2008 DOE Hydrogen Program Review

Intergovernmental Stationary Fuel Cell System Demonstration, Topic 7C

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FC-41

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OVERVIEW

Timeline

- Project start date August 2007
- Scheduled end date July 2010

Budget

- **Total project funding $ 8.5 M**
  - **DOE share $ 4.25 M**
  - **Plug Power share $ 4.25 M**
- **Funding received in FY07 $ 46 K**
- **Funding for FY08 $ 2.34 M**
- **Funding requested for FY09-10 $ 1.6 M**
- **$250 K added to fund intergovernmental demo with KeySpan in 2008**

Barriers

- System efficiency
- System & fuel cell stack direct material cost
- System & fuel cell stack durability

Subcontractors

- Construction Engineering Research Laboratory (CERL)
- Ballard Power Systems (in negotiation)
- KeySpan

OBJECTIVES

- ❖ To design and produce an advanced prototype PEM fuel cell system with the following features
  - 5 kW net electric output
  - Flex fuel capable – LPG, NG, Ethanol
  - Reduce material and production cost and increase durability
  - Increase electrical efficiency over the current alpha design
  - Increase total efficiency by incorporating combined heat and power (CHP) capability
- ❖ To show a path to meet long term DoE objectives
  - 40% system electrical efficiency
  - 40,000 hour system / fuel cell stack life
  - $750/ kW integrated system cost (w/ reformer)

APPROACH

- Concept Development (Task 1) - *30% complete*
  - ✓ Product requirements
  - ✓ Technology selection- ethanol evaluation
  - ✓ Prototype component and subsystem testing
  - ✓ Concept development
  - Go/ No Go - Concept design review
- System Definition (Task 2) - *Work not started*
  - System Specifications & requirements flow down
  - Module & component design
  - Module and component latitude testing
  - Go/ No Go - System interface review

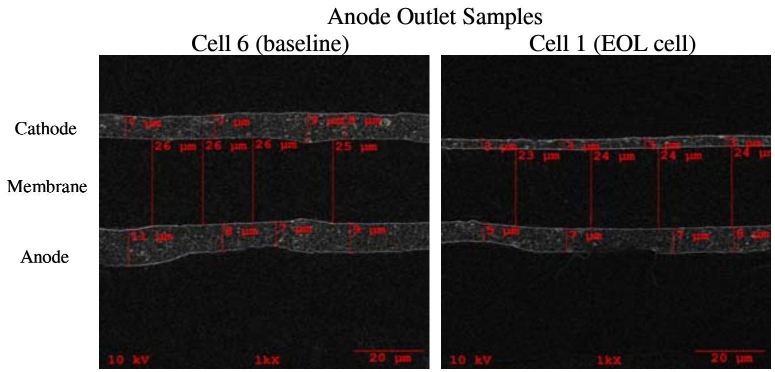
✓ Progress made

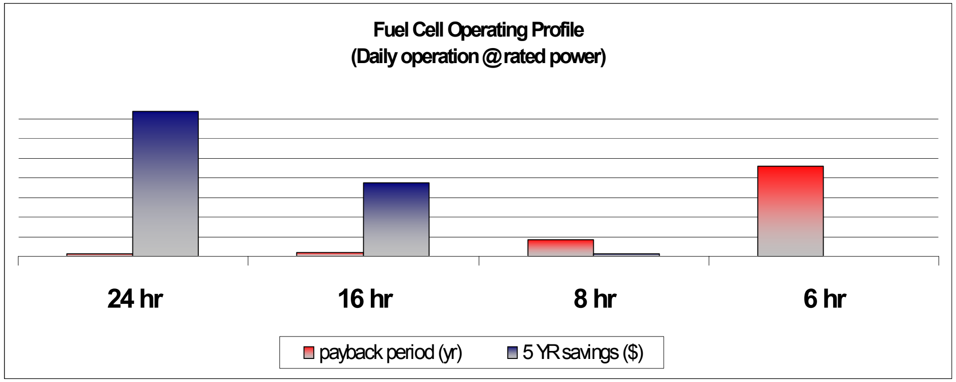
APPROACH – CONT.

