Liquid Tin Anode Fuel Cell Direct Coal Power Generation

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Liquid Tin Anode Direct Coal Fuel Cell

Background

- How it Works
- Potential Benefits

Direct Coal Power Gen

- System Concept & Analysis
- Contamination Studies
- Cell Scale-up
- Key Risk Areas

Direct Coal Fuel Cell System

Application of Liquid Tin Anode Fuel Cell to coal power gen

- Scale up of existing Direct JP-8 technology
- No gasifier or oxygen plant required
- Key questions for Phase 1 work:
  - What is projected system performance?
  - Impact of coal contaminants on the LTA cell?
  - Can existing cells be scaled up for utility application?

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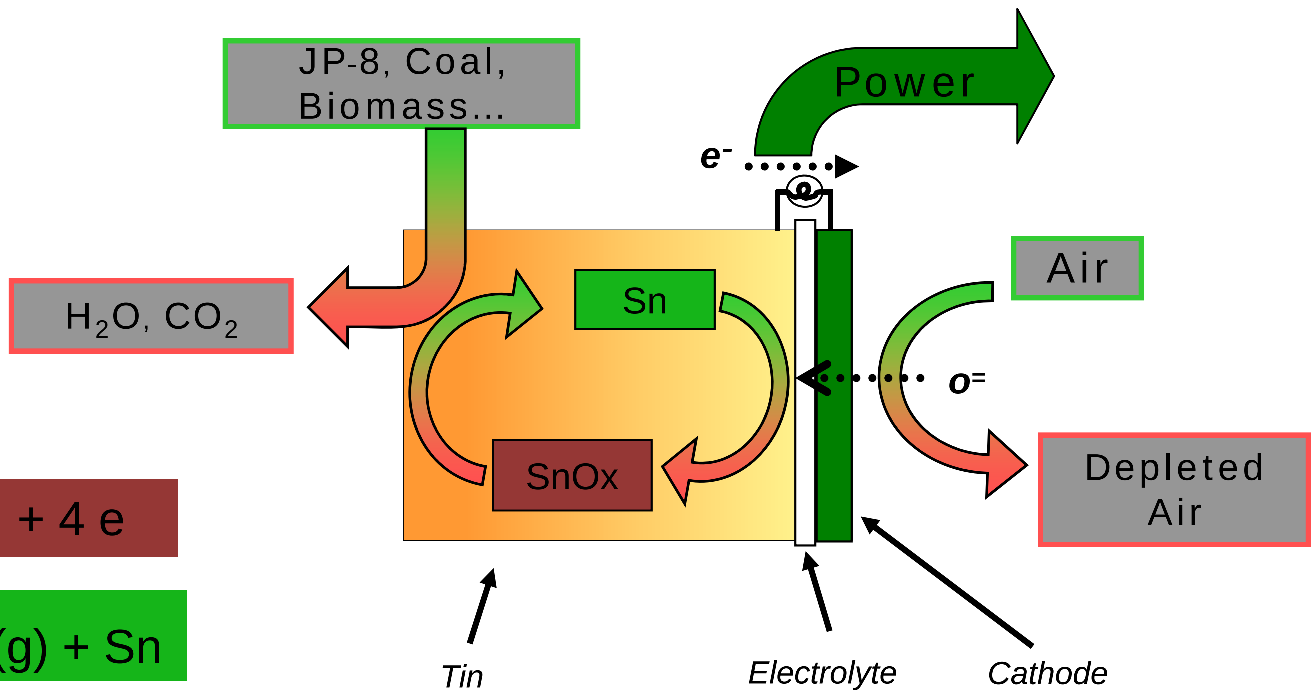
CellTech Technology: Liquid Tin Anode

