The Impact of Scale-Up and Production Volume on SOFC Stack Cost

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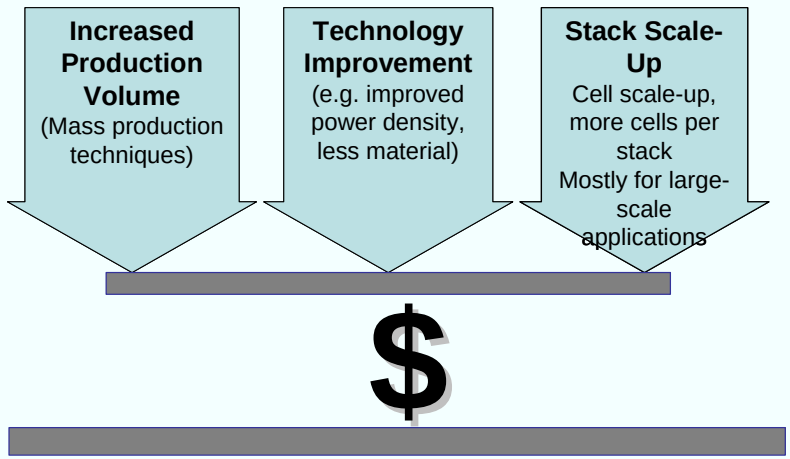
Background & Objective

Meeting SECA cost targets for SOFC will require technology improvement, mass production, and possibly scale-up.

- Achieving SECA SOFC cost targets ($400/kW) is critical for market success
- Previous studies quantified the impacts of technology improvements



- Impact of production volume and scale-up hadn't been quantified

The objective of this study was to quantify the impacts of production volume and stack scale-up on SOFC cost

Model Structure and Assumptions

Ceramic Cells + Interconnects		Balance of Stack		Assembly		Manufactured Cost
• Materials • Fabrication • Includes Seals	+	• Compression • Electrical Leads • Manifolds • Vessel • Insulation	+	• Assembly • Conditioning • QC	=	Excludes: • R&D • Sales &Marketing • General overhead • Shipping

Key Costing Assumptions

- Production volume: 250 MW/yr
- Capital charge rate: 15% of installed capital
- Auxiliary equipment, installation factors: 80%
- Maintenance cost: 4% of installed capital
- 3 shifts per day
- Manufacturing losses depend on cell geometry and size

Materials Cost (1 ton/yr)[1]

Ni-YSZ	$14/kg
YSZ	$12 / $25/kg[2]
LSM	$25/kg[1]
LSCo / LSCF	$36/kg
Ferritic Stainless[3]	$5/kg

1 Based on DOE and J. Thijssen, LLC estimates
2 For >1µm and <1µm average particle size respectively
3 Uncoated, e.g. Crofer 22 APU