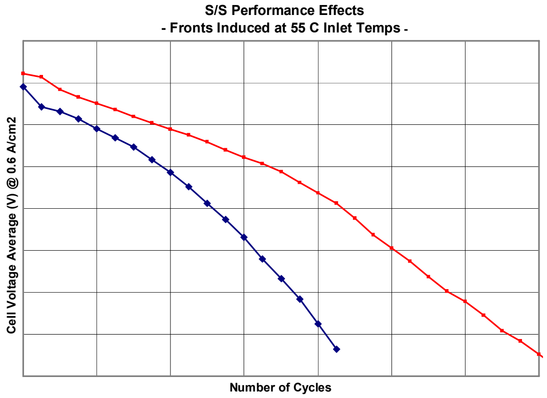
- System Integration (Task 3) - *Work not started*
  - Prototype system design
  - System design review
  - Prototype system build
  - Integrated system testing
  - System validation testing
  - Go/ No Go – Field readiness review
- Prototype Field Demonstration (Task 4) - *Work not started*
  - Site installation planning
  - Installation and commissioning
  - Field operations and support
  - KeySpan demonstration
  - Decommissioning
- Project Closeout (Task 5) - *Work not started*
  - Post demonstration testing
  - DOE final report

TECHNICAL ACCOMPLISHMENTS
PRODUCT REQUIREMENTS (TASK 1.1)

- Operating environment – Exterior, prime power / intermittent operation, stand alone / grid connected
- 5 kW – net electric output, 48 or 24 VDC / 120 or 230 VAC via aux inverter, LPG / NG or ethanol fuel



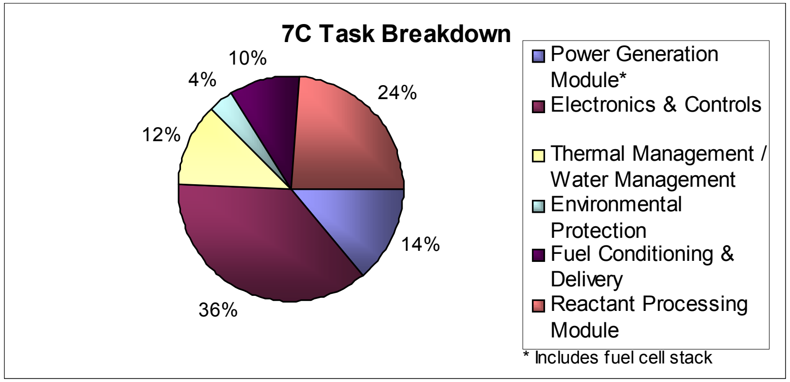




- Continuous run applications offer best financial return compared to traditional grid support
- Start / stop cycling PEM fuel cells w/ carbon supported catalysts shorten stack life

TECHNICAL ACCOMPLISHMENTS
TECHNOLOGY SELECTION (TASK 1.2)

- A gap analysis was conducted using the GenSys alpha system design as a baseline to develop the scope of work required to advance the design toward the end product goals
- Potential design improvements were listed for each module of the current design and each were evaluated individually on its ability to improve reliability, reduce material cost and improve overall system efficiency. A total of 325 items were evaluated
- The final down selected list included a total of 113 items which became program tasks

