Cost Modeling of SOFC Technology

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Updates to a 1999 SOFC cost model resulted in less than a ten percent increase in the cost of the stack on a kilowatt basis.

	Total Cost ($/kW)	
Model	Co-Fired	Multi-Fired
1999	90	80
2003	92	87

Drivers for Lower Cost
• Lower YSZ material cost

Drivers for Higher Cost
• More interconnect material • Additional QC steps and equipment • Overall process yield assumptions • Slightly lower power density for the baseline case

For the SECA Core Technology Program (CTP), we up-dated a 1999 SOFC cost projection.

- Cost and performance/mechanical models linked to capture the influence of design, performance, and mechanical limitations on cost
- Assessed the impact of manufacturing issues (e.g., tolerances and quality control) on cost
- Model used to assess the impact of manufacturing volumes on cost

We solicited inputs from the SECA industrial teams and the CTP participants.

The model uses a set of databases to calculate cost for defined production/process flow scenarios.

Inputs
- Design
- Performance Parameters
- Processes and Process Flow
- Production Scenarios

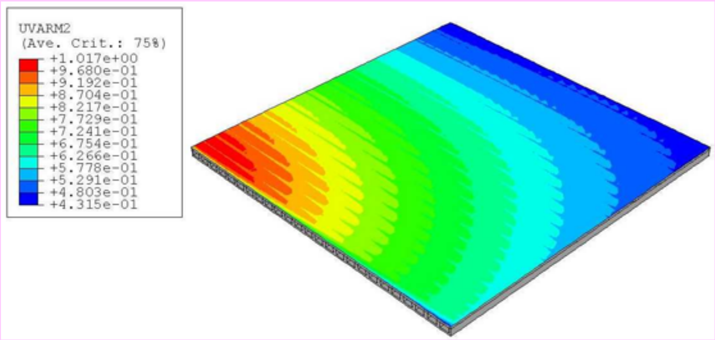
Calculation Engine (Activity-Based)
- Process flow
- Equipment options

Outputs (Results)
- Tables
- Graphs
- Crystal Ball Analyses

Manufacturing Costs	Material Cost Database	Material Properties Database	Purchased Components	Formulation Database	Process Database	Capital Equipment Database
• Labor • Real estate • Overhead . . .	• Vendors • Cost of material . . .	• Density • Particle size distribution • Surface area • Stress vs probability of failure	• Cost • Specifications . . .	• Anode • Cathode • Electrolyte • Interconnects	• Equipment process data • Throughput • Size limit • Automation • Scrap • Yield	• Cost vs. product volume

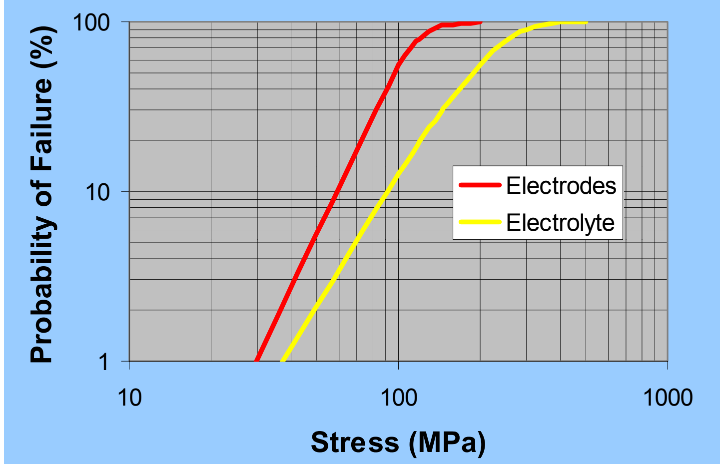
A performance-thermal-mechanical model developed for NETL was used to estimate power density and stress as a function of layer thickness.

