Breakout Group 5: Long Term Innovative Technologies
Participants

Name	Organization
Kateryna Artyushkova	University of New Mexico
Iouri Balachov	4D Power
Jim Boncella	Los Alamos National Laboratory
Gerry DeCullo	TreadStone
Kevin Colbow	Ballard Power Systems
Chris Detjen	Next Energy
Don Gervasio	University of Arizona
Will James	Savannah River National Laboratory
Sridhas Kanusi	UTC Power
Nancy Kariuki	Argonne National Laboratory
John Kerr	Lawrence Berkeley National Laboratory
Lennie Klebanoff	Sandia National Laboratory
Dennis Kountz	DuPont
Bryan Pivovar	National Renewable Energy Laboratory
Rob Privette	ECD
Robert Selman	Illinois Institute of Technology
Grigorii Soloveichik	General Electric
Richard Viens	EnerFuel
Mahlon Wilson	Los Alamos National Laboratory
Tom Zawodzinski	Oak Ridge National Laboratory
Donna Ho (Facilitator)	U.S. Department of Energy
Shaun Onorato	U.S. Department of Energy / Navarro

BREAKOUT GROUP 5: LONG TERM INNOVATIVE TECHNOLOGIES
KEY TECHNICAL BARRIERS

MEMBRANE	UTILIZATION OF NON-PURE HYDROGEN FUEL	STACK DESIGN FOR LOW COST DURABILITY	CATALYST
• Membrane development for alternative fuels is required with the qualities of low (zero) crossover, low swelling, high conductivity, and no blockage • Development of new ionomer concepts for membranes is necessary • Non-polymer based proton conductivity is needed for membranes in low temperature fuel cell system applications • Alternative electrolytes in membranes for medium temperature fuel cell systems are needed • Membrane selectivity and durability for liquid fuels (non-H_2) are needed	• Catalysis for liquid fuels is needed for high efficiency and durability • Contaminants should be reduced in hydrogen supplies • The need for development into direct energy conversion of biomass options • High temperature fuel cells should be capable of utilizing biomass directly • Research into catalysts for alternative fuels is needed; industry is currently focused on hydrogen • There is not enough information on the effects of impurities in PEM systems (electrode, membrane, etc.) • Cross-cutting technologies are not relevant to other alternative energy initiatives • The effects of contaminants in direct carbon fuel cells need to be addressed	• Stack costs are too high • The complexity inherent in stack manufacturing results in high costs • Improved stack (PEM) designs will lead to reduced costs, ease of manufacturing, and increased power density • Repair mechanisms for fuel cells need further development • Fuel cells need high performance at ambient temperatures and low pressure (compressors should be eliminated in PEM systems) • Robotic assembly for fuel cell systems would be beneficial along with improved assembly methods (seem to be made by hand) • Relationship between materials and components (structures) should be improved. Performance is lacking in fuel cell systems	• Catalysts are too expensive and are not durable and active enough • Catalyst costs are too high • In developing non-PGM cathode catalysts, the active sites for these materials to enable rational designs are not known • Non-PGM catalysts are still not performing well enough to replace PGM catalysts • Non-PGM catalysts for medium temperature fuel cells should not be susceptible to poisoning of the electrolyte (have a carbon monoxide tolerance, and have a high ECA stability of 10-15 years) • Catalytic activity for non-PGM catalysts should be improved for both the anode and cathode

HIGH TEMPERATURE PEM (HT-PEM)	BALANCE OF PLANT (BOP)	WATER MANAGEMENT
• High temperature PEM fuel cells with on-board fuel processor needs to be integrated into transportation applications using traditional fuels (e.g., diesel, gasoline, biodiesel) • A fundamental understanding of high temperature PEM (150-200°C) fuel cells is needed in terms of start-up, durability, etc. There is a lack of understanding of high temperature fuel cell hydrogen transport and electrode behavior	• Need to use hydrogen in fuel cells to really reduce CO_2. BOP for 100 kW mobile fuel cells coupled to large hydrogen storage systems is an issue • Sensors for balance of plant components need to be developed, as well a better BOP components • Hydrogen has low energy density when used as a fuel, with hazards, and poor storage options • BOP components for large mobile fuel cell units (>100 kW) are needed. A system that could be towed behind a pickup should be developed	• PEM fuel cells are plagued by the need for high water activities (need humidification but must avoid flooding) • Understanding of liquid management in the electrode and GDL is needed • Understanding of freeze (low temperature) behaviors in fuel cells is needed (start-up, durability, etc)