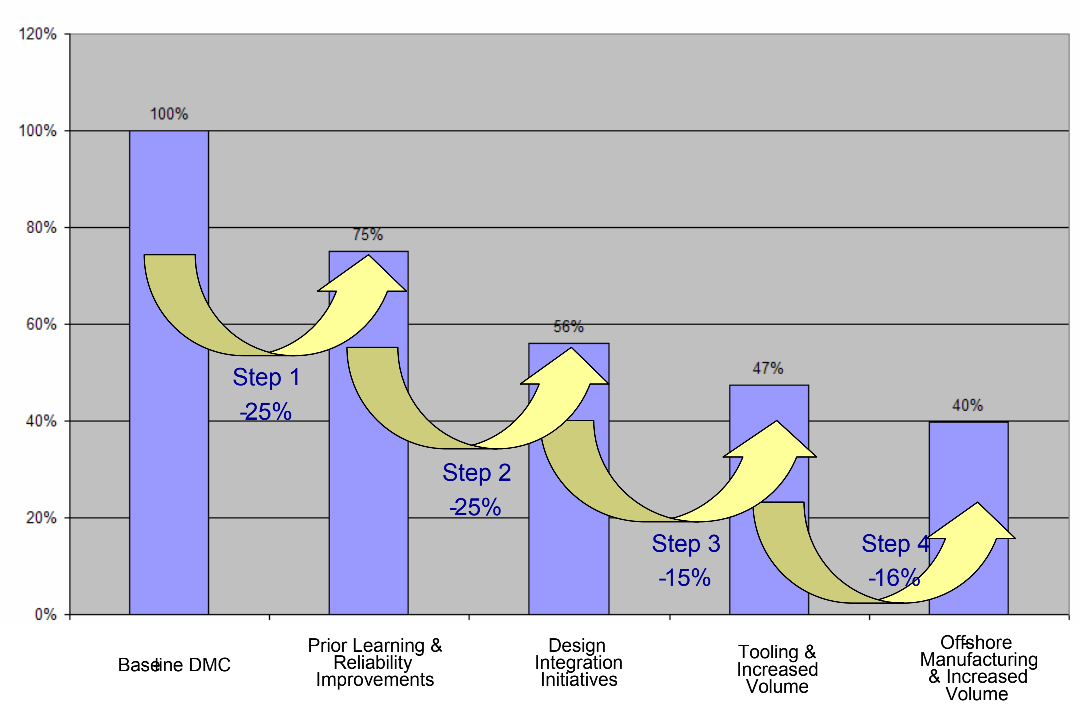


Initiatives are projected to

- Significantly improve reliability
- Reduce system material cost by approximately 25%
- Increase system efficiency by 4 - 5%

TECHNICAL ACCOMPLISHMENTS TECHNOLOGY SELECTION (TASK 1.2)

- Total DMC reduction projection:
  - Baseline cost @ Q100 of 100%
  - Estimated DMC based on new design @ Q10K → 40% of baseline (reduction of 2.5X)
- Is this realistic?
  - Functional analyses of sub-systems revea much room for cost improvement
  - Historical Volume-based Cost Curves support 15% to 25% reductions based on volume and tooling
  - Previous DFMA studies have identified ~10% to 15% savings
  - Alternate Stack: Incorporating an updatec stack technology will reduce DMC, warranty and service costs. (Estimated at ~20%)
- Currently Identified Potential Reductions (~80% of Goal)
- Further Reductions Required to meet DMC Target (~20% of Goal)



This is a realistic DMC reduction plan

TECHNICAL ACCOMPLISHMENTS TECHNOLOGY SELECTION (TASK 1.2)

Alpha Design

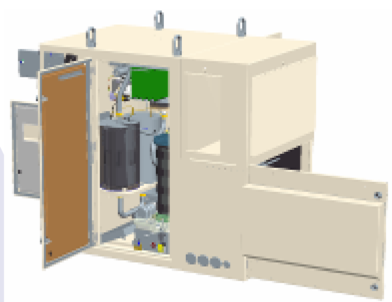
DMC Baseline: 100%

STEP 1

25% DMC Reduction

Current DoE Program

- 75% of baseline DMC
- Enclosure optimization (8%)
- Stack Modifications (9%)
- Reduction in part count (5%)
- Purchasing impact (3%)



STEP 2

25% DMC Reduction

- 56% of Baseline
- RPM & PGM Integration (4%)
- BOP and Controls Integration (5%)
- Volume based impact (13%)

