BACKUP/PEAK-SHAVING FUEL CELLS

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Project ID # FC47

Clean, Reliable On-site Energy

SAFE HARBOR STATEMENT

This presentation contains forward-looking statements, including statements regarding the company's future plans and expectations regarding the development and commercialization of fuel cell technology. All forward-looking statements are subject to risks, uncertainties and assumptions that could cause actual results to differ materially from those projected. The forward-looking statements speak only as of the date of this presentation. The company expressly disclaims any obligation or undertaking to release publicly any updates or revisions to any such statements to reflect any change in the company's expectations or any change in the events, conditions or circumstances on which such statement is based.

OVERVIEW

Timeline

- Project Start Date 8/11/03
- Project End Date 1/11/06
- Percentage Complete 70%

Budget

- Total Projected Funding = $7,201,881
  - DOE Share = $3,600,940
  - Plug Power Share = $3,600,941
- Funding Received in FY04 = $1,037,586
- Funding for FY05 = $1,474,271

Partners

- Interactions/Collaborations
  - BellSouth
  - Airgas
  - Argonne National Labs
  - Telcordia Labs

Barriers

- Barriers Addressed
  - –DOE Technical Barriers for Distributed Generation Systems
    - E. Durability
    - G. Power Electronics
    - H. Startup Time
  - –DOE Technical Barriers for Fuel Cell Components
    - O. Stack Material and Manufacturing Cost
    - P. Durability
    - R. Thermal and Water Management

PROJECT OBJECTIVES

The purpose of this program is to advance the state of the art of fuel cell technology with the development of a new generation of commercially viable, stationary, backup/peak-shaving fuel cell systems.

- Develop, build and test three identical fuel cell backup systems and field test them at three sites including an industry host site (BellSouth)
- Identify technical barriers and objectives
- Develop a cost-reduced, proton electrolyte membrane (PEM) fuel cell stack tailored to hydrogen fuel use
- Develop a modular, scalable power conditioning system tailored to market requirements
- Design a scaled-down, cost-reduced balance of plant (BOP)
- Certify the design to Network Equipment Building Standards (NEBS) and Underwriters Laboratories (UL)

APPROACH

- Determine product design requirements using BellSouth functional specifications
  - The design will be the first product off of a mass-manufacturable platform for telecommunications, broadband and uninterruptible power supply markets.
  - H2-in-DC-out product for telecommunications markets selected
  - The program will evaluate a variety of stack and BOP technology initiatives in order to develop a mass-manufacturable and commercially viable design.
  - Phase I employs Plug Power's Technology Delivery Process (TDP) which uses rigorous testing and evaluation methods to minimize new technology risks.
  - Phase II uses Plug Power's New Product Delivery Process (NPD) to introduce technology initiatives as hardware modules for integration.
  - Phase III also uses NPD to bring the hardware to an integrated system through field-testing and certification.
  - BellSouth will perform evaluation of onsite test unit.
  - Test and Evaluate two units at Argonne National Labs (ANL)

TECHNICAL ACCOMPLISHMENTS

- In 2003 and 2004, the Program executed a broad-based initiative to determine requirements for the platform's commercial design, collecting data by:
  - Extensive laboratory testing at Plug Power
  - Field testing of the GenCore® prototype system (13 systems)
  - Certifying the prototype to UL and NEBS requirements
  - Developing a Backup Power Fuel Cell System Requirements Document (SRD) with BellSouth

- Additionally, the Program evaluated ten enabling technologies and selected six for inclusion in the commercial design.

- Finally, the Program began the new product development of the commercial product design, combining the technical, certification and customer requirements with the feasible technology initiatives in the design of the next-generation platform.

TECHNICAL ACCOMPLISHMENTS

- Task 1.0 System Technology Development
  - The purpose of this task was to select enabling technology concepts for inclusion into the platform, integrate them into test rigs and evaluate them in high-level system testing against product requirements.
  - “Go/No Go” determination completed in 12/04.

