CellTech Power

Fuel Cells for Real Fuels

Direct Coal Power Generation

Using

Liquid Tin Anode Fuel Cell

9th Annual SECA Workshop

Pittsburg, PA

August 7, 2008

Liquid Tin Anode Direct Coal Fuel Cell

Background

- How it Works
- Technology Experience
- Direct JP-8

Power Gen Applications

- Potential Benefits
- Challenges
- Experimental Work
- Development Activities

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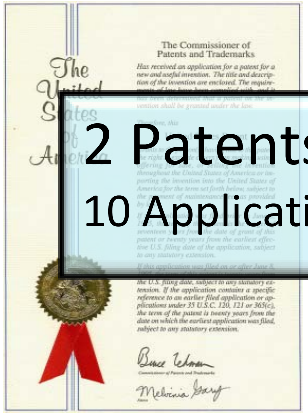
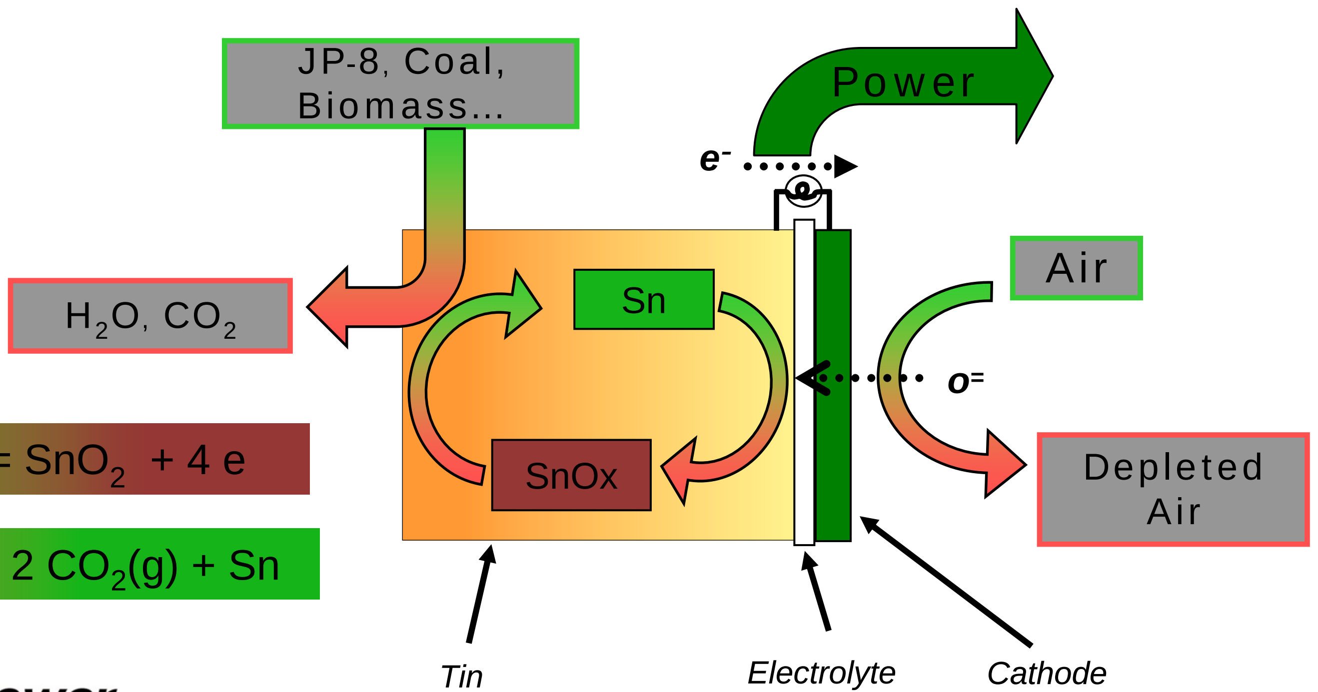
CellTech Technology: Liquid Tin Anode

<u>Tin is Ideal Anode</u>

✓Low Cost
✓Non-toxic
✓Not harmed by sulfur, carbon
✓Wide industrial application



2 Patents
10 Applications



$Sn(l) + 2\ O^{2-} = SnO_2 + 4\ e$

$SnO_2 + C(s) = 2\ CO_2(g) + Sn$

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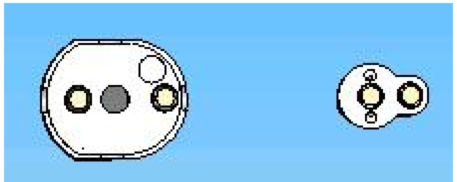
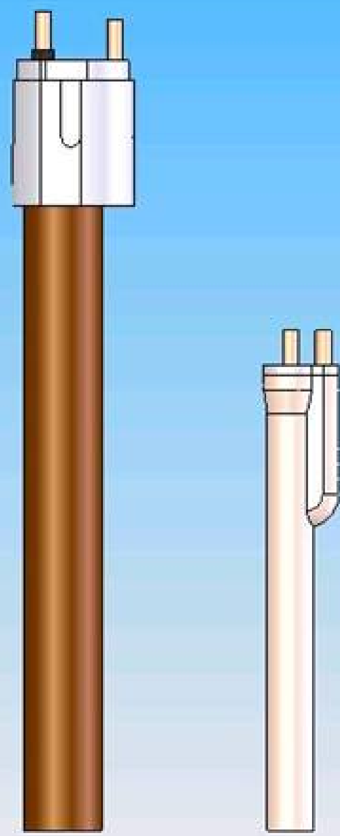
Liquid Tin Anode: Experience