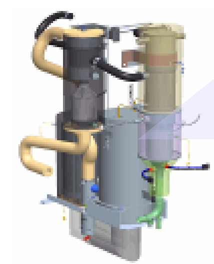
STEP 3

15% DMC Reduction

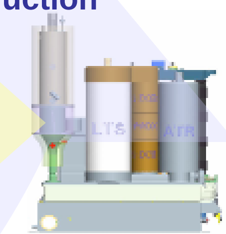
- 47% of Baseline
- RPM & PGM Tooling (6%)
- BOP Tooling (4%)
- Volume based impact (5%)

STEP 4

16% DMC Reduction



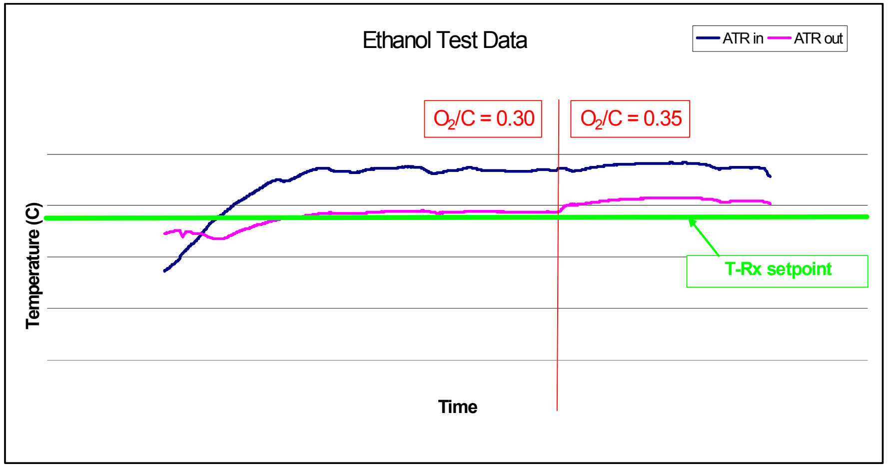
RPM &PGM Tooling & Integration

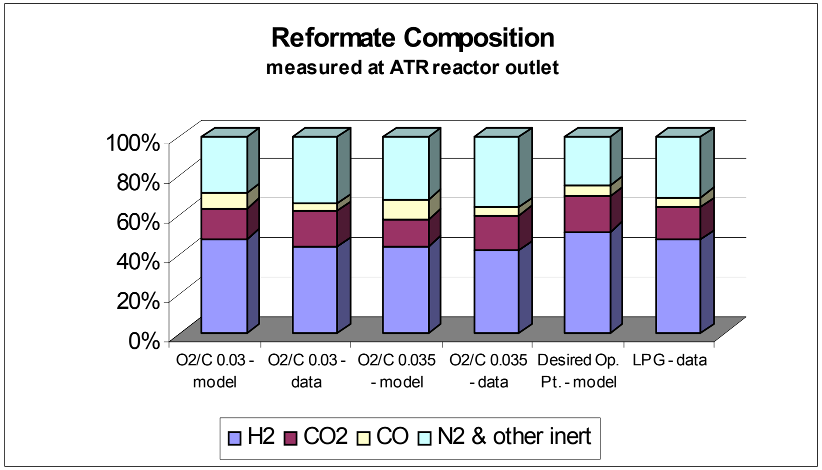


- 40% of Baseline DMC
- Integration (3%)
- Off-shore volume manufacturing (13%)

TECHNICAL ACCOMPLISHMENTS
TECHNOLOGY SELECTION (TASK 1.2)

- ASPEN simulation used to predict optimum reformer operating parameters
- Lab tests used to verify analysis