TECHNICAL ACCOMPLISHMENTS

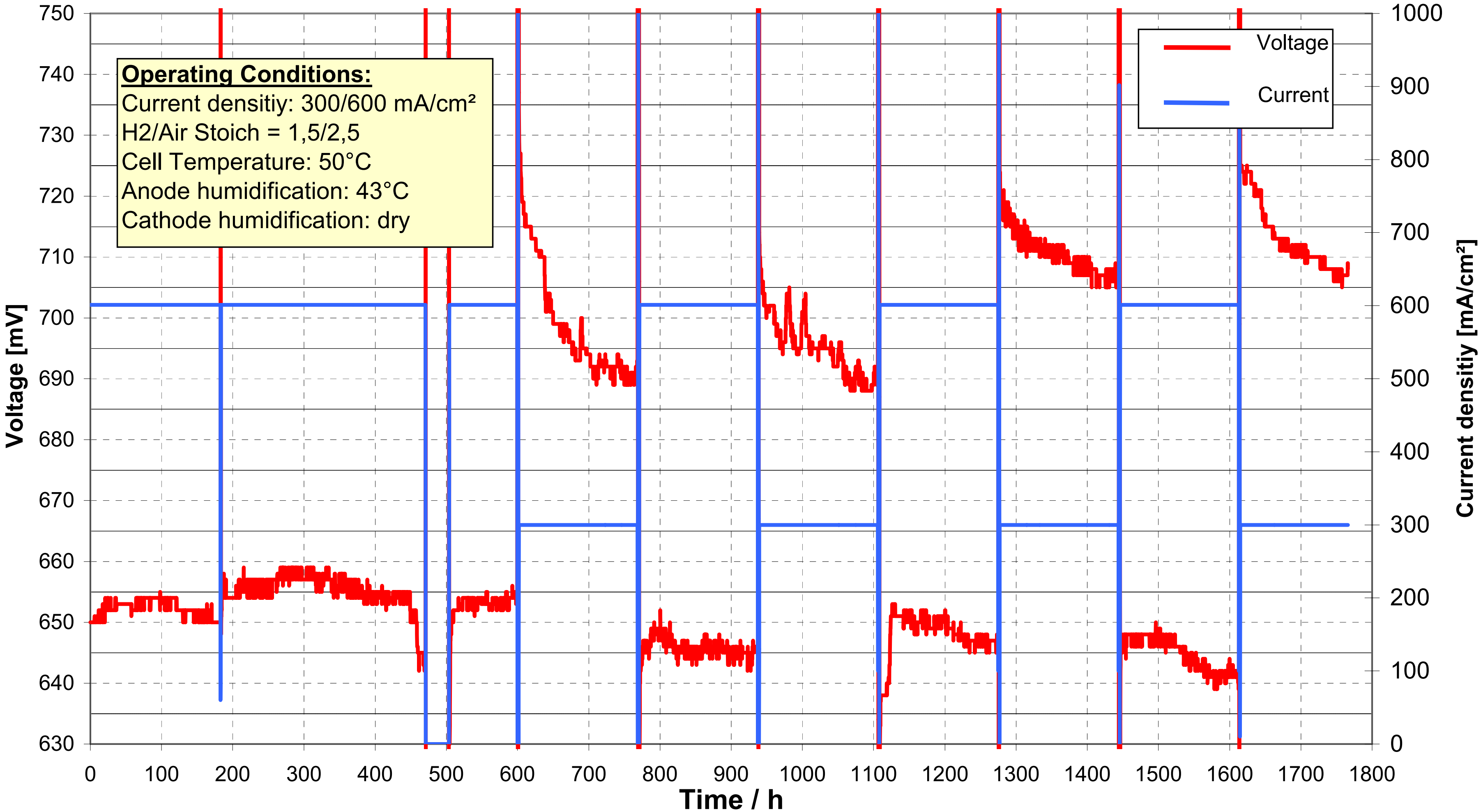
Technology Go/No Go Results Summary

Enabling Technology	Go/No Go	Comments
2.1 Dry Cathode Operation	No Go	Will not yield in program timeframe
2.2 GenSys® Stack Integration	No Go	Will not yield in program timeframe
2.3. Power Scalable Stack	Go	In final design
2.4. H2 Regeneration Options	Go	Advanced Exhaust Gas Recirculation (EGR) Option. No electrolyzer.
2.5. Power Conditioning Platform	Go	In final design
2.6. Advanced Electrical Energy Storage	Go	Non-lead acid solution in place
2.7. System Water Balance	No Go	Will not yield in program timeframe
2.8. Advanced H2 Storage	No Go	Will not yield in program timeframe
2.9. Scale System	Go	In final design
2.10. GenSys Stack	Go	In final design

TECHNICAL ACCOMPLISHMENTS

- Task 2.1 Dry Cathode Stack Operation
  - The purpose of this task was to develop the capability for Membrane Electrode Assembly (MEA), stack and system to operate without cathode humidification and evaluate in extended endurance tests.
  - A variety of commercial MEAs were tested under GenCore operating conditions with an unhumidified cathode. While there were distinct variations in the performance of the MEAs the general trends were similar; i.e.. The membrane dried out but not to the point where the system would fail.
  - Testing concluded that for GenCore stack life (1500 hrs over 10 years), dry cathode operation is feasible, however, the selected MEAs do not currently meet program cost targets.