Performance Model



+ Stress

Material Failure Data



Parameters from ORNL, Edgar Lara-Curzio

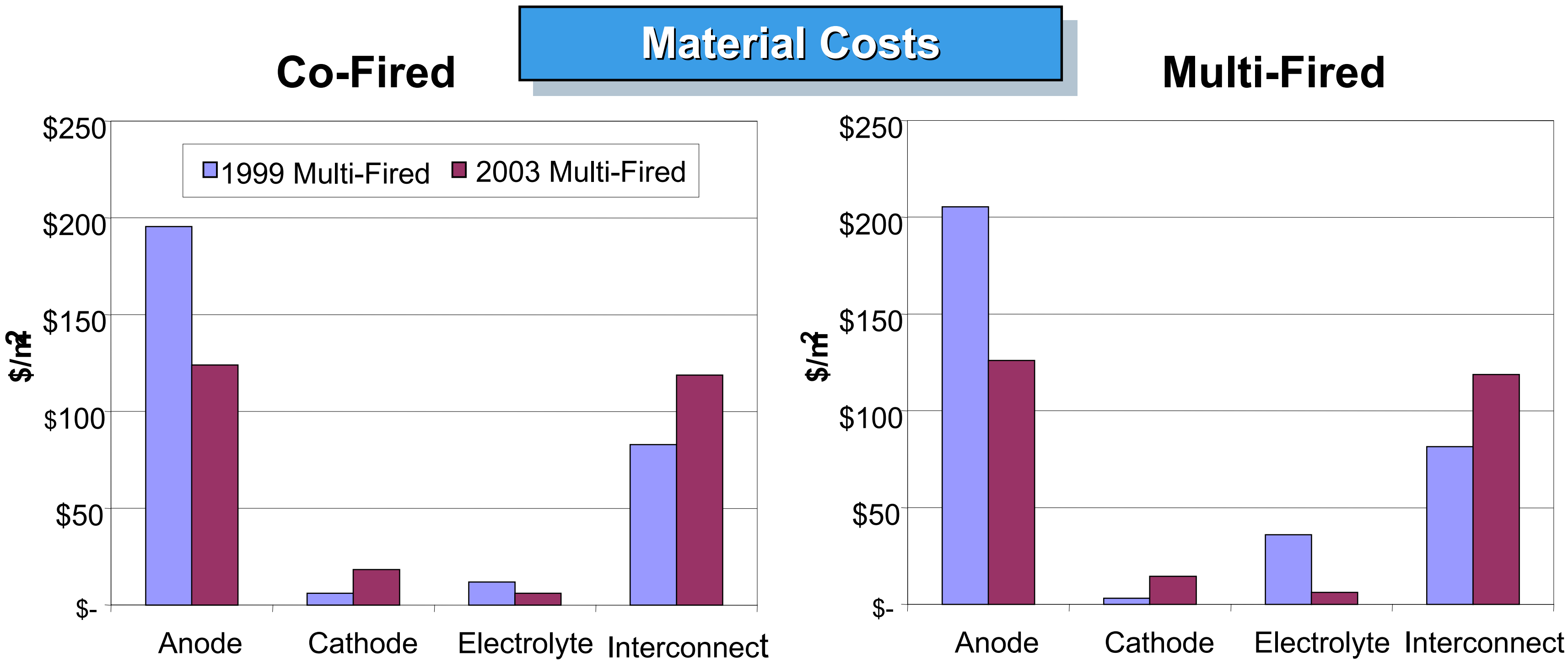
Power Density

Stress Related Yield Losses

The 2010 SECA goals target a system manufacturing cost of $400/kW. This project focused on the stack materials only.

- Only the electrochemical (anode, cathode, and electrolyte) and interconnect materials are considered in this model
  - The interconnect cost does not include a coating
- Factory costs were estimated
  - Corporate overhead, profit, and installation costs were not included
- High volume production was assumed for the baseline cost estimate (total of 250 MW with 5 kW stack as basic unit)