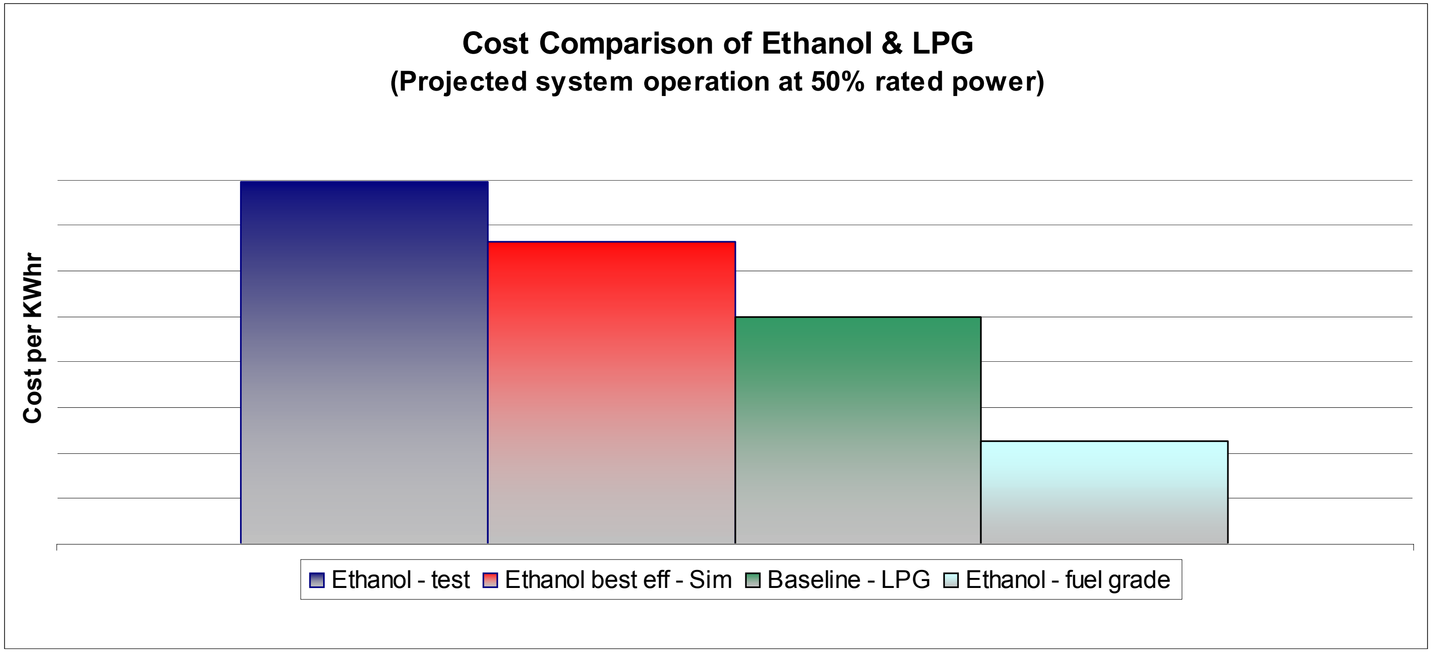




- Stable operation with ethanol fuel was achieved
- ATR outlet composition similar to operation with LPG
- Unable to reach desired operating set points without hardware changes to reformer

TECHNICAL ACCOMPLISHMENTS
TECHNOLOGY SELECTION (TASK 1.2)