ENDURANCE TEST: Commercial MEA, 50 cm² GenCore Conditions



DATA ANALYSIS

- Our hypothesis for for the voltage drop at 0.3 A/cm2 is:

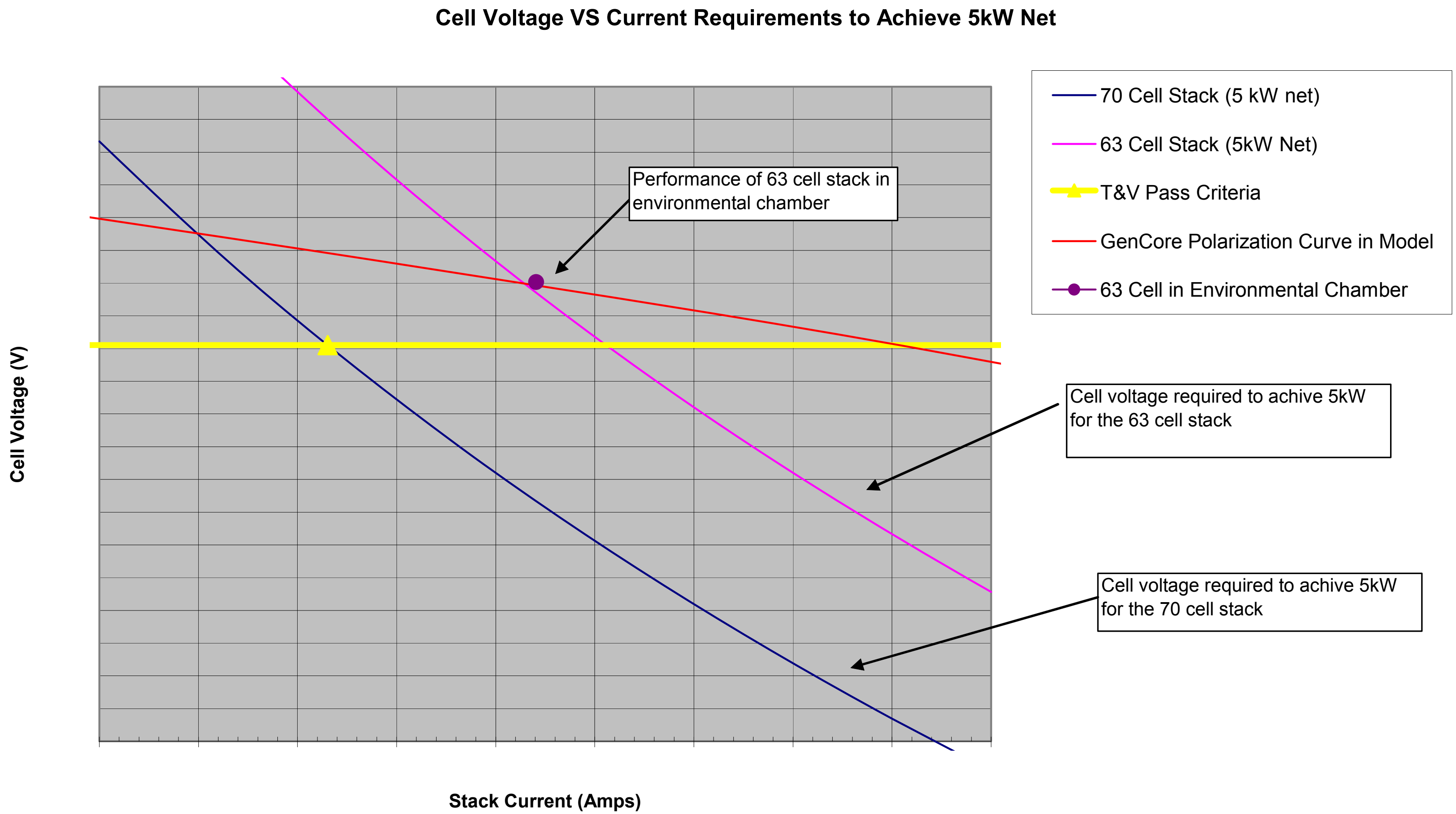
  - Higher current produced higher water drag and therefore greater membrane humidification.