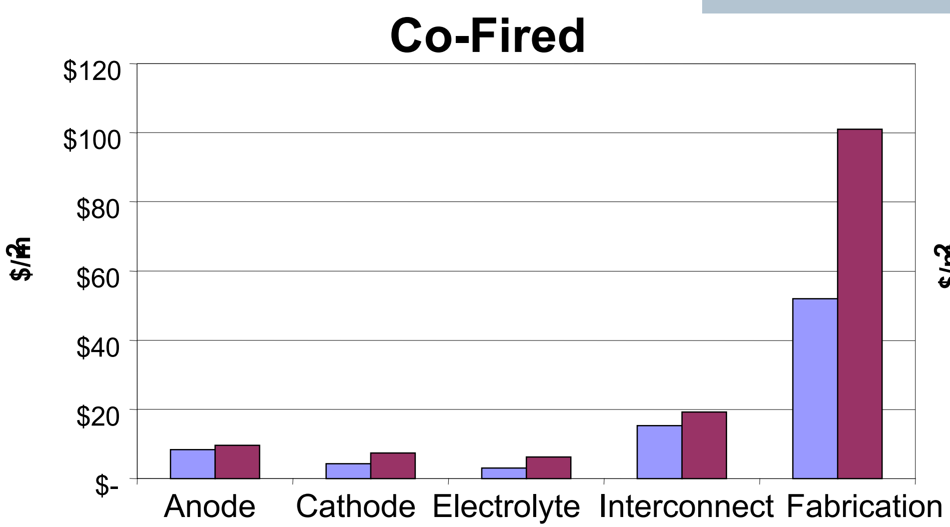
On an area basis, the 2003 model material cost decreased, largely driven by the reduced electrolyte (YSZ) cost.

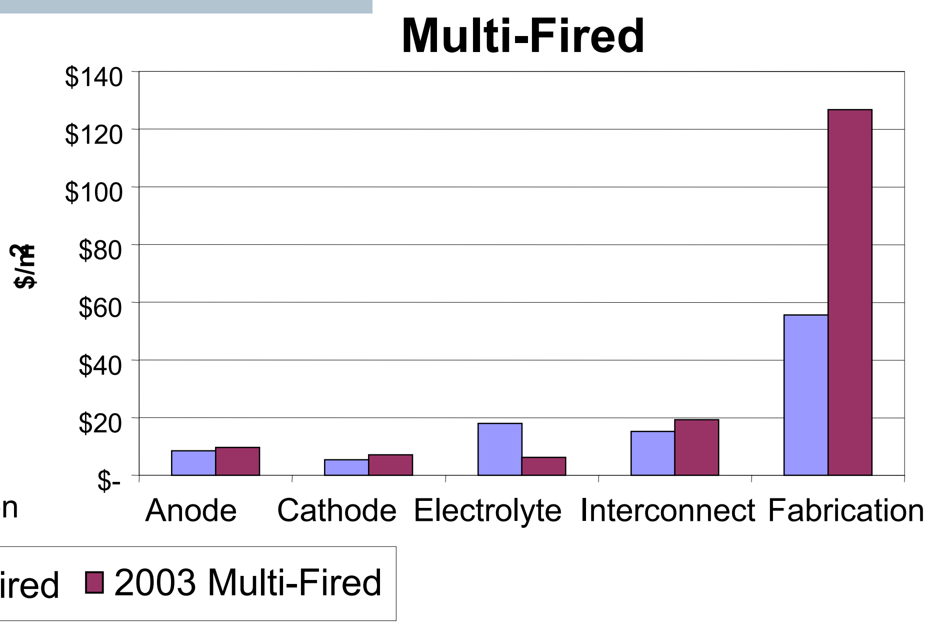


Material Cost ($/m²)	Co-Fired	Multi-Fired
1999 Model	296	326
2003 Model	267	265

Process costs increased by 60-75% because of added QC steps, the final assembly step, and reduced yields.

