Current SECA Participants / Landscape

- **Argonne National Lab**
  - Perovskite materials development for catalysts – derive alternative materials – primarily for ATR-based systems
  - doing Diesel and JP-8 reforming
  - Multi-component chemistry (complicated)
  - Cool-Flame (self-sustained) combustion/pre-reforming
  - Diesel injector work (previously funded by EERE)

- **Ceramatec**
  - Plasma-arc reforming

- **Goodrich** – Fuel injection and mixing strategies
  - Pre-heated, gas-assist, piezo-electric, …

- **NETL** – Dave Berry, and Todd Gardner
  - Ceria and other conductive substrate materials use for introducing sulfur tolerance, …
  - Hex-alumina substrates into which substitutions of various cations can be made – combinatorial methods being applied to identify promising materials

- **NETL** – heterogeneous chemical kinetics

- **PNNL** – strontium titanate anodes for increased sulfur tolerance; on-anode reforming

- **Georgia Tech (Meilin Liu)** – sulfur tolerance and mechanisms of sulfur poisoning

- **Franklin Fuel Cells** – sulfur tolerance, internal fuel processing, impregnation tech. for anode and cathode mfg.

- **Colorado School of Mines** – in anode compartment fuel processing and electrochemical analyses (e.g., with CFD and detailed gas-phase and heterogenous chemical kinetics), “monster” PAH and combustion developed mechanism effectively simulated observed deposition, hex-aluminates

- **Penn State and U. Mich** – sulfur removal from liquid fuels (funded by ARL)

- **Tufts University** – novel high temperature sulfur removal materials
Initial Thoughts

- Automotive fuel processor technology – directly relevant to our challenge
  - Sprays, mixing, rapid start, preheating, coking, …
  - Much of this work may be “under wraps”
    - ANL did much work in this area
    - Automobile manufacturers, Industry (e.g., Goodrich, Delphi, …), Universities, other National Labs
- Has structure of bed been determined (foam, bed, monolith, …) – no, but much work, design dependent
- Continuous versus pulsed injection
- ACTION: conduct detailed literature review of publicly available research and development in this field (esp. University of Wisconsin, other universities conducting diesel spray/mixing research)
- Injector design and spray characterization
  - What are criteria?
  - How can criteria be met in small space over broad range of operation?
- Melting of catalyst beds observed in real diesel injection cases (droplets)
- How can methane be introduced into fuel cell by producing sufficient CH₄ in a CPOX reactor without coking?
- CO₂ reforming (perhaps with a separation membrane using anode recycle)
- Cannot count on equilibrium to be sole guide of design (kinetics can govern some processes and lead to nasty surprises)
- Turn-down requirements
- Low pressure liquid fuel (only) available, low pressure gas assist (only) available
R&D Areas that Need to be Addressed

- Fuel Handling Hardware
- Understand and enable use of synergies between fuel processing and fuel cells
- Understanding of multi-component fuel issues/differences/needs for robust fuel processor operation
- Possible use of single-component fuels (ethanol, methanol, …)
  - Think outside box – What is the desired diesel spec. – maybe simply a different standard (not cetane or octane number) would make all the difference for FC fuel processing?
- Robust, Flexible, Multi-fuel processing would be a significant market benefit
  - Same developments could handle seasonal variations, …
- Upstream sulfur management
- Downstream carbon management – how can carbon formation (if it is inevitable) be handled?
- What are the issues/barriers to achieving closer to “ideal” performance (no addition of excess steam or excess oxygen)? – intimate integration, internal reformation
- Chemical recuperation/cooling as part of an integration strategy – development of additives for delaying onset of coking in fuel stream
- Waste heat management
- Fuel Sprays and mixing
  - Including integration of such with full fuel processing system design
  - Nature of integration is fuel specific
- High temperature sulfur removal (downstream sulfur management)
- Fuel characterization
R&D Areas that Need to be Addressed (cont’d)

• Characterization and understanding of coke formation mechanisms and regimes
• Impacts of fuel additives (nitrogen-based, lubricity, other)
• Alternative sulfur removal technologies (both high and low temperature)
  – Upstream liquid
  – Low temperature, integrated
  – Low cost
  – Low maintenance
  – Variable concentrations and species
• Supported nickel catalyst work not directly applicable to anodes – fill knowledge gap
R&D Areas that Need to be Addressed (cont’d)

- Controls for high efficiency while meeting all other requirements
- Tight integration of reforming and fuel cell function
  - Design tradeoffs regarding efficiency, power density, …
  - Thermal and mechanical integration
  - Manifolding, separation membranes, mixing, recycle
  - Materials selection
- Fundamental chemistry and electrochemistry understanding and chemical mechanisms for complex fuels – especially for on-anode reformation
- A better understanding of the optimal output stream composition from a pre-reformer or external reformer
  - Controls for actually accomplishing this in the system without compromising on efficiency, coking, …
  - Strategies for achieving this composition and integration
- Development of low-cost sensing devices and strategies for fuel processing devices and systems and for multi-fuel process control
- Reactor light-up, start-up, shut-down
- Fluid mechanics, heat transfer, mixing, flow understanding and simulation
- Experimental investigation and model verification in generic reformer systems – end up with design guidelines
- Renewable fuels (bio-diesel, ethanol, etc.)
- Novel anodes and cell architectures
- Process simulation for fundamental system controls development and understanding
- Shock, vibration, relative motion, …
R&D Areas that Need to be Addressed (cont’d)

• Shock, vibration, relative motion, … impacts on performance
• Blowers, fans, pumps, and other BOP
• Assess approaches (ATR, CPOX, SR, plasma, …) for applicability, performance
• Life, durability, carbon balance (throughout system), lifetime design matching
• High temperature CO₂ and sulfur removal
• Recycle strategies and technologies
  – Condensation, cooling strategies versus hot recycle
• Pressurized reformation
Proposed Categories of R&D Areas

• Fuel Handling, Sprays and Mixing

• Fuel Reforming

• Sulfur and Carbon Management

• Reforming / Fuel Cell Integration

• System Integration, Sensors and Controls

• Modeling and Simulation