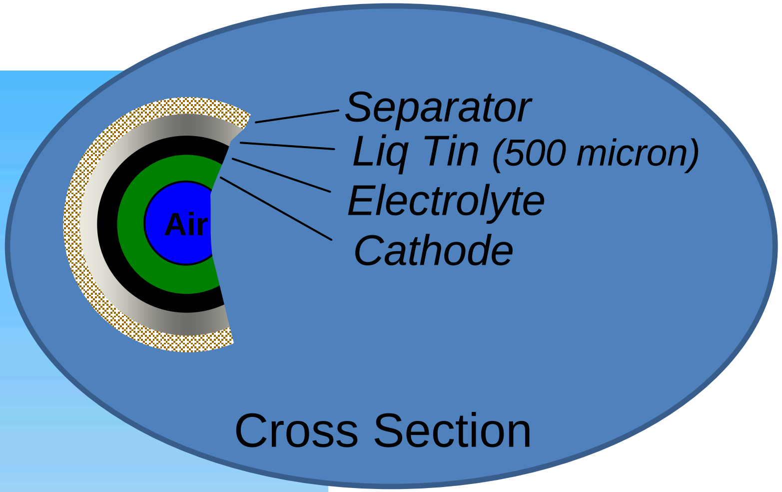
- Strong DoD support (Direct JP-8, portable)
  - 4X power density increase demonstrated in 2007
    - Additional 6X possible
  - Fundamental, Cell & System development support
- 1 kW Natural Gas prototype operated 2000 hrs
- EPRI Direct Coal and Biomass
  - Direct Coal experimental evaluation
  - Short term, no detectable contaminants in tin

Direct JP-8 Conversion



Top View





Gen 3.0

Developed 2005-6:

For DARPA/MISER Direct Waste Plastic Conversion

Gen 3.1

Developed 2007-8:

For DARPA/ARMY Direct JP-8 Conversion

4x reduction

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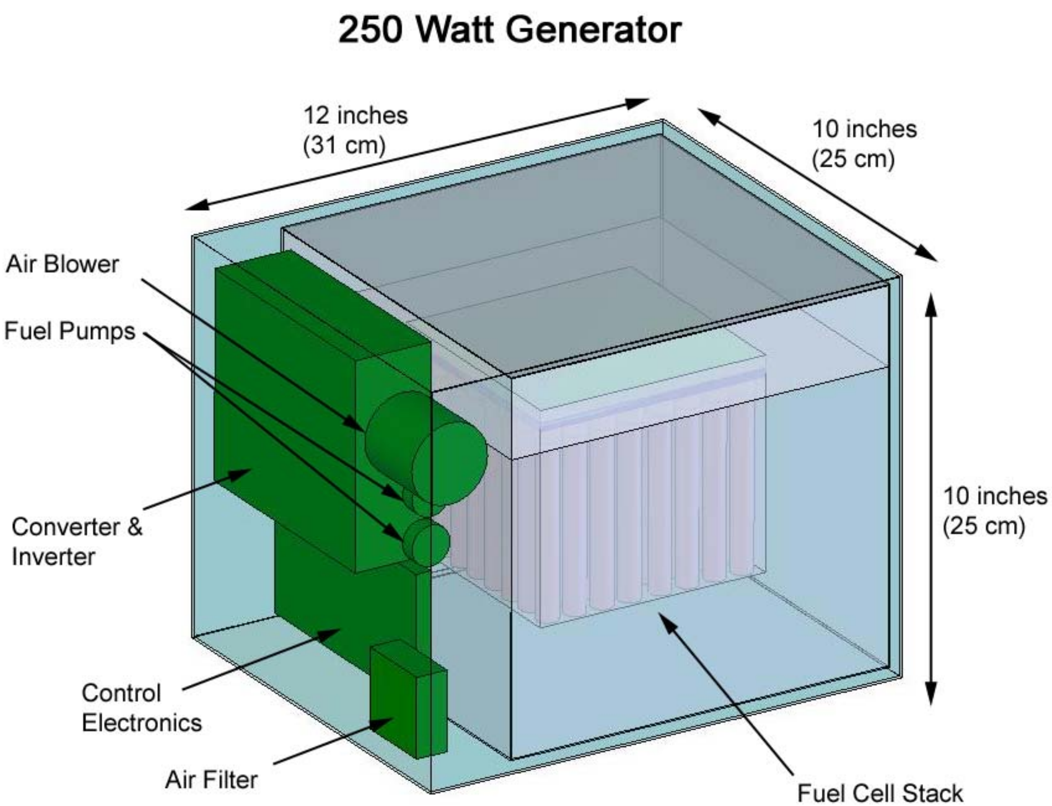
250 Watt JP-8 Fuel Cell Generator Concept