Process Costs

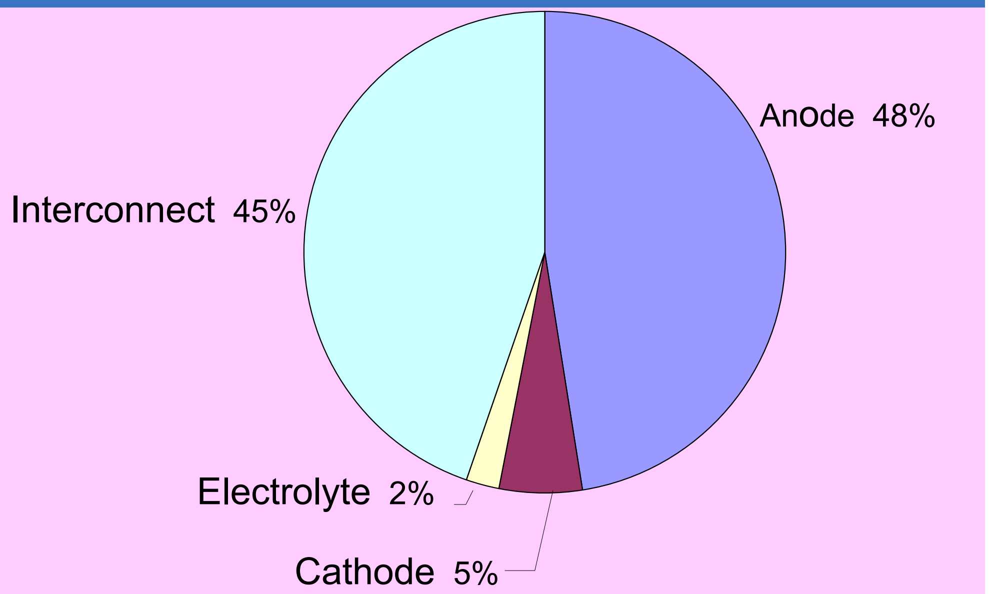




Processes Cost ($/m²)	Co-Fired	Multi-Fired
1999 Model	$82	$103
2003 Model	$143	$169

Anode cost is large because of the materials costs, while the interconnects are massive.

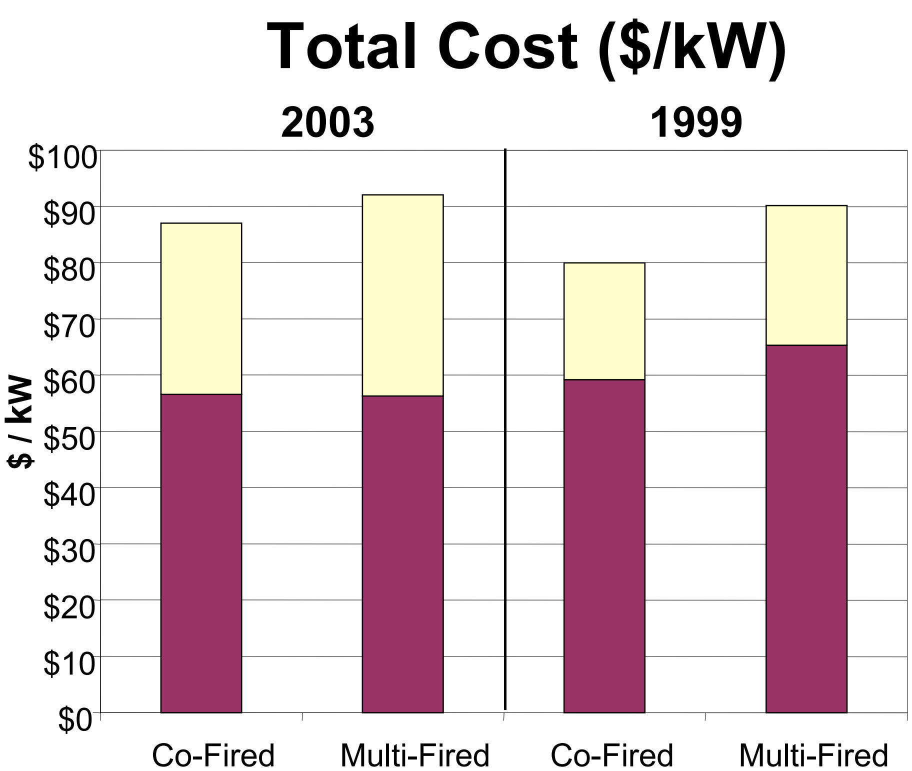
Material cost ($/m²)