<u>Tin is Ideal Anode</u>

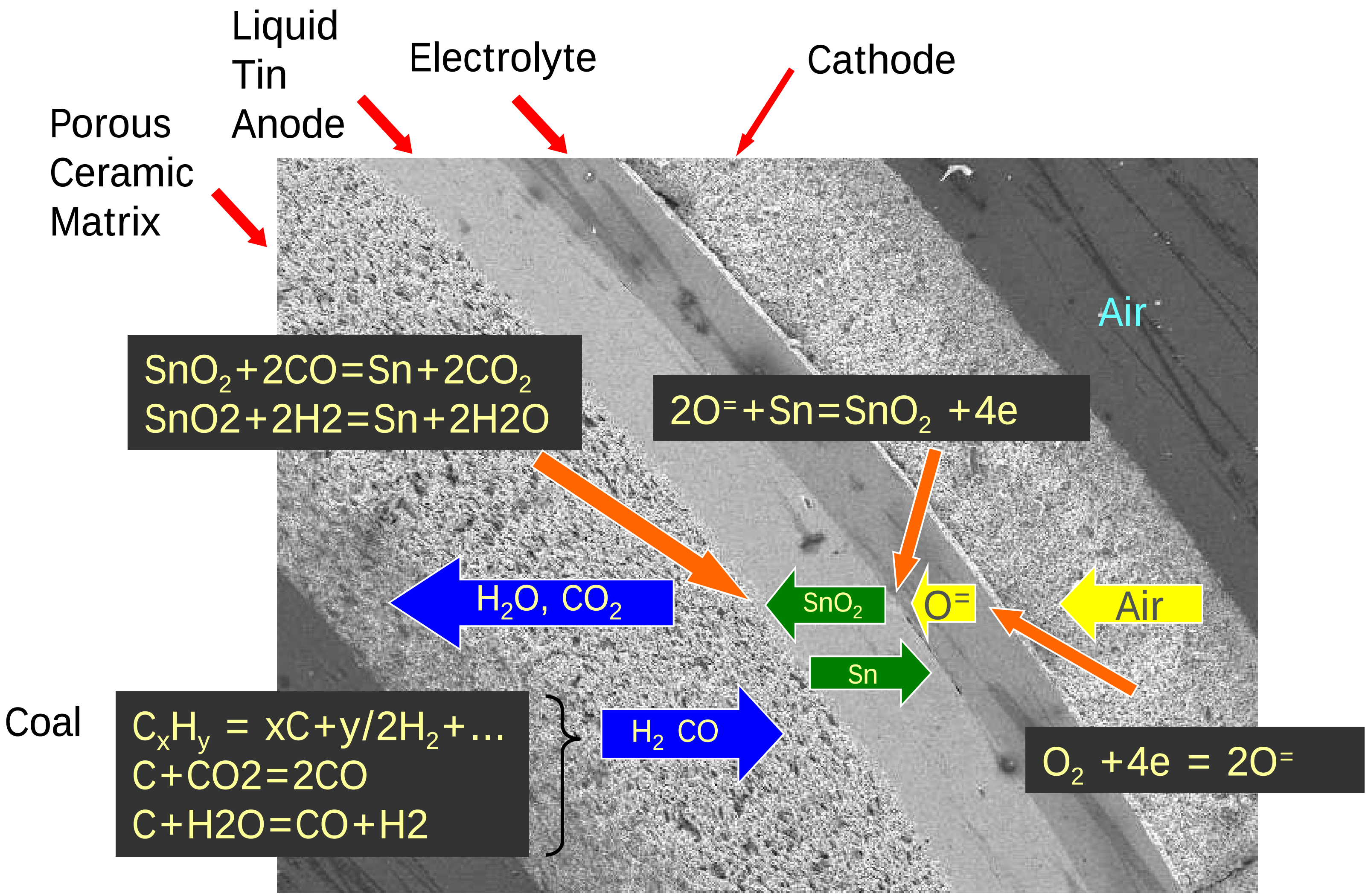
- ✓ Low Cost
- ✓ Non-toxic
- ✓ Not harmed by sulfur, carbon
- ✓ Wide industrial application



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

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

Chemical and Electrochemical Reactions



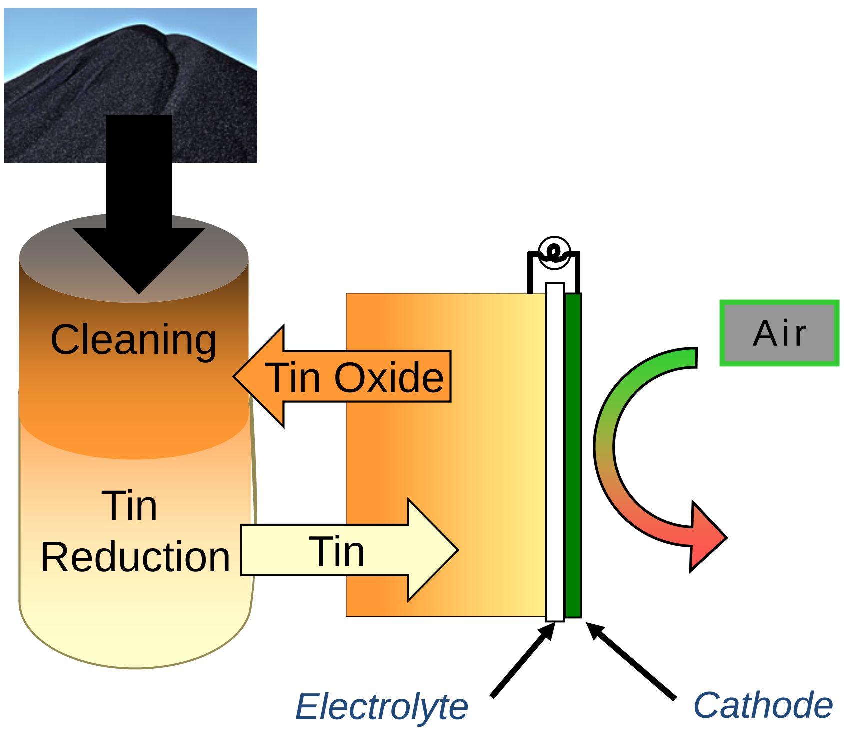
Architecture Options (Poster Session)