System Specifications

250 Watt DC or AC output

12 kilogram dry weight

20 liter volume

1 week operation on 5 gallons of JP-8

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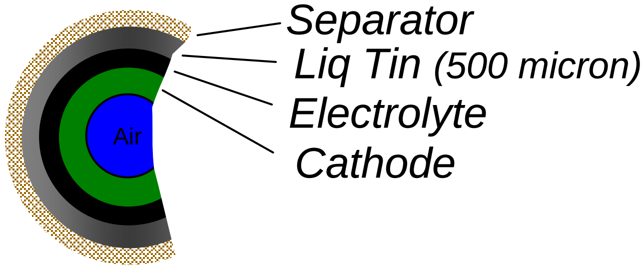
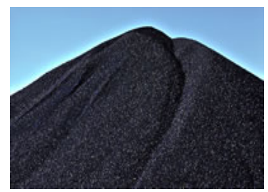
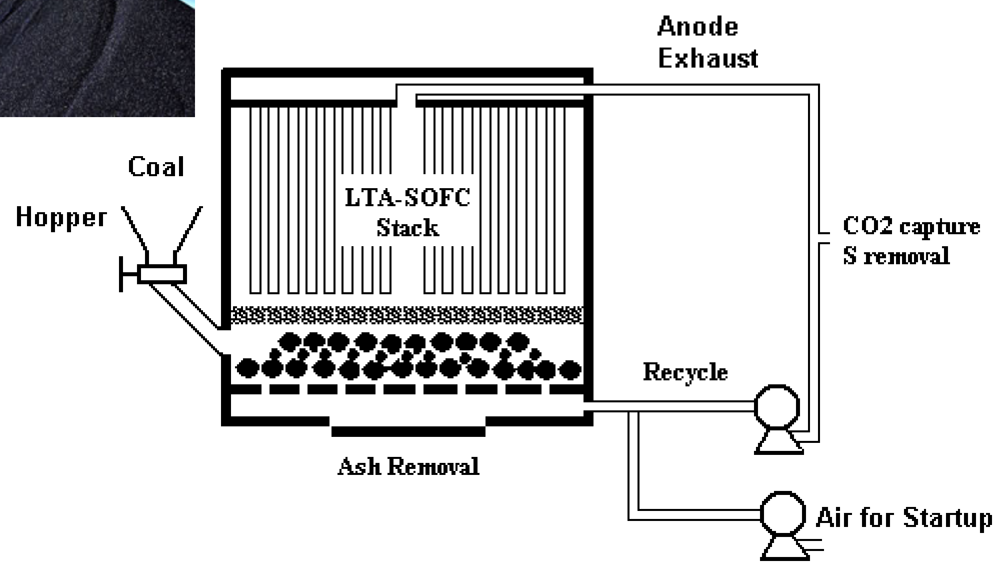
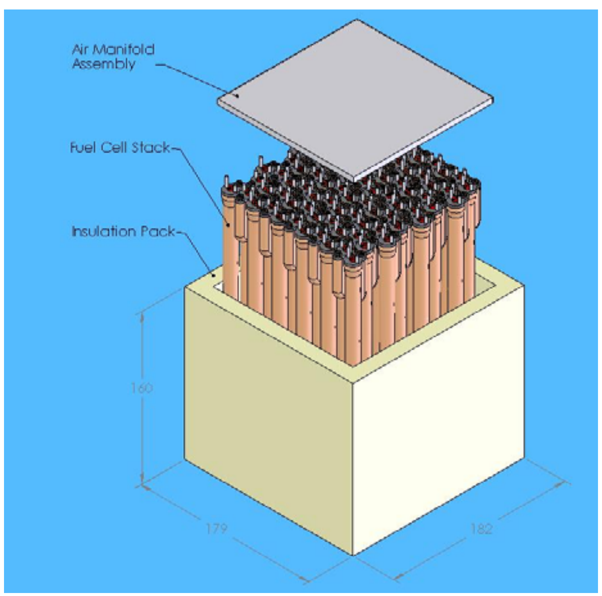
LTA- SOFC Direct Coal
Use existing Gen 3 Architecture



