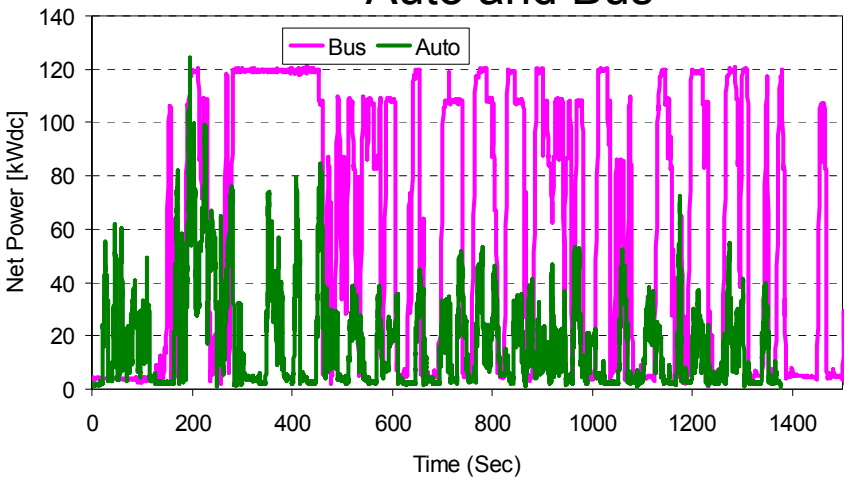
Demonstrations should focus on "auto-like" early market entrants. Potential applications include fleet vehicles (including fork lifts)

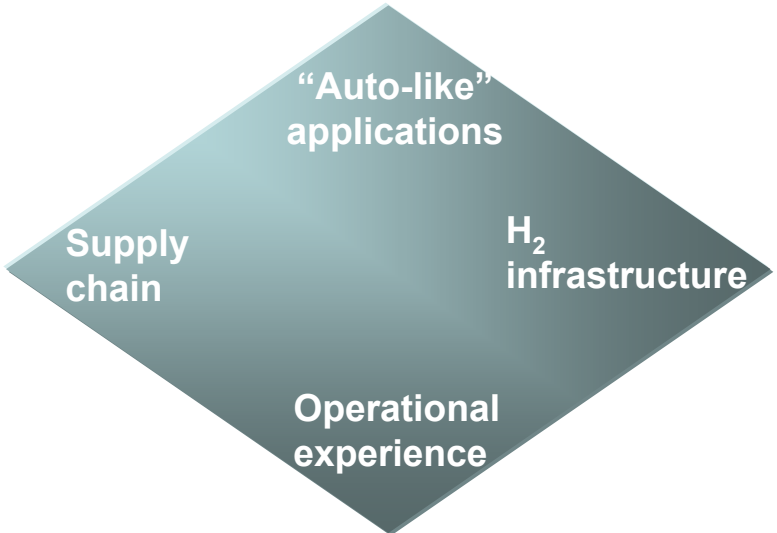
Synergies include:

- Auto-like operating conditions
- Establishment of a supply chain
- Fuel, infrastructure experience

DOE should challenge industry to define appropriate early markets based on maximizing synergies with the auto application

Simulated urban drive cycles for Auto and Bus





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FUEL CELL RESEARCH NEEDS

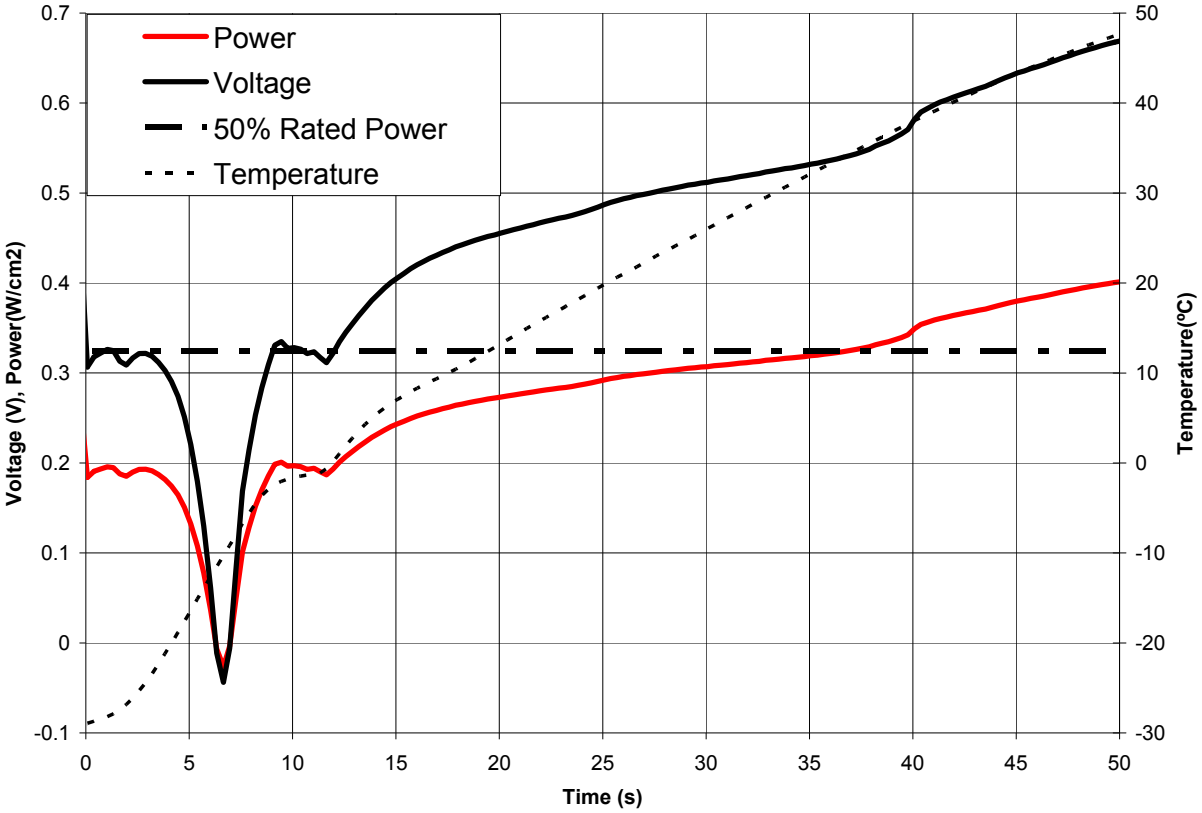
Water transport fundamentals for robust cold start