ElectroChemical Looping

Tin Reactor - Direct Coal

Cathode/Electrolyte cell

Chemical reactor separate from fuel cell power reactor

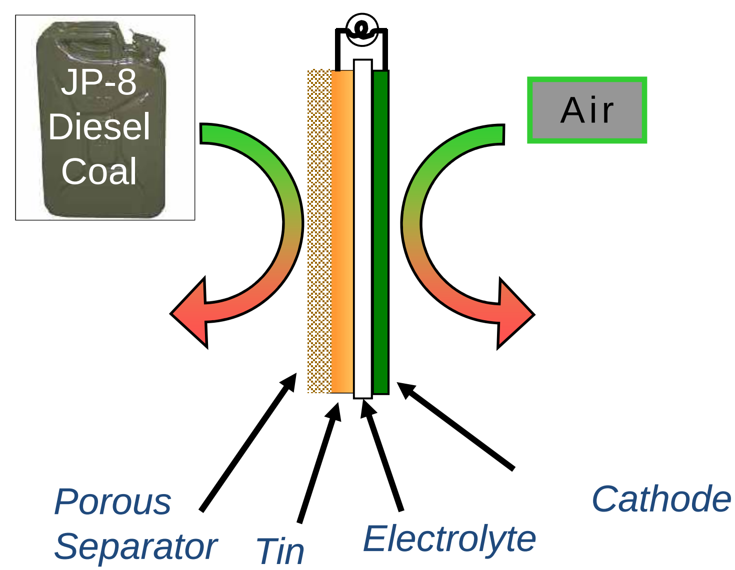


In-Situ Gasifier– alternative

Based on Gen 3.1 cell design used for portable power

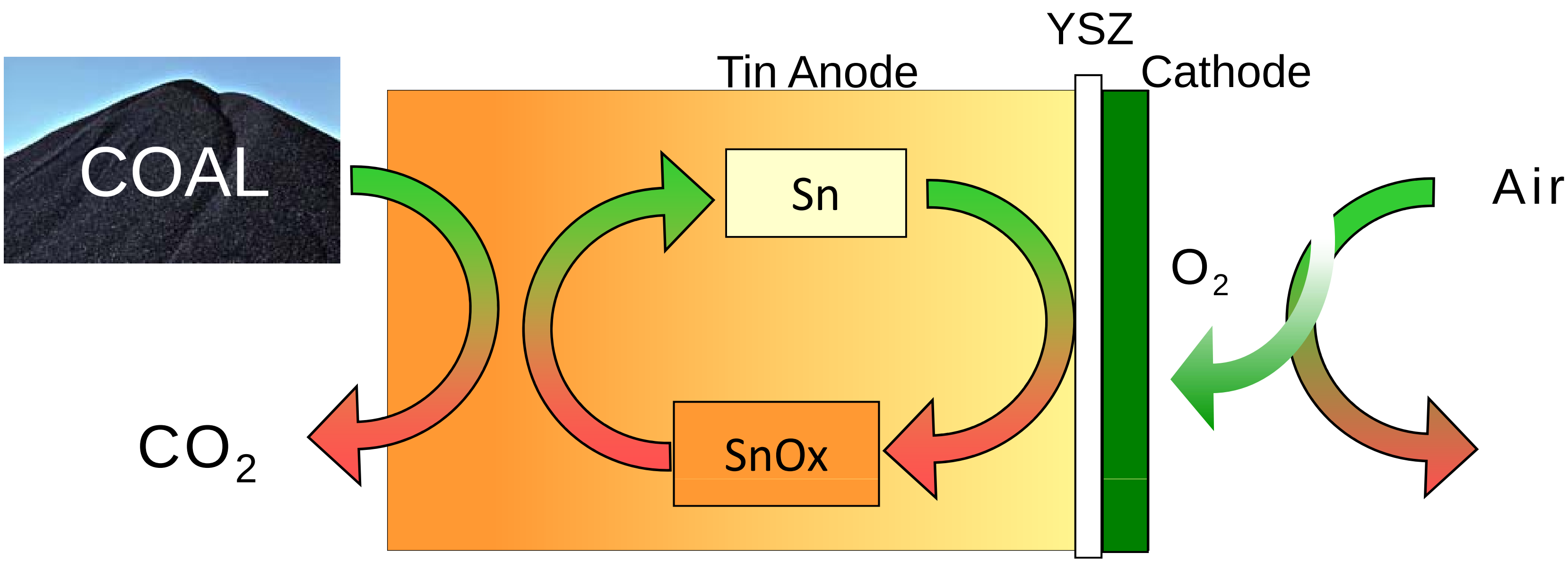
Thin static tin layer

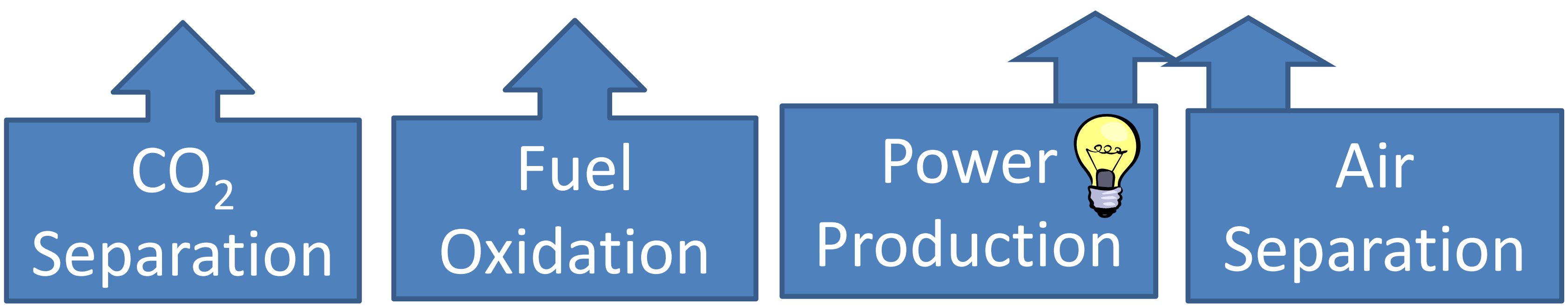