Cell Cross Section

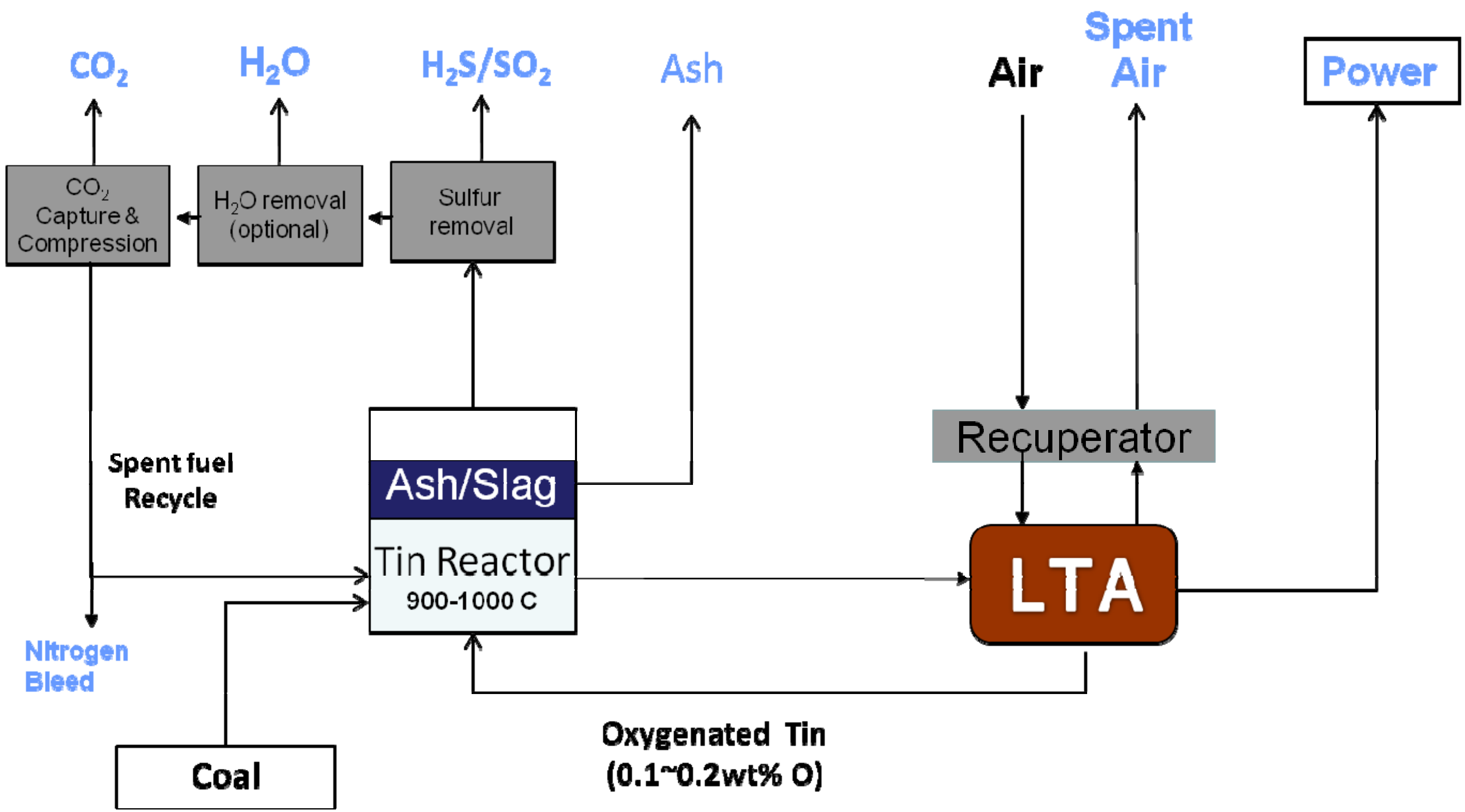






Stack

Tin Reactor Flowsheet with CCS



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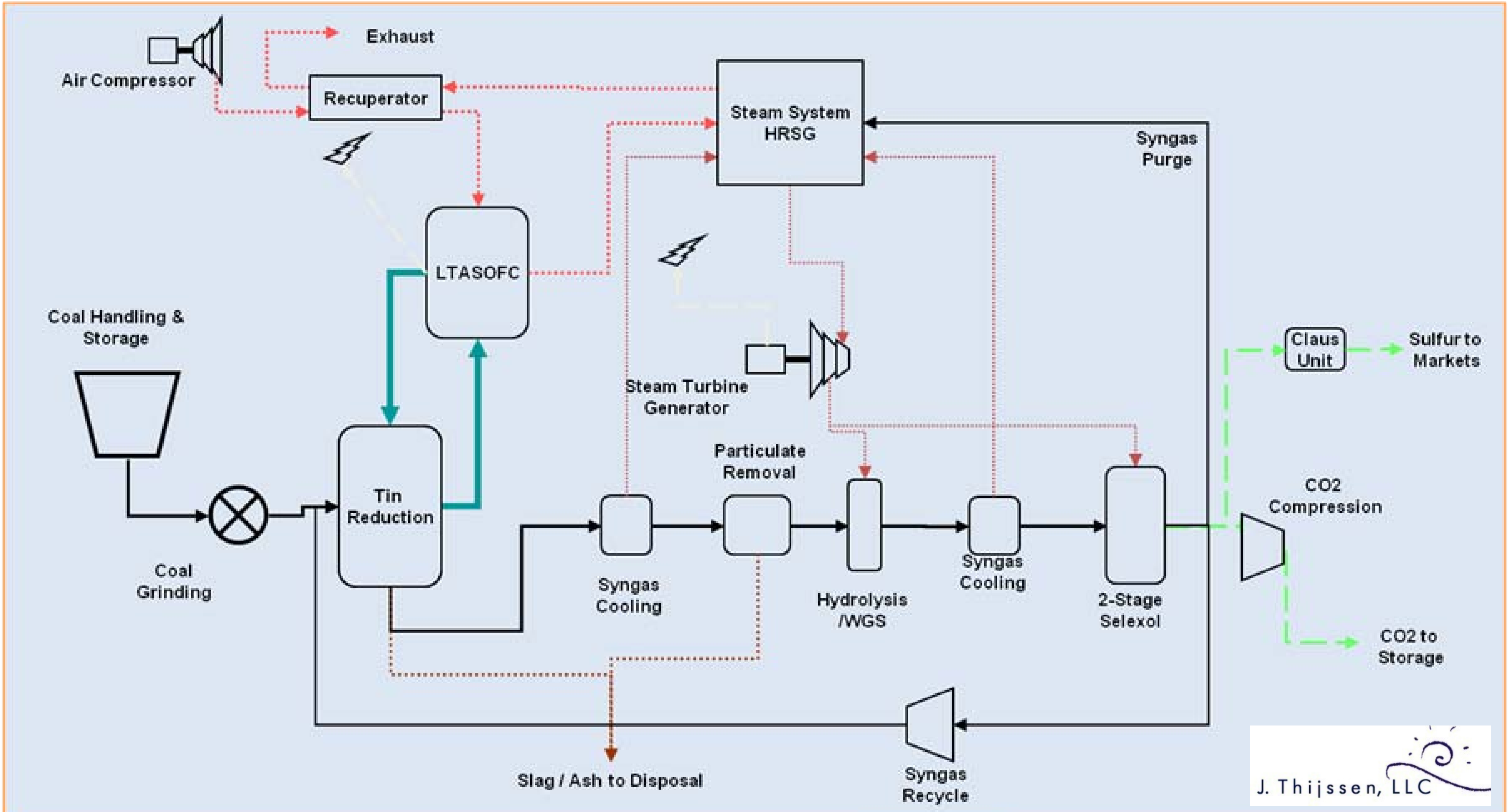
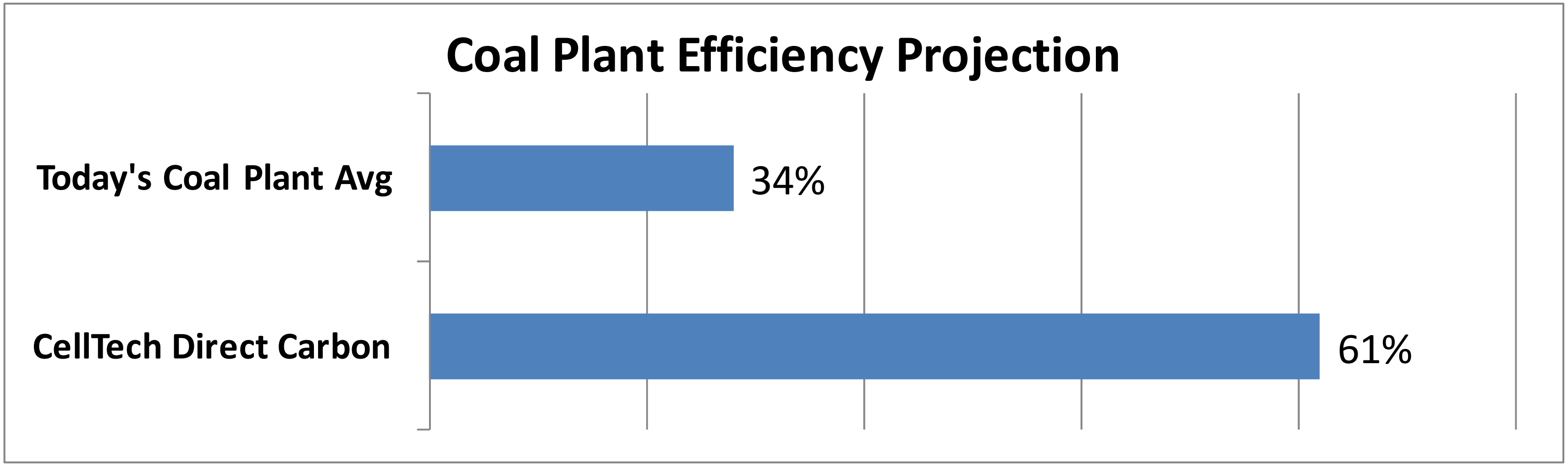
Tin Reactor Flowsheet with CCS



CellTech Direct Coal: Potential

- Near 100% CO_2 capture
- Similar capital cost to conventional coal
- Lower efficiency penalty for CO_2 capture
- Scalable for early biomass markets (1 MW range)



Systems Assessment of Direct Carbon Fuel Cell Technology, EPRI, Palo Alto, CA: 2008. 1016170.