  - At lower current the membrane tends to dry out.

  - Upon rehumidification, by operating at high current, the voltage recovers but the dryout process is reinitiated in low current operation.

TECHNICAL ACCOMPLISHMENTS

- Task 2.3 Power Scalable Stack
  - The purpose of this task was to design, test and integrate power scalable stack initiatives into the next generation design.
  - The final stack design has the following characteristics:
    - Cost-reduced, next-generation MEA
    - Reduction in number of required cells over Plug Power's current stack
    - Significant reductions in weight and volume
    - Significant reductions in DMC
    - Increase in heat generation by the stack requiring a small increase in stack operating temperature
  - Data shows we can operate the stack with the advanced MEA at increased current densities without compromising performance or reliability.



Stack data after scaled stack initiatives meets performance criteria.

TECHNICAL ACCOMPLISHMENTS

❖ Task 2.4 H2 Regeneration Options and Task 2.7 System Water Balance

- The purpose of this task was the development of Advanced Exhaust Gas Recirculation (EGR) and Electrolyzer options for the next generation design.

- The Advanced EGR option was very successful by maintaining the advantages of EGR:
  - No purge
  - Near 100% fuel utilization
  - Steady performance at very low turndown (zero net power output)

- The Advanced EGR configuration demonstrated a 15% more efficient loop while lowering DMC

TECHNICAL ACCOMPLISHMENTS

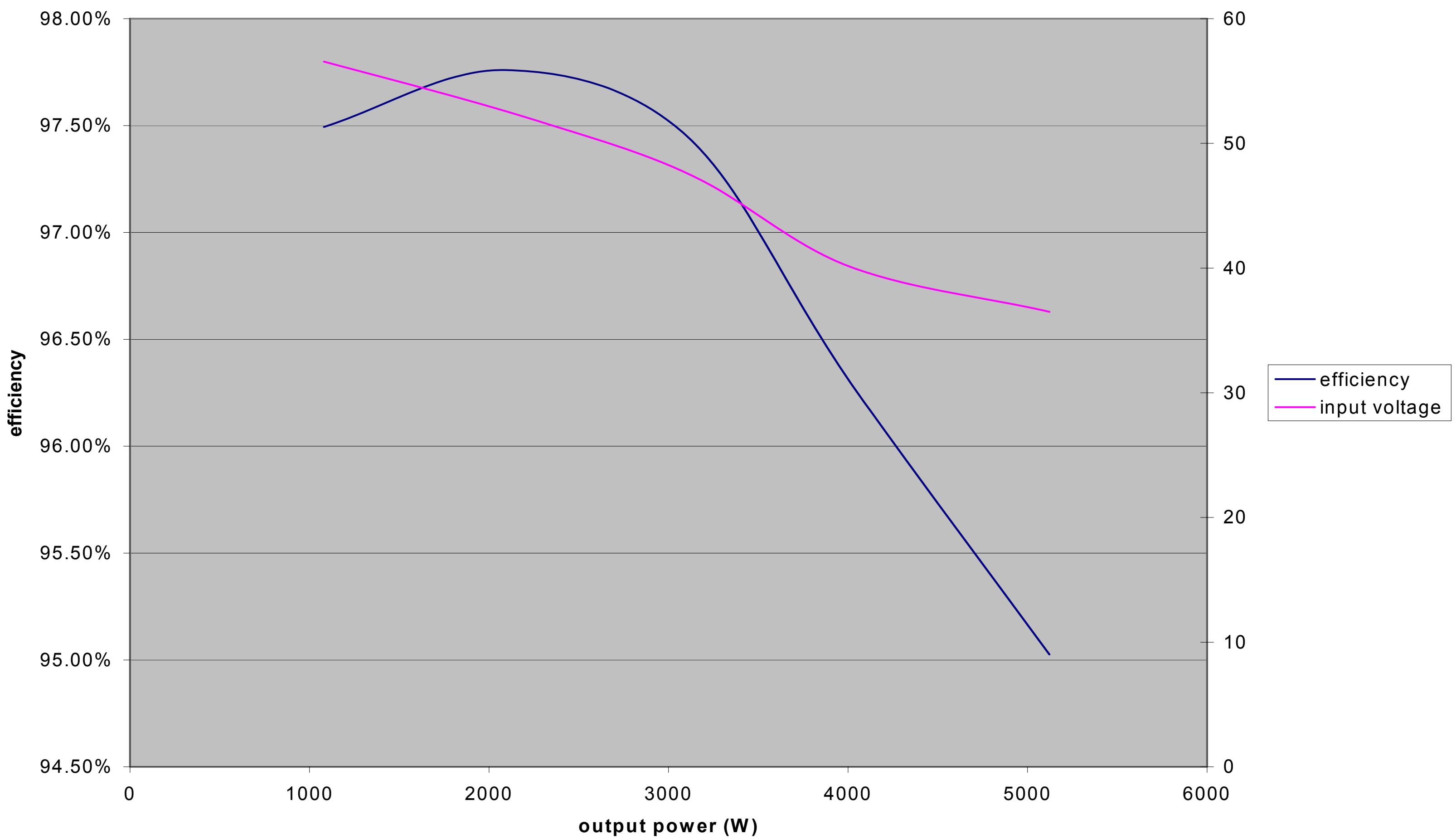
- For the Electrolyzer option, 22 electrolyzer suppliers were evaluated based on experience, product cost, desire to collaborate, etc.
- The supplier list was downselected to a single electrolyzer technology (KOH) and vendor.
- While the technology passed our feasibility assessment the supplier was unable to deliver to purchase order requirements.
- The system water balance initiative was in support of an electrolyzer option. Without an electrolyzer the GenCore system requires no external humidification. This initiative was a No-Go.