Contained by separator



ElectroChemical Looping

Direct Coal Power Using Liquid Tin Anode





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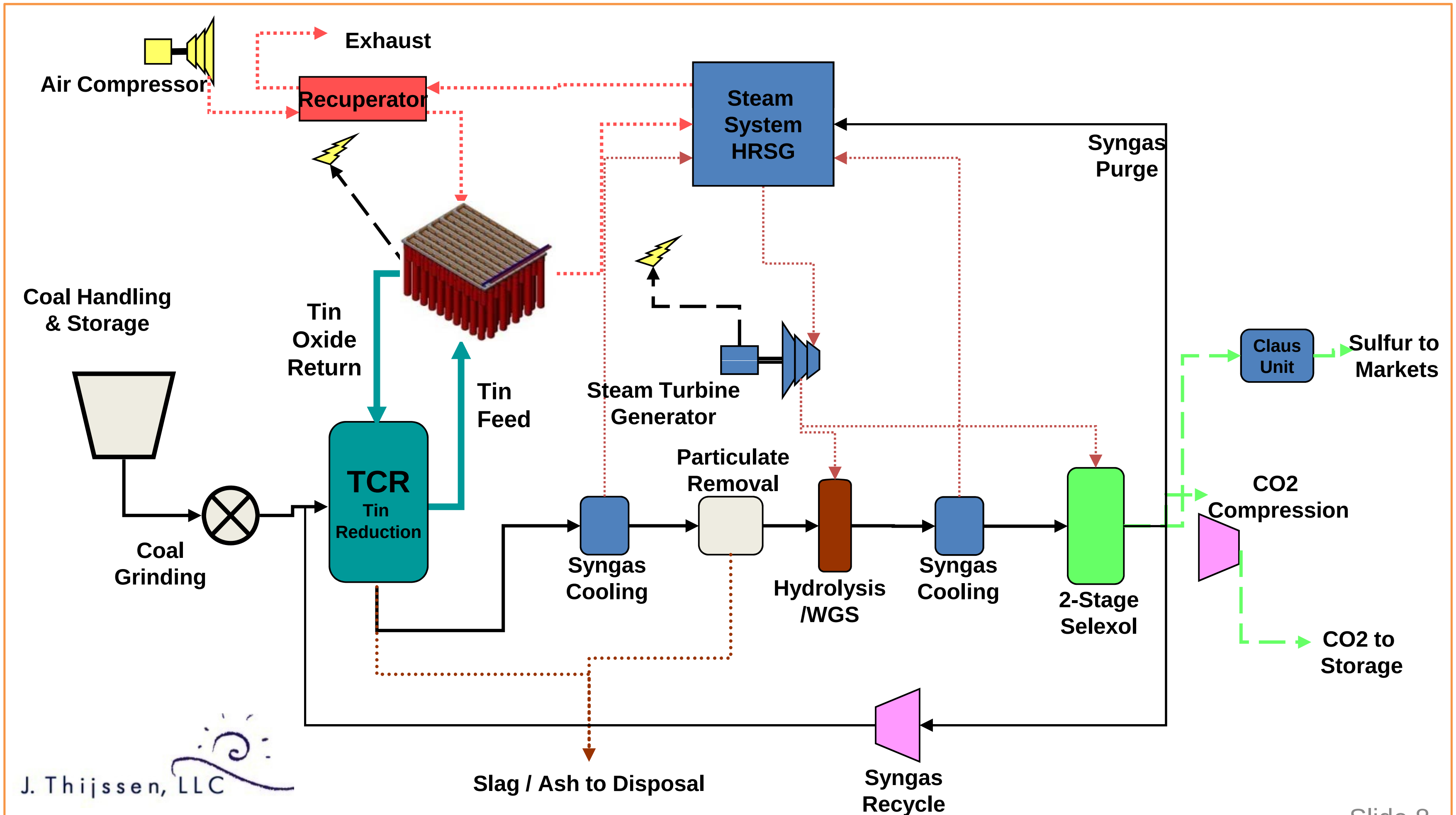
Baseline concept: ElectroChemical Looping

TCR processes coal and all recycled syngas. LTA-SOFC immersed in tin pool. Circulating tin provides all species transport to anode. Conventional clean-up.