Automotive freeze requirement is a challenge for water management

Robust start from -30 C a key focus

Low start energy

30-s start time to 50% power at system level



Start performance from -30 C

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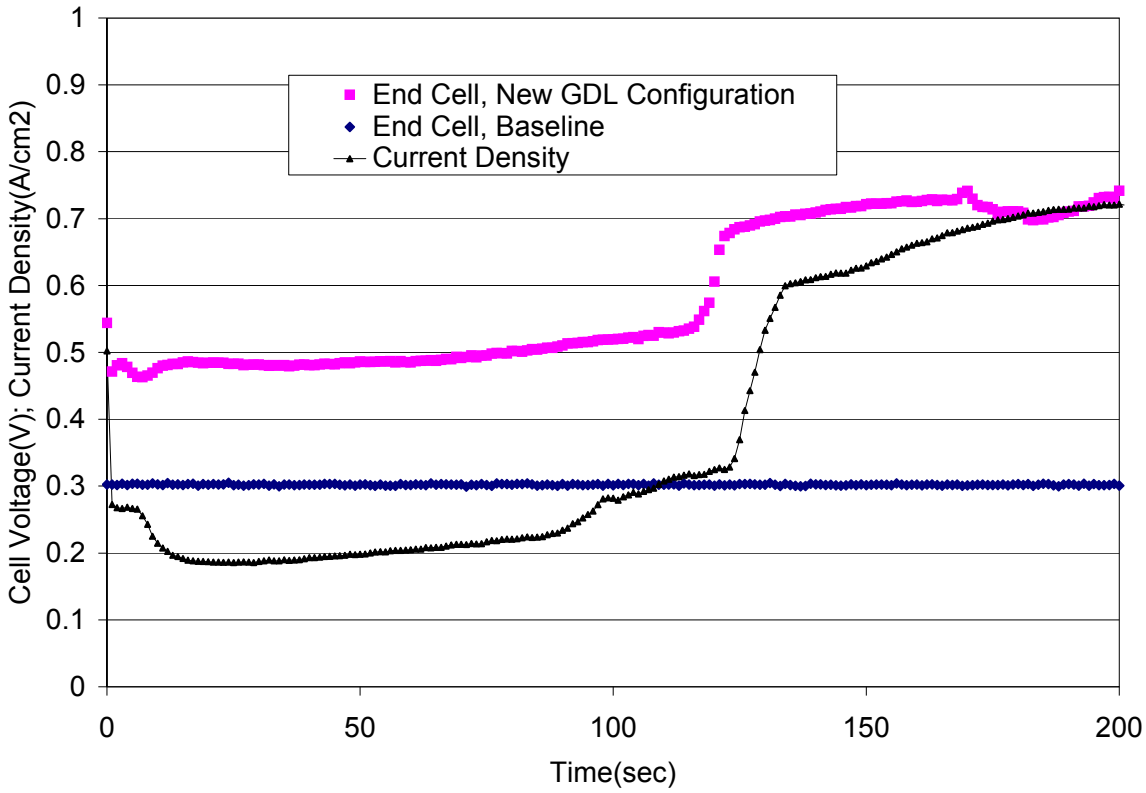
FUEL CELL RESEARCH NEEDS

Transport fundamentals improve performance

End cells are exposed to cold end plates

Optimized GDL configuration improves cold start performance of end cells



Comparison of end cell performance for two GDL configurations during cold start from -15 ºC

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CONCLUSIONS

- DOE has identified most of the key research areas
- More program integration is necessary
  - Catalysts, electrodes, MEA optimization need to be linked
    - Teaming requirements to ensure applicability of resulting materials
  - Demonstration programs and accelerated testing
- Early market research needs more attention
- Focus on early applications that share attributes with automotive
  - Operational modes
  - Supply chain
  - Fuels