TECHNICAL ACCOMPLISHMENTS

- Task 2.5 Power Conditioning Platform
  - The purpose of this task was to develop a power-conditioning platform with increased efficiency, lower cost and wider voltage options.
  - The final platform design has the following characteristics:
    - High efficiency
    - Greater than 50% cost reduction over the prototype design through effective power board and DC-DC stage design
    - Flexible platform capable of delivering +48V DC, -48V DC, 24V DC and 120V DC

TECHNICAL ACCOMPLISHMENTS

Power Conditioning Efficiency – 120V System

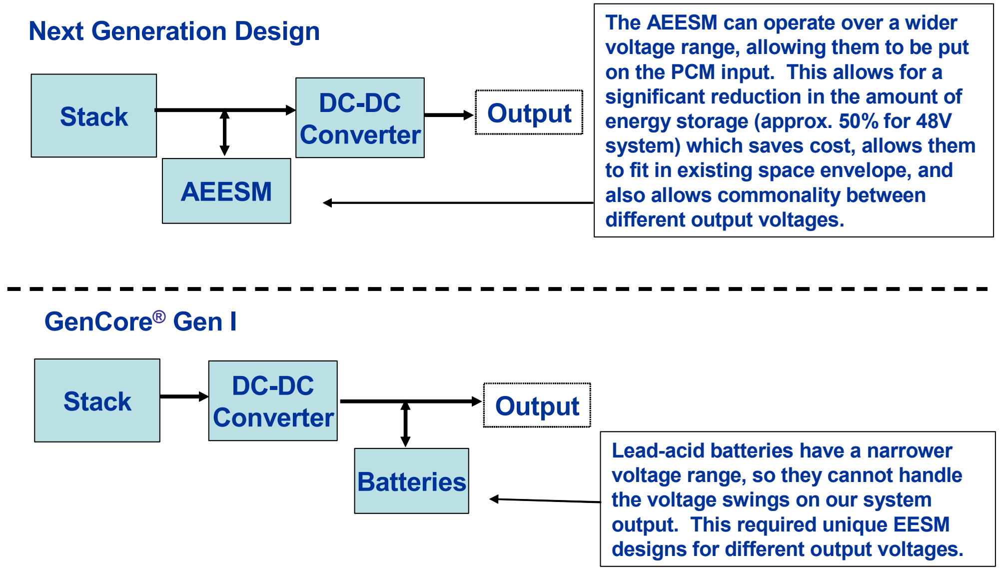


TECHNICAL ACCOMPLISHMENTS

❖ Task 2.6 Advanced Electrical Energy Storage (AEESM)

- The purpose of this task was to integrate advanced electrical energy storage into the design of the next generation system.
- Energy storage must be maintained on the input side of the PCM. This requires a more robust system characterization and startup reliability.