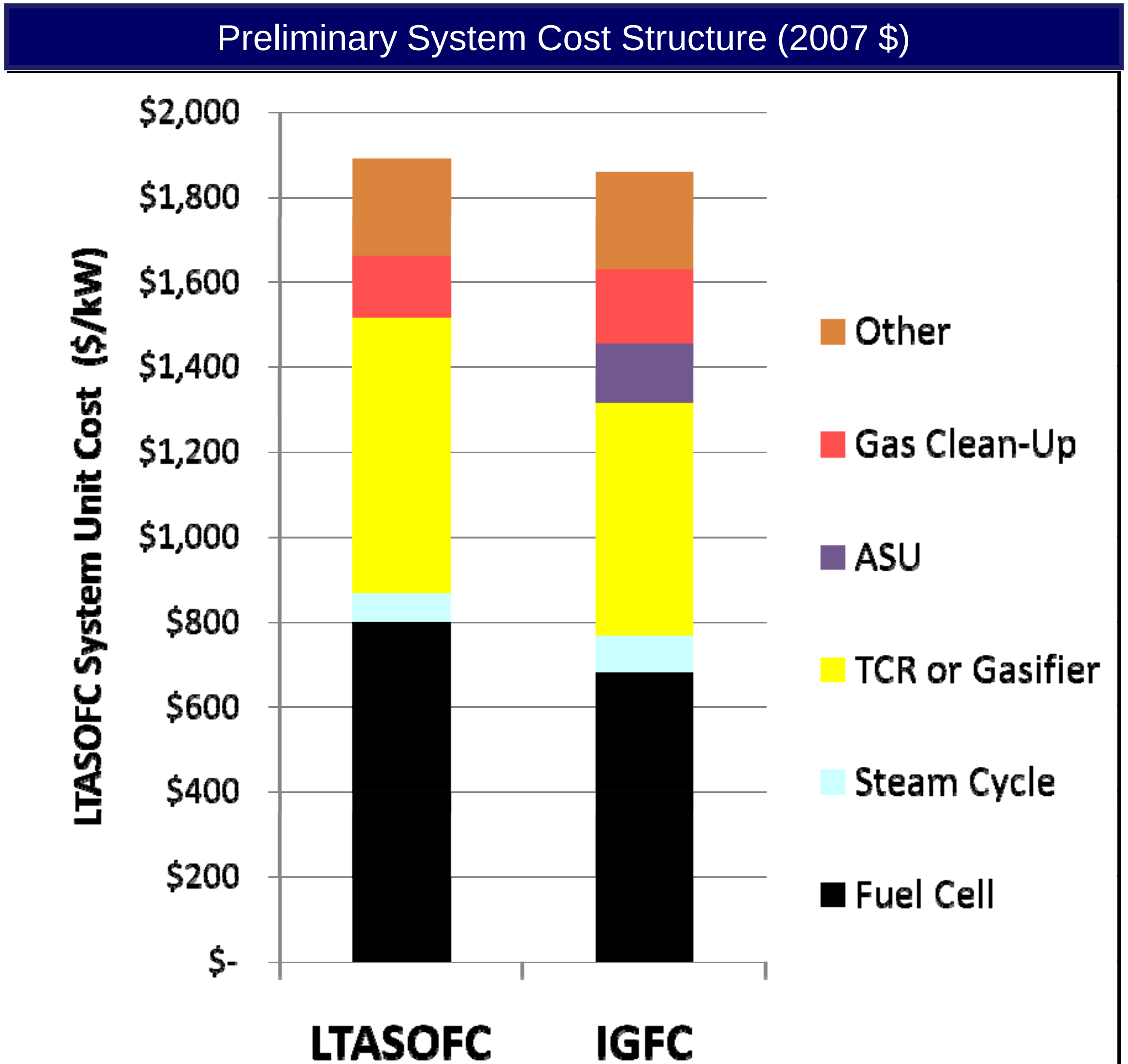
High-Level PFD of LTASOFC with CCS



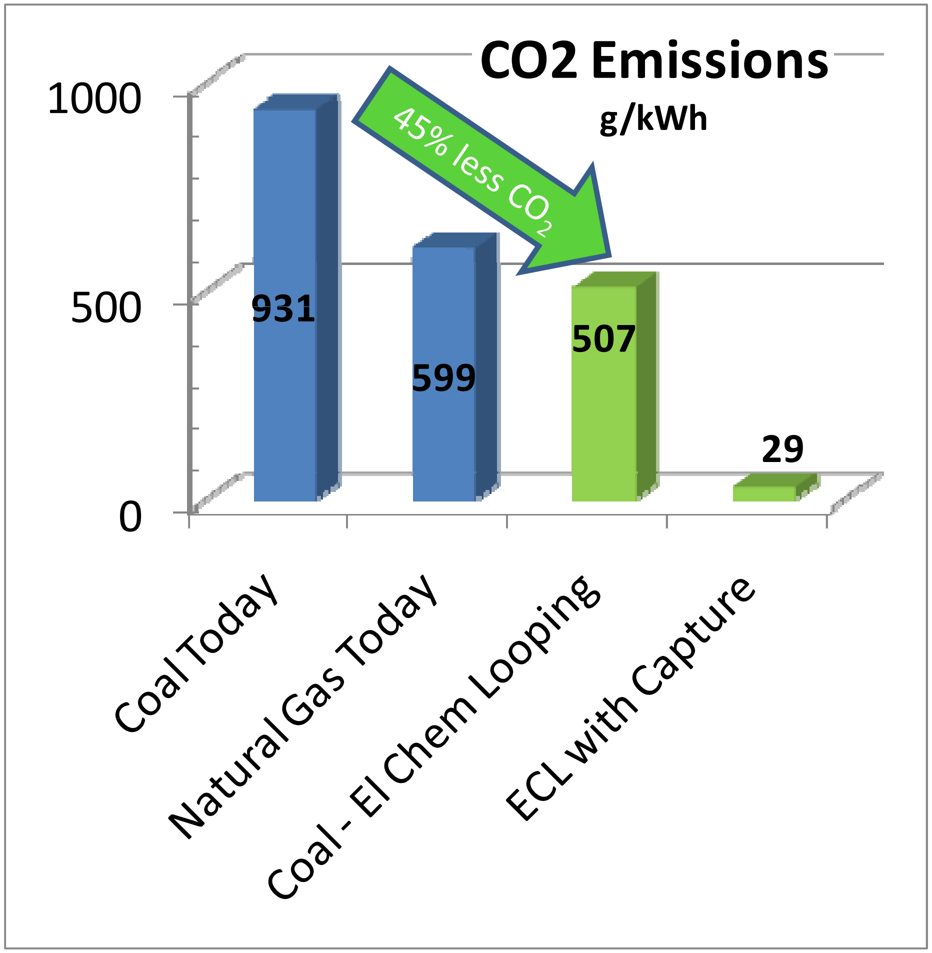
250 MW System Performance Estimate

Projected System Performance		
Fuel Cell Stack	Maximum O Content (mass)	0.1%
	Cathode Stoichiometry	1.22
	Stack Temperature	1000°C
	Cell Voltage	0.69 V
	Fuel Cell Gross Power	250 MW
TCR	Anode Recycle	75%
System	Steam Cycle Power	45 MW
	Parasitic Load	13 MW
	System Efficiency (HHV)	63.0%
	Carbon Emissions	29 g/kWh

System Cost Estimate



More Energy, Fewer Emissions From Coal Power



ElectroChemical Looping is more efficient- makes 45% less CO_2, pollutants and ash.