REGENERATIVE FUEL CELLS	ALKALINE FUEL CELLS (AFC)	DOE COST TARGETS
• Regenerative fuel cells have poor reversibility. There are currently no effective regenerative fuel cells and have poor solutions for energy storage • Regenerative fuel cell's round trip efficiencies are too low	• A fundamental understanding of alkaline fuel cell chemistry is needed • OH^- conducting membranes designed for alkaline fuel cells • Development of a CO_2 rejecting electrolyte or CO_2 removal technology would be beneficial for alkaline fuel cells • Development of base metal (e.g. Ni) catalysts is needed	• The DOE should set cost targets for low power fuel cells (<10kW)

BREAKOUT GROUP 5: LONG-TERM INNOVATIVE TECHNOLOGIES
CRITICAL R&D NEEDS

MEMBRANE	REGENERATIVE FC/UTILIZATION OF ALTERNATIVE FUELS (CHEMISTRY)	STACK DESIGN FOR LOW COST DURABILITY	CATALYST
• Research and development on low humidification, low temperature membranes (PEM) with high conductivity • Radical but credible new electrolytes • Inorganic ion-conducting materials with H_2O free ion conduction with stable and high conductivity (-20-250°C • Water insoluble low equivalent weight ionomers for ion (H^+ and OH^-) conductive membranes • Inorganic and composite PEM membranes • Self repairing PEM membranes that have longer lifetime and durability characteristics • Modification of existing electrolytes for high performance that will mitigate (e.g. additives) catalyst poisoning or improve conductivity • Modeling work is required to help identify new materials for membranes • Mechanistic studies are needed for membranes that explore both in-situ and ex-situ characteristics	• Development of liquid fuel based regenerative fuel cells with high energy density • Regenerative fuel cells with alternative chemistry • Reversible liquid fuels as hydrogen carriers • Operation of high temperature fuel cells (solid oxide and molten carbonate) on liquid or solid biofuels (needs design and mechanism) • Investigation of base metal clean-up catalysts for dirty syngas products and reformates (e.g. woody biomass)	• Design rules based on end use (for stacks, components, MCAS, etc.) • Novel stack designs with specific power capabilities (portable, stationary, and transportation) that are drop in units. Benefits are lower cost (manufacturing), repairable, recycle-able, and unitized systems • Alternative cell and stack geometries for higher power density • Research into initiating operation and preserving durability of a frozen stack • Understanding and mitigating fuel cell break-in mechanisms • Research and development into fuel cells that operate without oxygen	• Non-PGM catalysts for liquid and alternative fuels • Development of stable and more catalytically active non-PGM anode catalysts for PEM fuel cells • Material studies should be conducted on how to reduce contamination sensitivity of catalysts • Non-carbon catalyst supports should be developed with high corrosion stability and high conductivity

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Critical R&D Needs (cont'd)

High Temperature PEM (HT-PEM)	Balance of Plant (BOP)	Water Management
• Materials development for high temperature PEM operation (MEA components, plates, seals, gaskets, and adhesives) • Mechanistic understanding of degradation failure modes for high temperature PEM (150-200°C) fuel cells • Demonstrate HT-PEM fuel cells with traditional fuels (diesel, gasoline) • Development for low power, (1-10kW) high temperature PEM fuel cells as range extenders for electric vehicles	• Engineering studies (prototype build) of mobile 100 kW fuel cell systems coupled to hydrogen storage systems • Engineering projects that involve "end users" in the design and test of BOP integration studies	• Development of physical characterization techniques to support modeling efforts of electrode, electrode/ membrane, water transport (i.e. interface)

Alkaline Fuel Cells (AFC)	DOE Cost Targets	Solid Oxide Fuel Cells (SOFC)	Systems - Synergy, Enabling
• Understanding of stability of electrode structure and composition in AFCs • Alternative ionic liquids for electrolyte • Understanding the role of CO_2 in limiting alkaline technology • Alkaline membrane conductivity improvement • Electrode/membrane interface and interaction in alkaline membrane fuel cells • Novel regenerative CO_2 scrubbers	• Set low power fuel cell cost targets for automotive and stationary applications	• New ionic conductors for "Mid" temperature SOFCs	• Additional non-invasive failure analysis needs to be performed • Study the synergetic benefits achieved through the combination of batteries, fuel processors, and high temperature PEM fuel cells for automotive applications • Carbon inventory for stationary systems and life cycle analysis • Hydrogen production, use, and re-capture from chemical production facilities (chlor-alkali) • Component standardization