ENERGY STORAGE – (input vs. output side of the PCM)



TECHNICAL ACCOMPLISHMENTS

- Task 2.8 Advanced H2 Storage
  - The purpose of this task was to develop a hydrogen storage system (enclosure, delivery, safety, telemetry) using both standard steel bottles and composite cylinders.
  - While several composite cylinder commercial products were available this initiative was abandoned for the following reasons:
    - We were unable to find products that were DOT certified and the certification process was formidable and beyond the scope of this program.
    - Limited availability of high-pressure (over 3500 PSI) cylinders required either Plug Power or a commercial supplier to stock an inventory of cylinders.
    - Through customer surveys we were unable to demonstrate a business case that justified these investments.
  - Customers accept industrial steel cylinders and this initiative concentrated solely on this concept.
  - Plug Power has developed a design (enclosure, delivery, safety, telemetry) that packages industrial steel cylinders to meet the requirements of the customer, UL and NEBS.

TECHNICAL ACCOMPLISHMENTS

❖ Task 2.9 Scale System

- The purpose of this task was to scale the system's BOP to meet reliability, size and cost targets. This was accomplished in two iterations.
- The first was a systems integration and optimization effort which significantly reduced the volume, the weight and the DMC
- The second is a manufacturability, service and reliability effort designed to create a mass-manufacturable product.

TECHNICAL ACCOMPLISHMENTS

- Task 2.10 GenSys Stack and Task 2.2 GenSys Stack Integration
  - The purpose of this task was to develop a next-generation, architected stack platform that can be used in GenCore that increases life, reliability and reduces cost.
    - The goal of this stack design is to optimize the following critical characteristics:

      Very high manufacturability

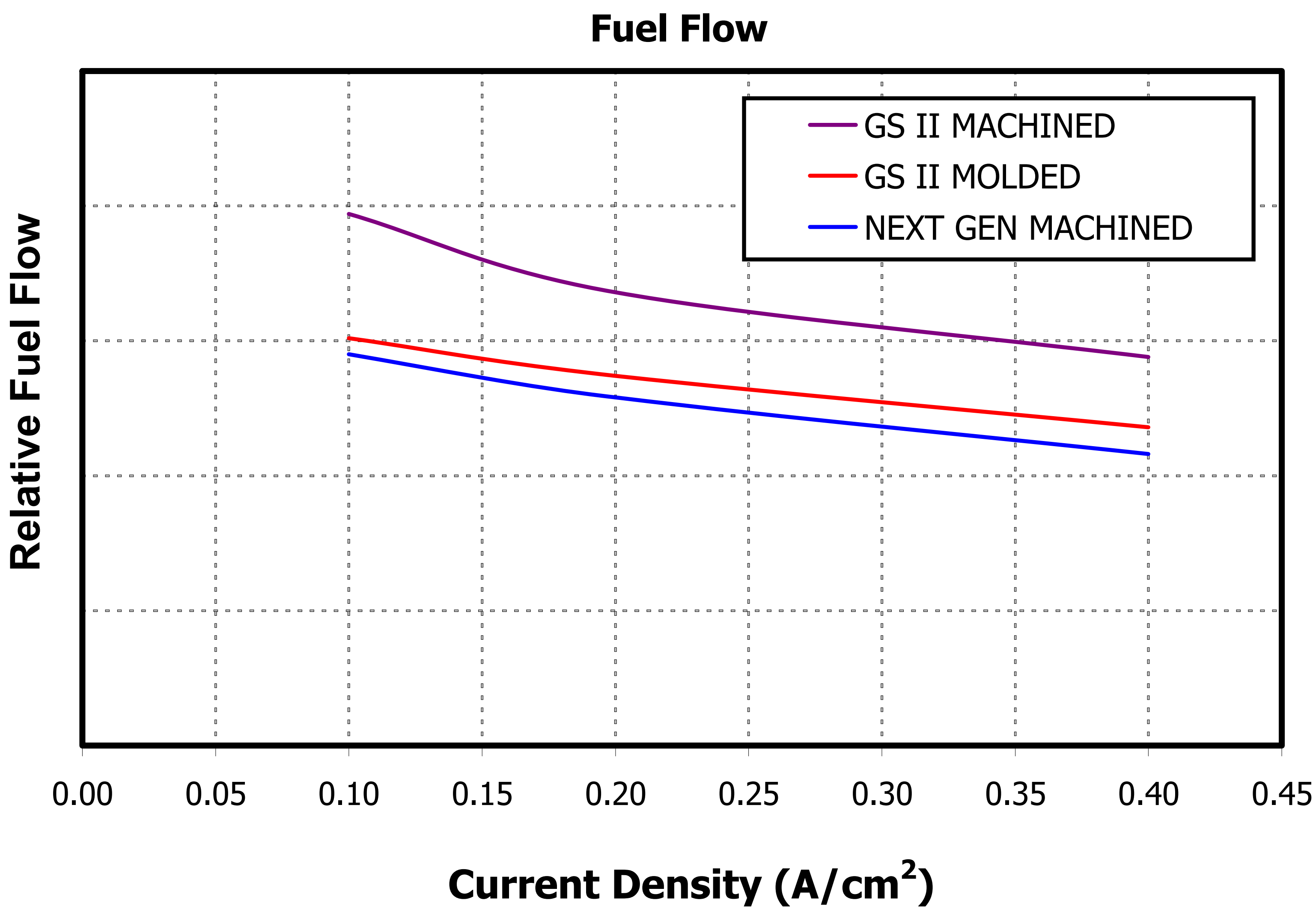
      Low cost

      Long life

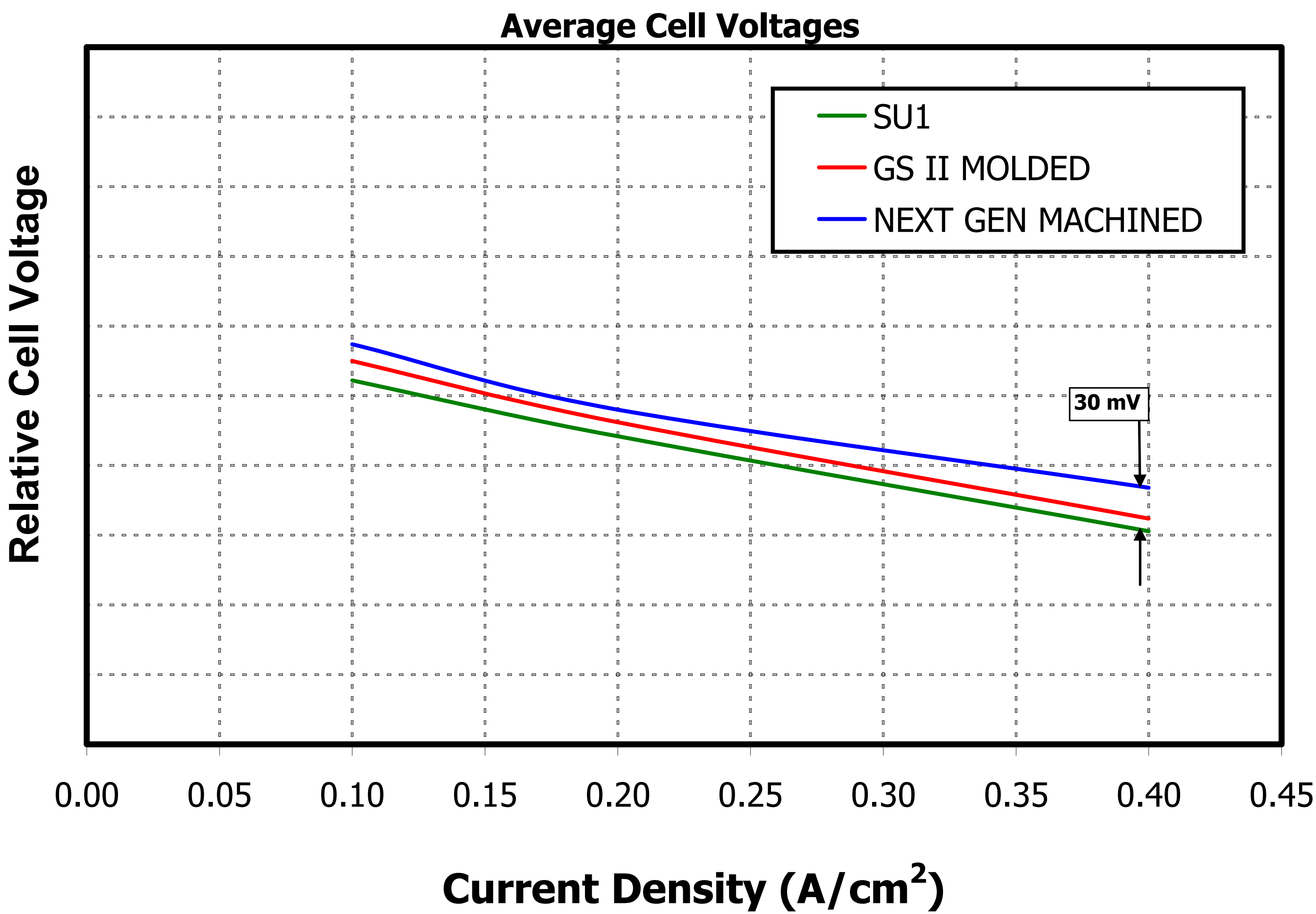
      Robust operation

      Easily serviced
  - Module and first stacks are on target
  - Improvements will continue to end of program
  - Based on the readiness state of the technology, the decision was made to delay cut in of the GenSys stack into GenCore until its better characterized.

GENSYS® II STACK PERFORMANCE



GENSYS® II STACK PERFORMANCE



TECHNICAL ACCOMPLISHMENTS

- Task 3.3 Perform Field Testing
  - The purpose of this task was to field test the GenCore prototype system and gather customer requirements.
  - To date thirteen systems under this program have been installed in installations ranging from lab facilities to telecommunication huts and switchyards connected to DC busses.
  - The systems have logged over 3000 operational hours and over 2500 starts and stops to date. Detailed information on customer training, shipping, installation, commissioning, data collection and operation has been received and continuously drives design and process improvements.
  - Plug Power is eager to continue learning and would gladly consider partnering in government or private programs involving the testing and operation or our equipment beyond the demonstrations at BellSouth and ANL.

TECHNICAL ACCOMPLISHMENTS




RESPONSES TO PREVIOUS YEAR REVIEWER COMMENTS

- *"Establish definite evaluation points for either Go/No-Go or backup plan to implement"*
  - Yes, definite evaluation points were established at program start and enabled "Go/No-Go" decision in 12/04.

- *"Looks good but has several variables that must come together."*
  - Yes, the technology downselect process allows concepts with varying degrees of risk to be worked in parallel without effecting the delivery schedule for the design. Example: Advanced EESM was a "Go" but the electrolyzer was a "No-Go. All of the selected initiatives were brought together in the final design.