Coal power with lower CO_2 than natural gas.

Adding Carbon Capture reduces CO_2 to 3% of today's coal plants.

Contamination Evaluation

YSZ

- Analysis of contaminants that can harm YSZ electrolyte
- Experimental confirmation

Tin

- Experimental evaluation of contaminants solubility
- Coal/tin equilibrium reactor

Cell

- Electrochemical testing of cell spiked with contaminants.
- Using existing Gen 3.1 cells

Coal Contamination

Tin is unique anode for Direct Coal

- Liquid = no physical structure
- High contact with fuel
- Gravimetric separation of ash

Direct Coal Challenge: Impurities

- Metals such as Vanadium attack YSZ
- Can tin reduce or eliminate impurities?
- Is what remains in tin harmful to cell?

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

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Contaminant Spiking in Tin

<u>Gen 3.1 Cell spiked</u>

V, Cr, As: 400 ppm

Mo, Nb: 200 ppm

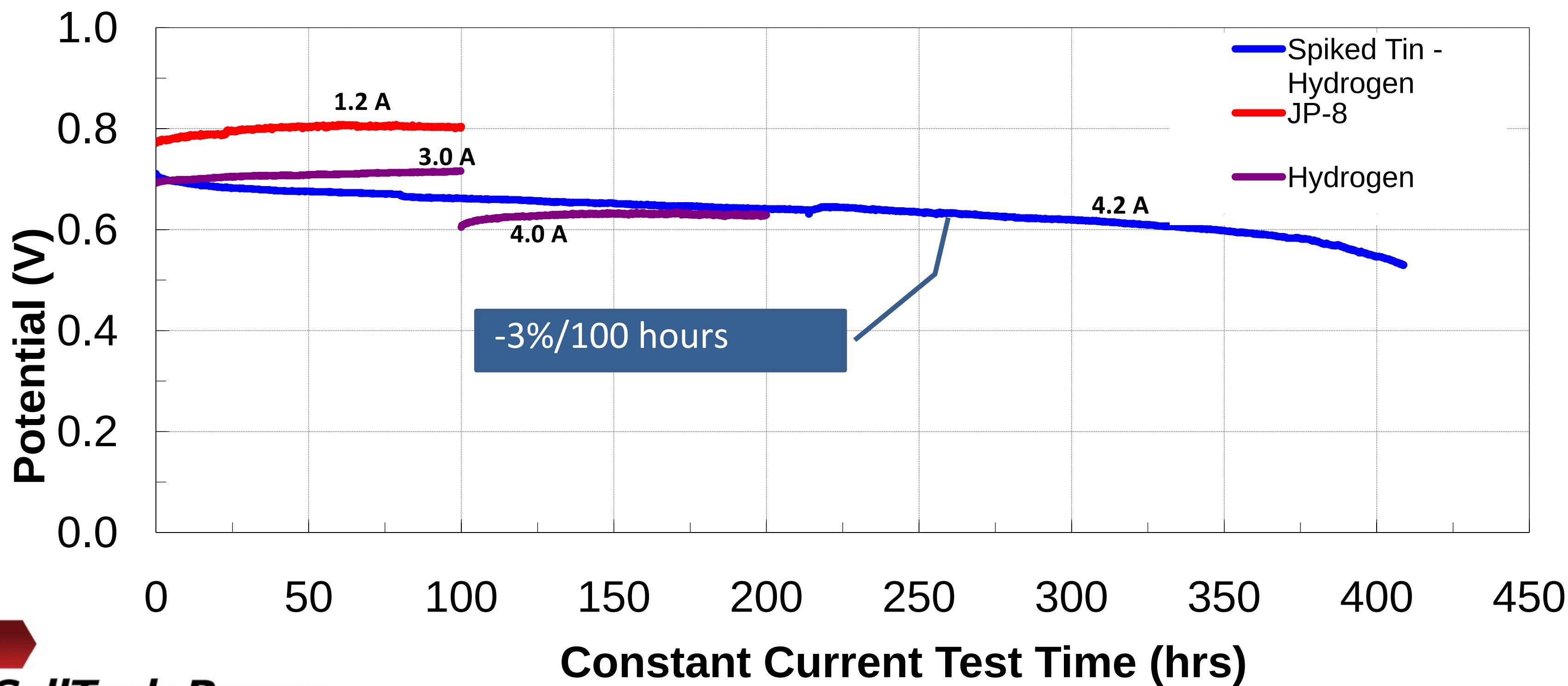
Constant current

<u>Results</u>

Uncontaminated cells: no degradation

Spiked cell: 3% decay per 100 hrs

Electrolyte morphology chgs



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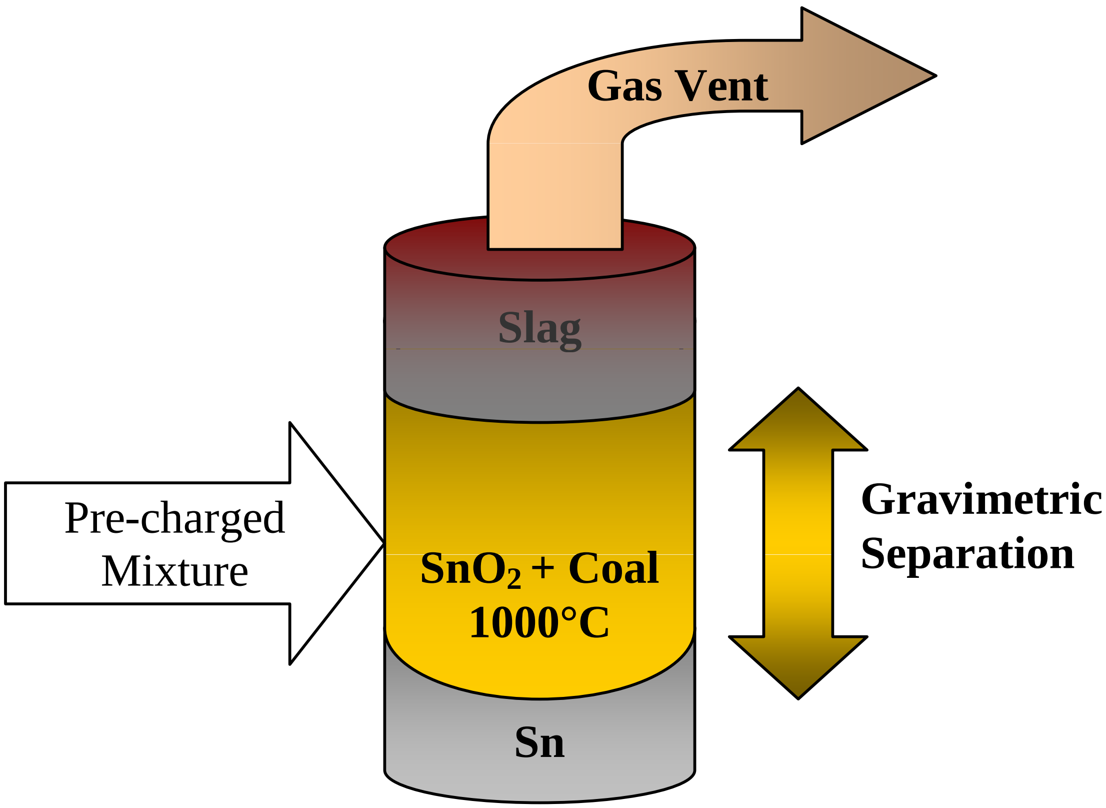
Experimental Evaluation of Contamination Levels



Procedure
Batch mode
Coal in tin reactor 1000° C
Wyoming-DECS 26
Slightly reducing stoich
Coal reacted to completion
GDMS analysis of tin

Results
Arsenic, Selenium present after reaction
All others below detectable limits 10ppb

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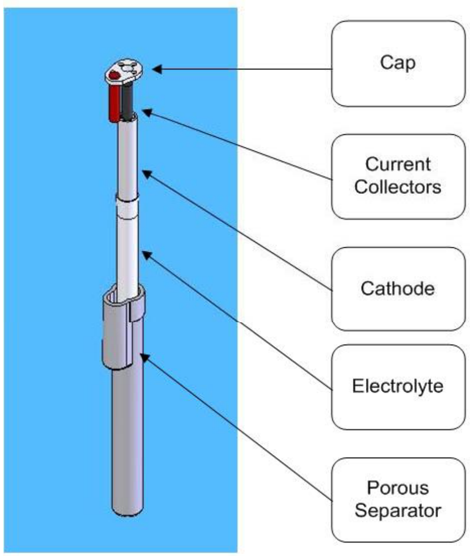
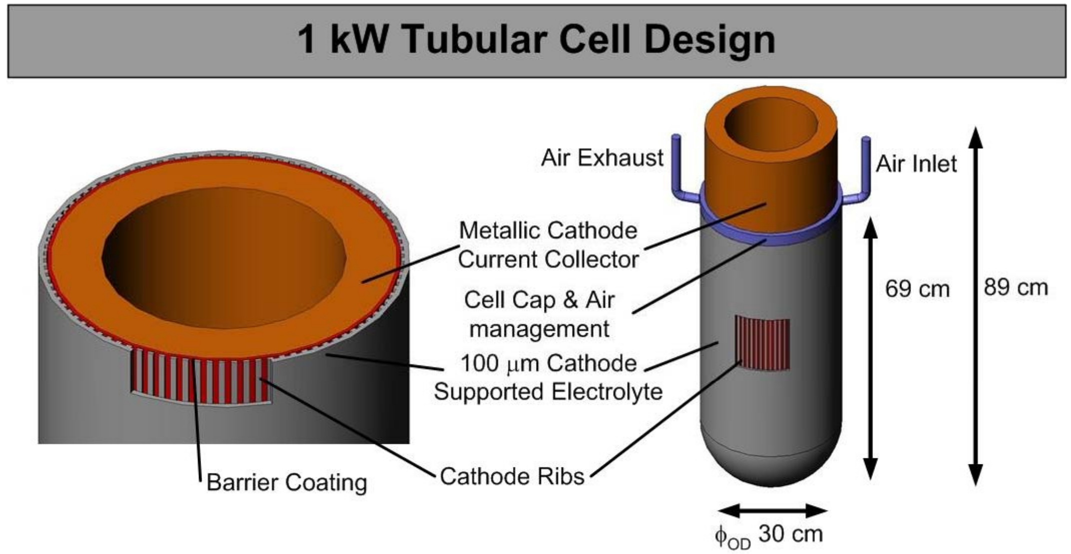
1kW Tubular Design – Similar to Gen 3.1