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Direct Coal - Major Challenges

DOE Programs

DoD Programs

Collaboration

Cell/Stack

- Impurities
- Cell Scale-up
- Power density
- Cathode improvement
- Longevity

System

- Molten Metal Anode Chemistry
- Molten Tin Processing
- 100% Fuel Utilization
- Electrical Isolation
- Tin Circulation

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Direct Coal Experimental
Efficiency Evaluation

Batch mode, single cell

	Bio-char **Univ of Hawaii**	**Coal** **Pulverized East/West**
Net power measured at test stand load	**34%**	**37%**
IR and Air Corrected	**67%**	**>57%**

Without correction for fuel utilization

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Direct Coal Experimental
Contaminate Evaluation

Contaminants of Interest
Arsenic (As)
Chromium (Cr)
Molybdenum (Mo)
Niobium (Nb)
Selenium (Se)
Tantalum (Ta)
Tellurium (Te)
Tungsten (W)
Uranium (U)
Vanadium (V)

Procedure
Batch mode
Coal in tin reactor 1000° C
Coal reacted to completion
100 hr test

Results
Contaminants of interest below detectable limits

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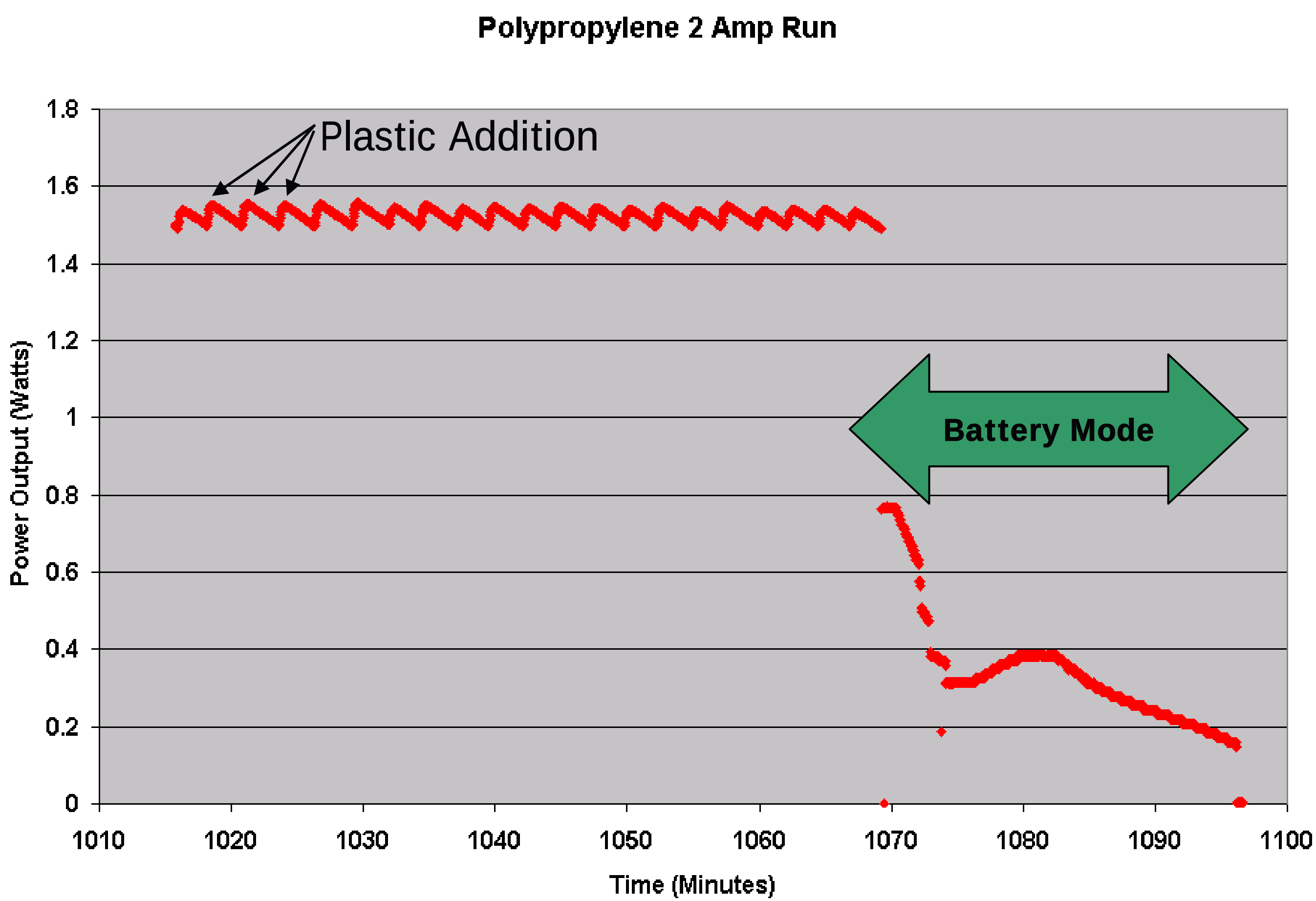
Operation on Plastic