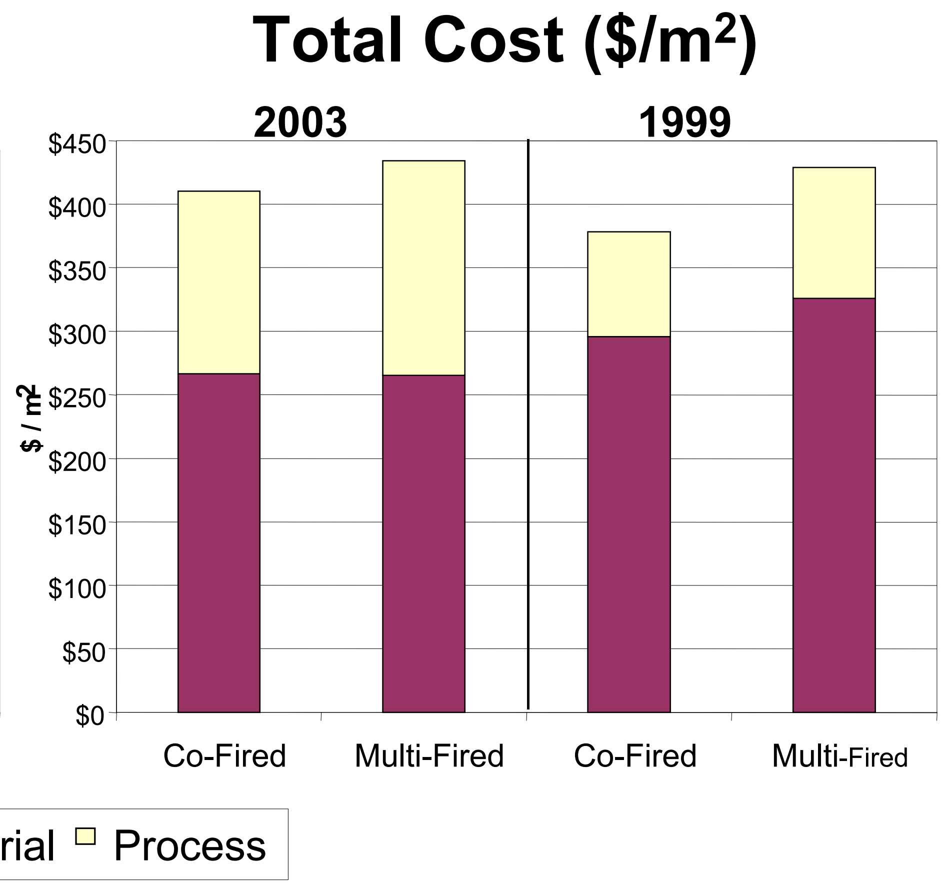


	Cost ($/m²)	
	Materials	Total
Anode	$126	$136
Cathode	$15	$22
Electrolyte	$6	$12
Interconnect	$119	$138
Fabrication		$126
Total	$266	$434

Materials represent approximately 60% of the stack cost.

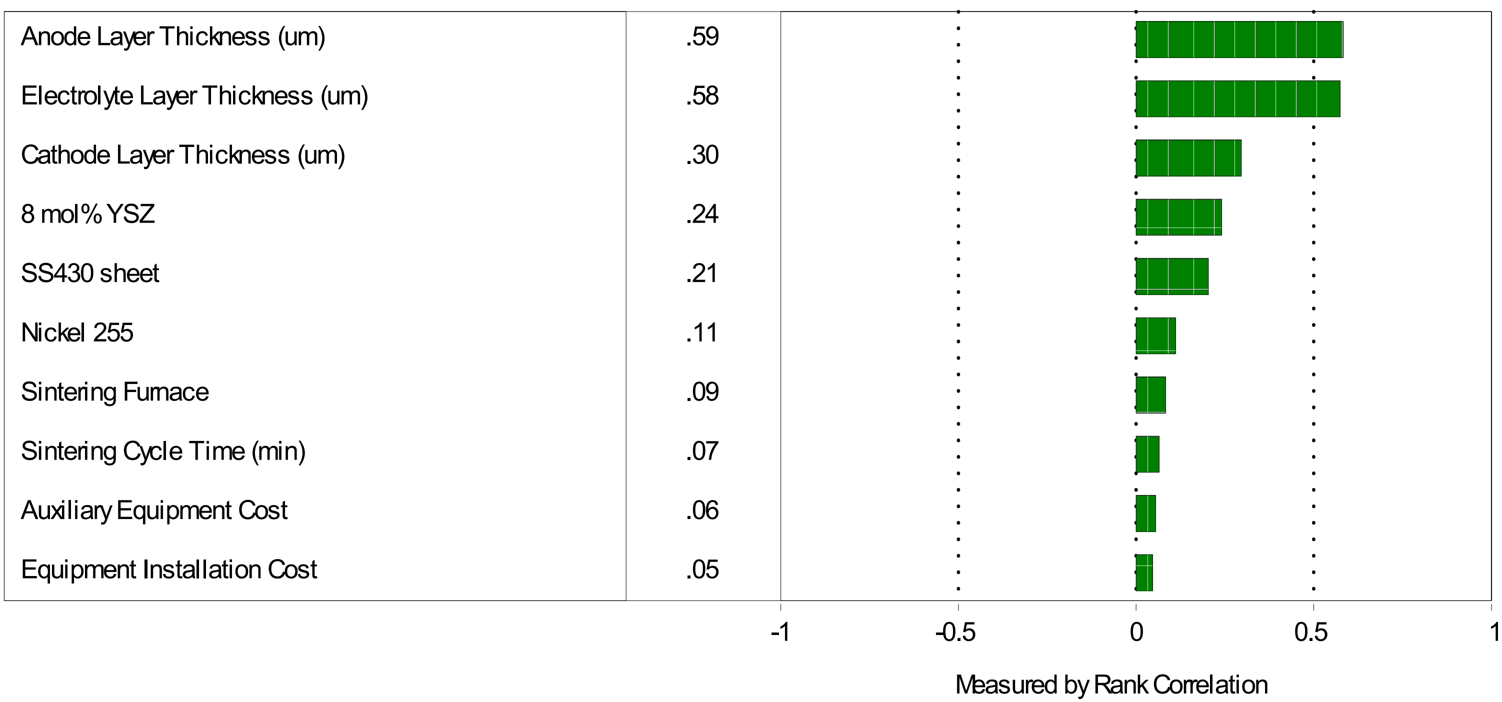
In 2003 lower material costs partially offset the increases in process cost resulting in similar $/kW cost and $/m^2 costs with the previous study.