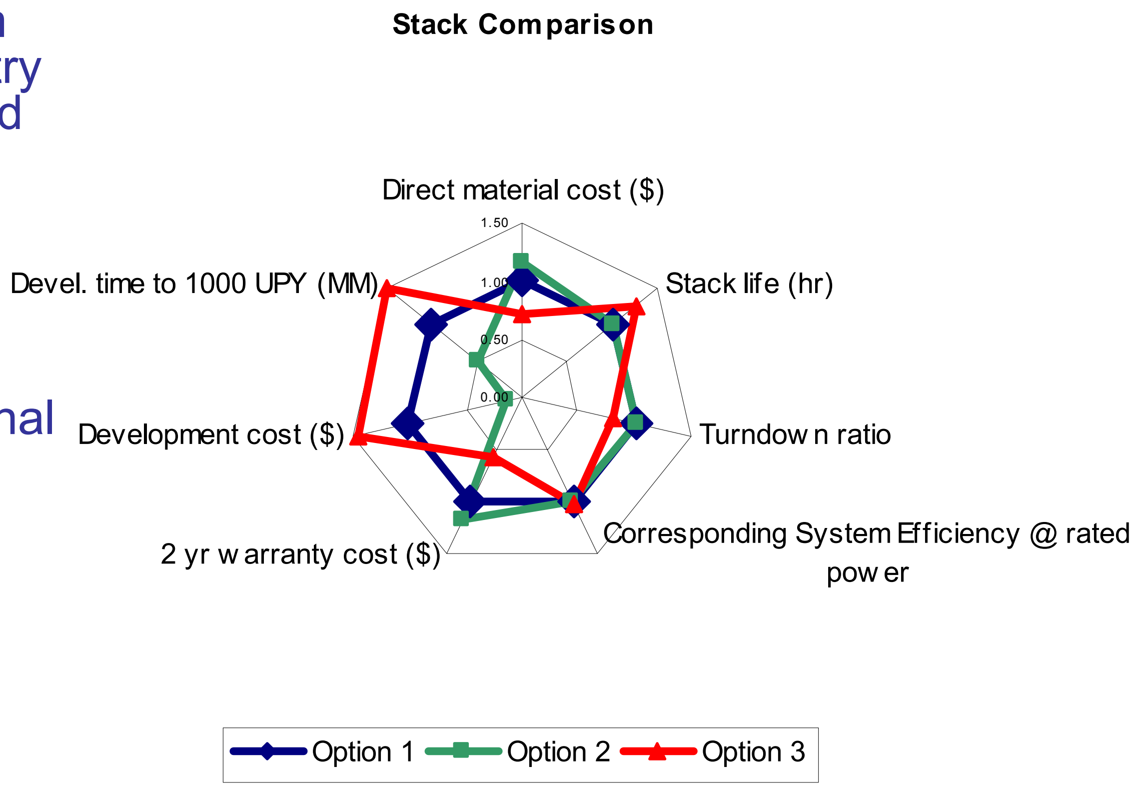
- Using the results of the simulation and data from lab tests the cost of energy was compared between ethanol and other fuels



- Cost per kWhr of ethanol generated electricity is higher than LPG
- Higher cost is driven by the need for laboratory grade ethanol for compatibility with reforming catalysts
- Cost advantages exist if automotive fuel grade ethanol could be used however, alternate denaturants would be needed

TECHNICAL ACCOMPLISHMENTS
TECHNOLOGY SELECTION (TASK 1.2)

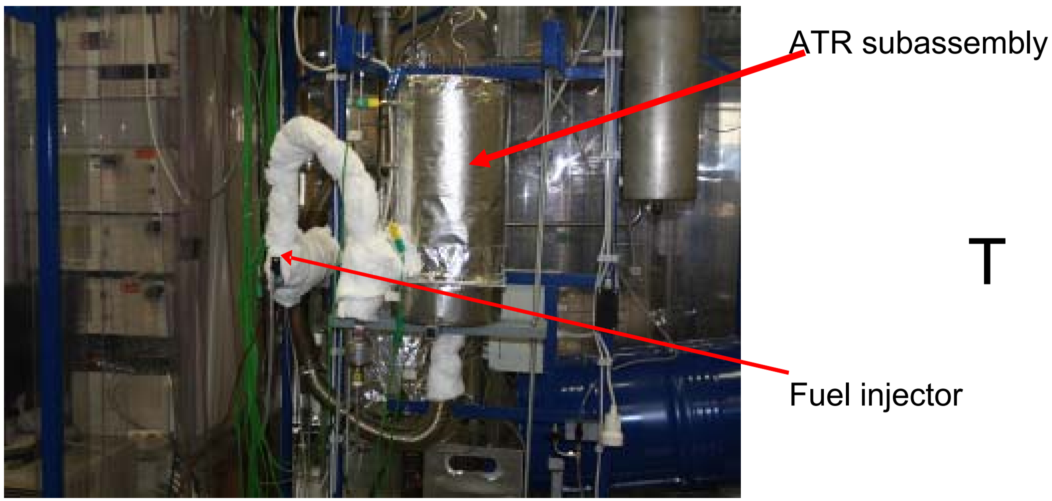
- Five stack technologies from Plug Power and other industry suppliers were evaluated and compared to the baseline GenSys alpha stack
- Three leading candidates underwent a detailed assessment and system modeling to determine the final choice
- Evaluation criteria
  - Material cost
  - Projected life
  - Resulting system efficiency
  - Service (warranty) cost
  - Development effort required