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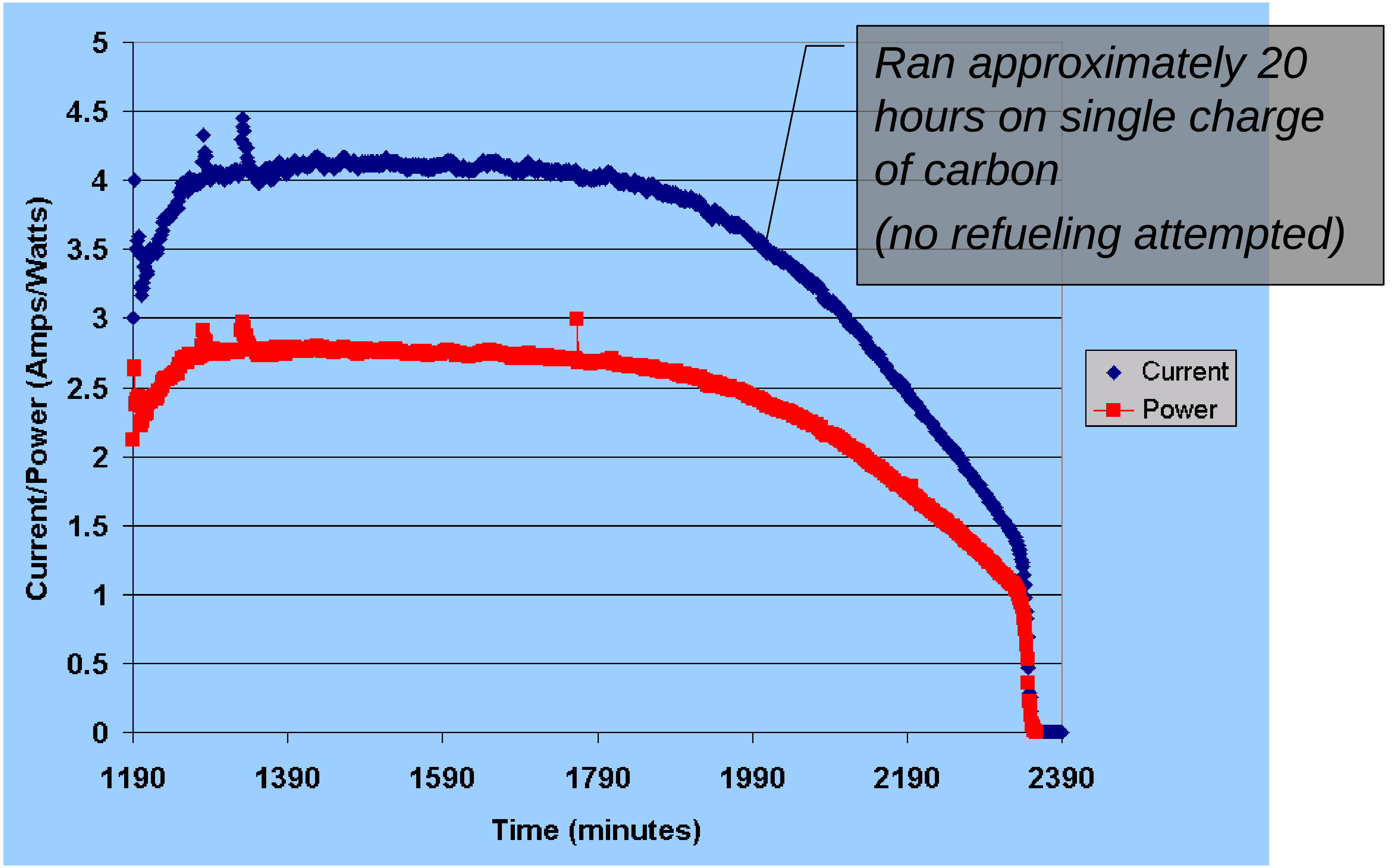
Operation on carbon



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DOE Programs- Key Technical Tasks

Two Programs to look at key risk areas for Direct Coal using Liquid Tin Anode

1. Novel Coal Cooperative Agree. – Phase 1: 18 months
   - Contamination Evaluation–
     - Non-electrochemical
     - Electrochemical
   - Provide input to DOE Systems Analysis