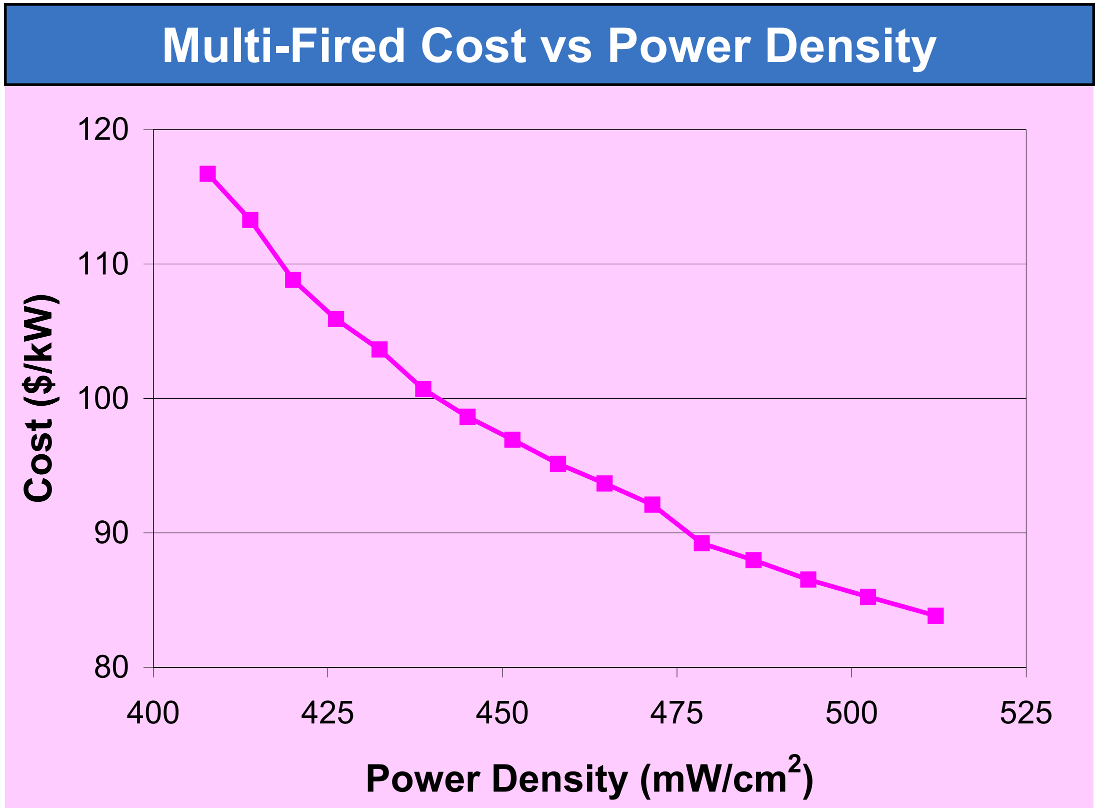
Unit cell cost per kilowatt is most sensitive to the thickness of each EEA layer and YSZ price.