5 watts on JP-8
12cm x 1.5 cm Ø
Portable Power





46 micro-ohm meets scale-up requirements

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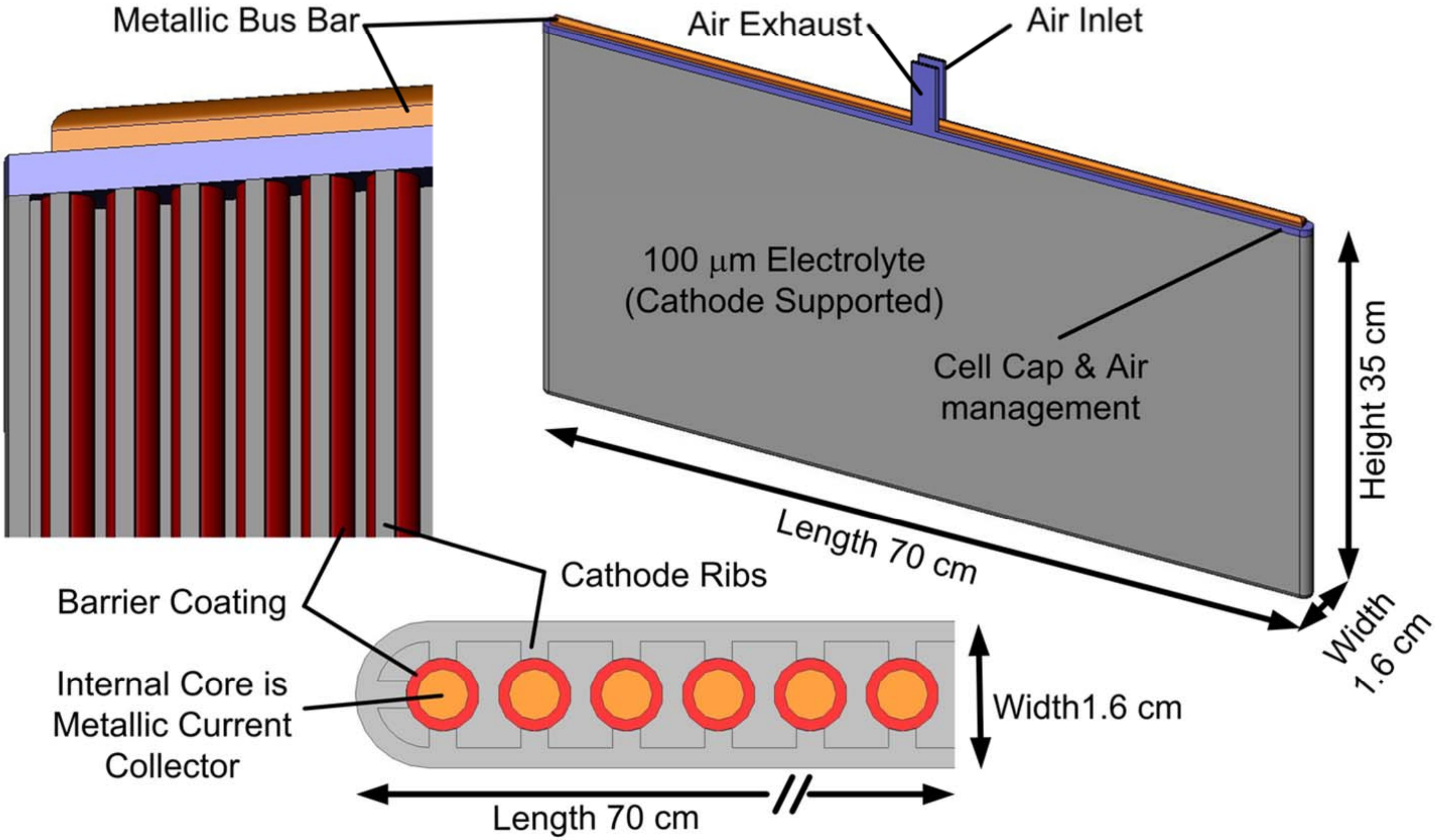
1 kW Flat Tube Cell Design



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Conclusions

- ElectroChemical Looping based on circulating tin anode looks promising
  - 63% efficient
  - Competitive cost
- Coal contamination is major area of concern
- Tin/Coal Reactor acts as a separator and purifier- rejecting contaminants under certain conditons.
- 1 kW cell feasibility study complete

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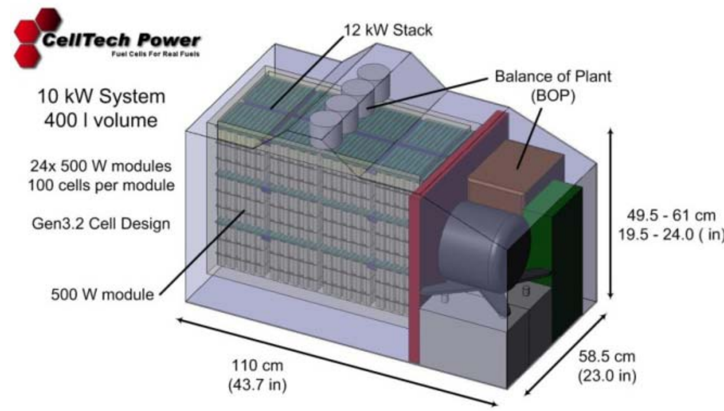
Development Path and Next Steps

- Early Commercialization via small scale
  - Direct JP-8: military power
  - Commercial APU markets



- Parallel development for utility scale
  - Further evaluation of contaminants
  - Longevity testing
  - System integration feasibility study including alternative configurations

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Acknowledgements

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