2. Direct Coal SBIR – Phase 1: 9 months
   - Cell scale up analysis and design

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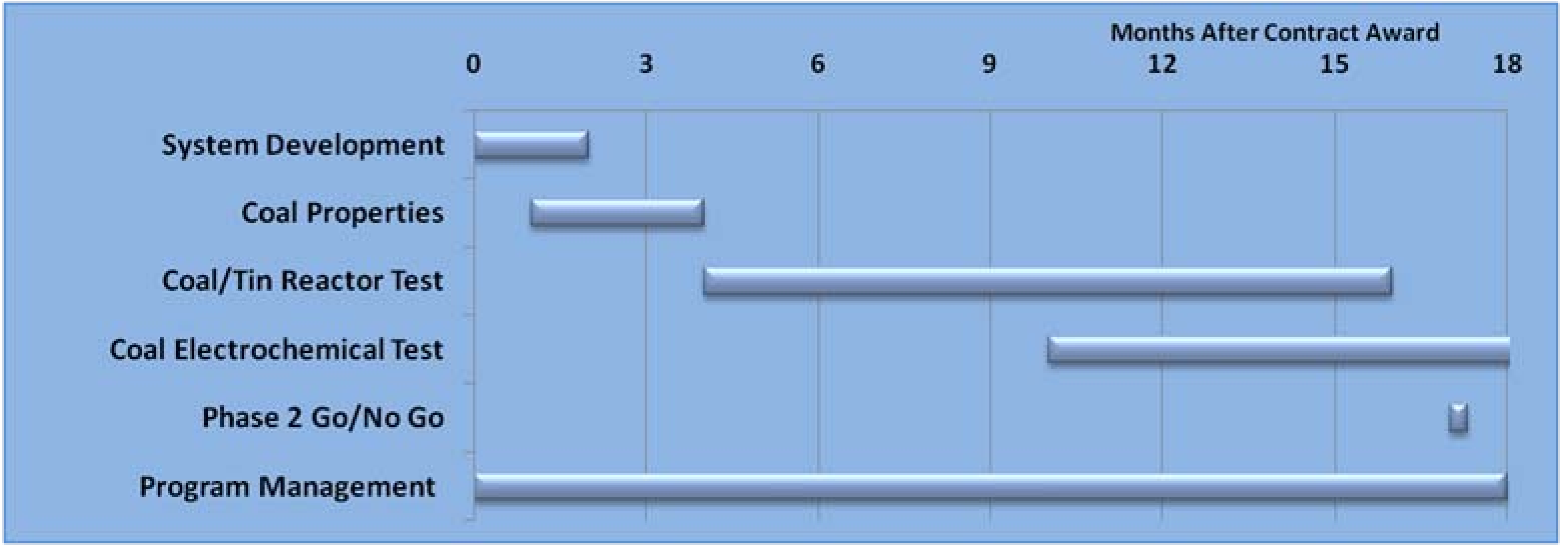
Novel Coal Phase 1 – 18 Months



Coal Tin Reactor Test: Batch testing to establish equilibrium levels of contaminants

Coal Electrochemical Test: Evaluate impact of tin contaminants on YSZ. Use Gen 3.1 JP-8 cells.

Phase 2: Cell/Stack Testing in molten tin

Co-funded by EPRI

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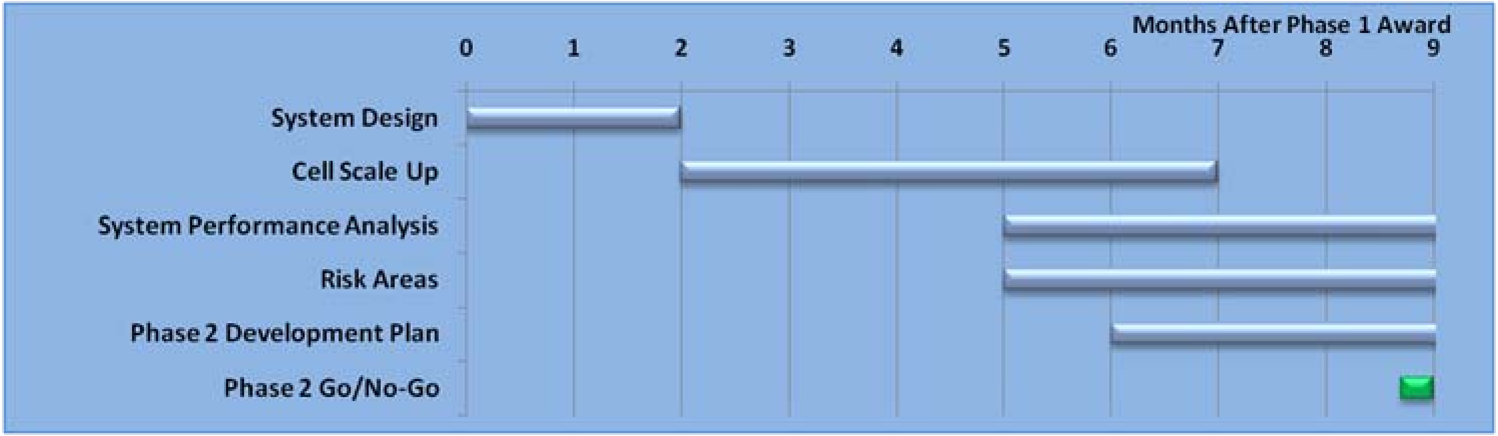
Phase 1 SBIR



Cell Scale Up

a) Use existing data to develop a polarization curve
b) Cell scale up to 1kW- Preliminary design
c) Cell Degradation SnO_2-YSZ plus contaminants
    i. Areas of concern, possible mitigation techniques

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Summary – Liquid Tin Anode

- Tin "purification" decouples coal oxidation from power production
- Could achieve breakthrough efficiency and enable 100% CO_2 capture
- EPRI & DARPA programs have established feasibility of Direct Coal/JP-8
- Strong DoD support for small cells provides an R&D platform for coal
- DOE/CellTech programs focus on impurities and efficiency validation
- Cooperative programs planned for "balance of system" technology development

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