Sensitivity Chart
Target Forecast: Multi-Fired Metal Planar Cost ($/kW)



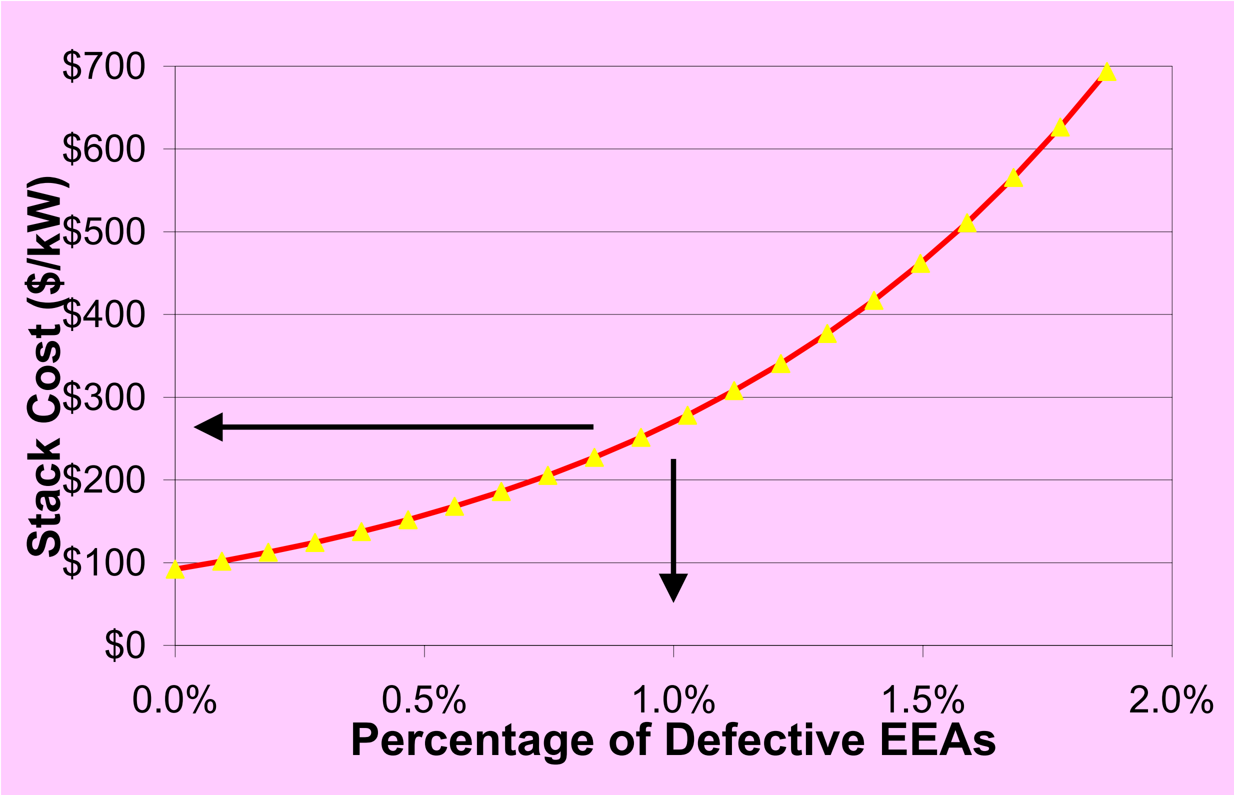
The electrolyte cost is small, but its thickness has a large impact on power density.

Achieving high power densities is critical to lower stack costs.