- *"Not clear that development of product for niche market with low duty cycle operation advances the state-of-the-art toward long-term goals. Fuel cell community will not benefit from the learning."*
  - Disagree. Examples of benefits to the fuel cell community are:
    - BellSouth now knows the requirements of commercial fuel cell systems
    - GenCore systems are available for study and testing purposes
    - Fuel cell suppliers' capabilities and volumes increased
    - Component and system technologies advanced
    - Publication of field test results early next year in DOE program final report
    - Public awareness of fuel cells and their safe operation is increased

FUTURE WORK

- FY 2005 – 1Q06
  - Complete Technology Initiative Development through the Engineering Change Process
  - Complete Development of the GenSys Stack
  - Complete Design and Design Verification Testing
  - Complete Integrated System Testing
  - Build Verification Test Units
  - Conduct Field Demonstration at BellSouth
  - Certify Design to NEBS and UL
  - Demonstrate at 2 DOE sites

HYDROGEN SAFETY

- The most significant hydrogen hazard associated with this project is a secondary hydrogen fire created by the overpressurization of a GenCore chemical energy storage module (CESM). The overpressurization would have to be caused by an external event such as a fire at a site host's facility.

- Our approach to deal with this hazard is:
  - The GenCore system and the CESM are UL Listed to ANSI Z21.83 and are NEBS Level 3 Compliant.
  - Plug Power works closely with field test site hosts to ensure the systems are installed compliant with all applicable NFPA codes.
  - Site hosts receive Plug Power Fuel Cell Operator certification to ensure the systems are operated and maintained safely.

PLUG POWER. PLUG WILL.



plug power FUEL CELL SYSTEMS

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