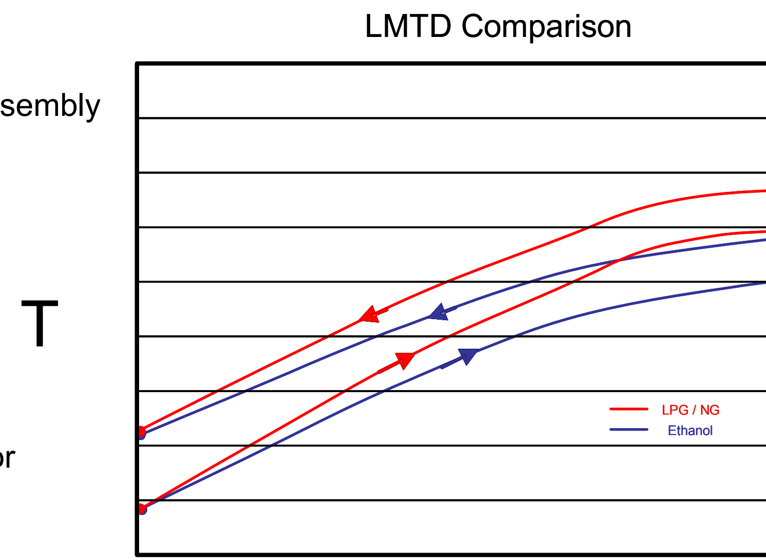


Selected stack will reduce long term DMC by 10%, improve system efficiency slightly and reduce potential warranty costs by 40%

TECHNICAL ACCOMPLISHMENTS
PROTOTYPE SUB-SYSYTEM TESTING (TASK 1.3)

- Internal goal is to minimize hardware change to reformer to allow for ethanol as feedstock
- Only fuel injection added for fuel conditioning prior to ATR reactor





- An ethanol pump and fuel injection system were successfully added to the GenSys fuel conditioning system
- Operating set points updated via control software
- ATR heat exchanger design fixed (same part as NG / LPG)
- Current design is approx. 2X oversized to reach desired ethanol operating point

FUTURE WORK

- FY2008
  - Complete prototype component testing of fuel cell stack
  - Conclude concept development activities & exit concept design review phase gate
  - Finalize system specifications and module flow downs
  - Complete prototype system design
  - Pass integrated system design review and exit phase 1 of program
- FY2009
  - Build prototype system
  - Perform system level problem identification & design verification tests
  - Conduct field readiness review
  - Complete site planning and system installation
  - Commission prototype system & commence field operation and support
- FY2010
  - Complete field operation and support
  - Decommission system
  - Post demonstration testing
  - Project close out

SUMMARY

- Product requirements have been identified and technologies selected to form a system capable of supporting a viable business case for a commercial product
- Cost model and reduction strategy created that when executed will close the gap between present state and DOE target
- System modeling & simulation supported by laboratory testing have shown acceptable system performance when operating on ethanol fuel stock
- Tasks required to optimize operation on ethanol have been identified for future consideration once reforming ethanol becomes economically viable
- The project has progressed technically to a point where system definition, design and development is possible and will culminate in a field ready prototype in early 2009

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