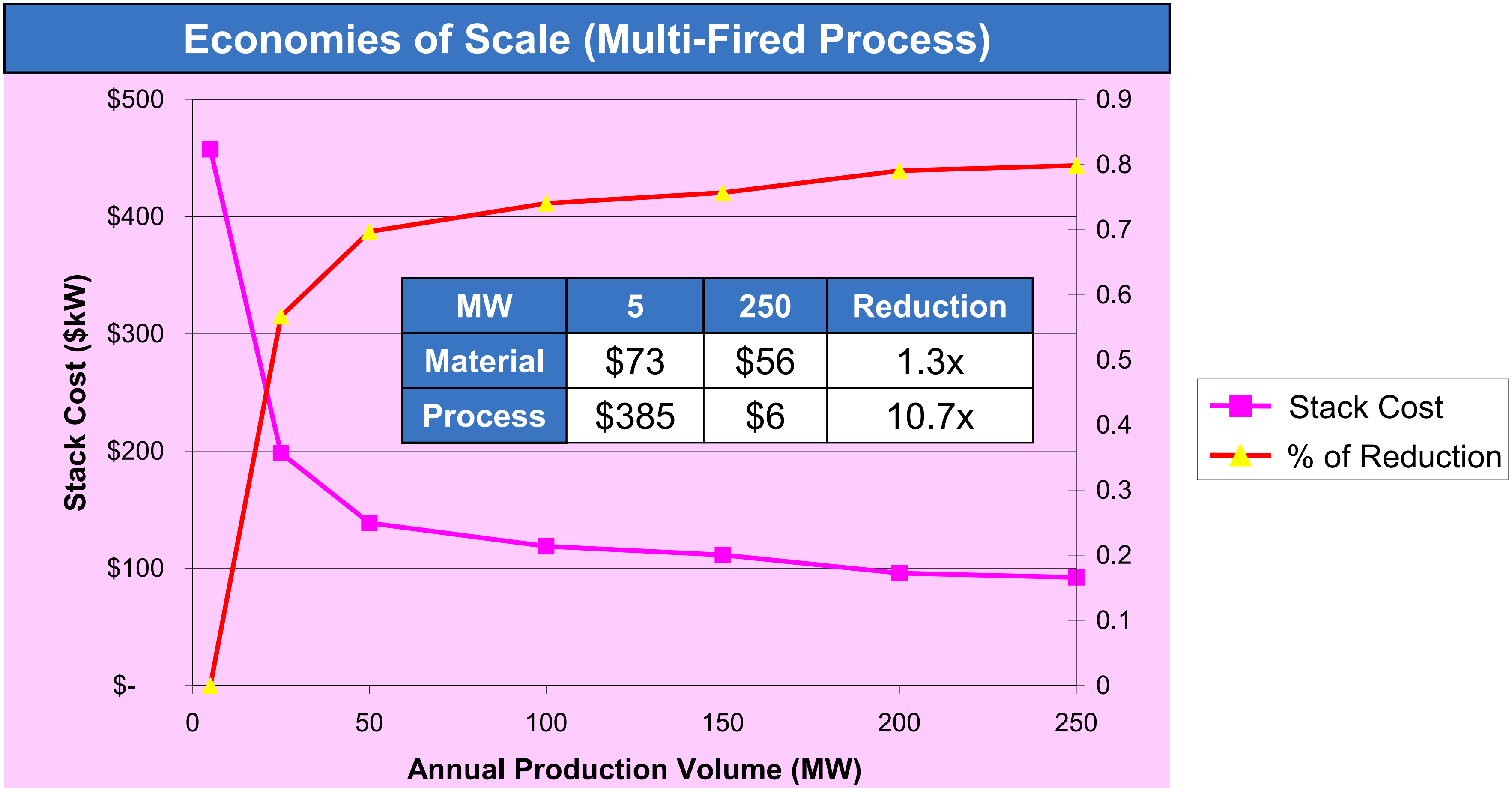
	Layer Thickness (μm)	Status
Anode	700	Fixed
Cathode	50	Fixed
Electrolyte	5~20	Vary

Assembled stack cost will be highly sensitive to the percentage of defective EEAs.



For example, for the MF process, a 1% defect level could increase the stack cost from $92/kW to $278/kW.

The stack cost decreases by 80%, driven by more efficient processing, as production volume increases.



MW	5	250	Reduction
Material	$73	$56	1.3x
Process	$385	$6	10.7x

Conclusions

- Increasing power density will be critical to achievement of low stack cost since materials represent approximately 60% of the cost.
- Quality control of the repeat units (electrode electrolyte assemblies) will be critical to stack yield and cost.
- Increasing production volume 50-fold from 5MW to 250MW decreased process costs resulting in an 80% reduction in stack cost.

Thank You!

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  - Final Report available in April
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