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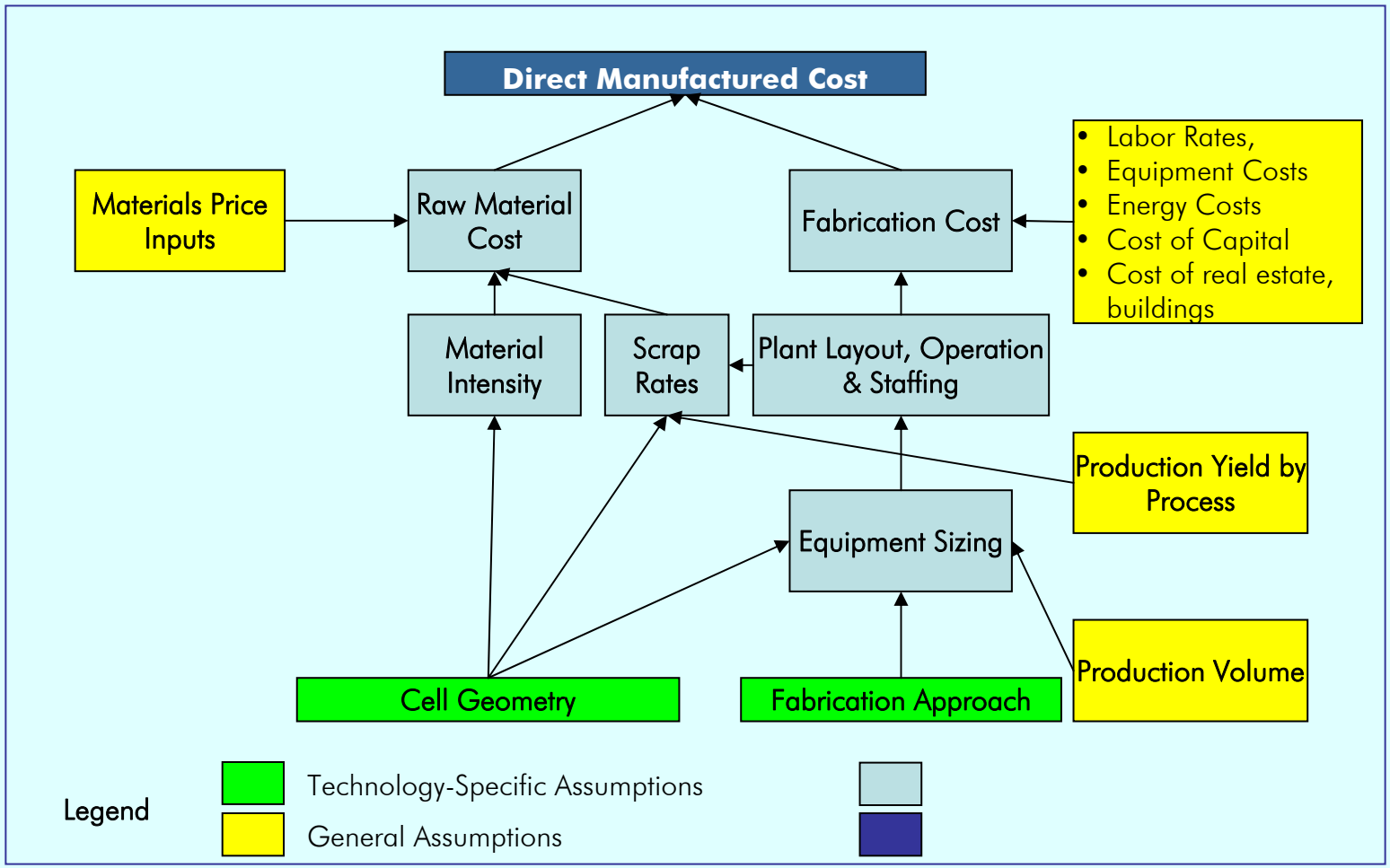
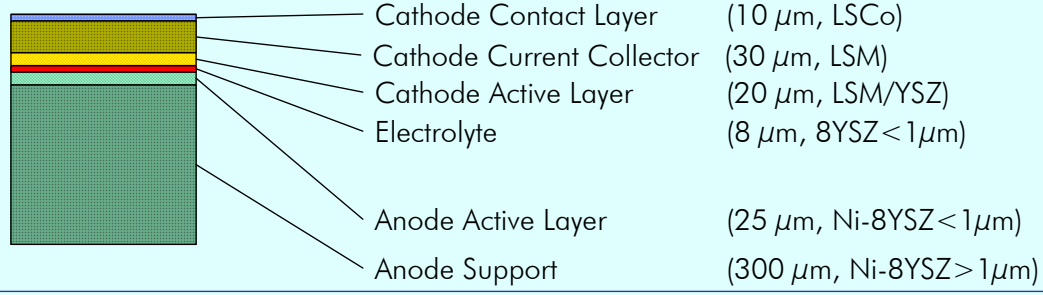
Detailed Manufacturing Analysis Cells & Interconnects

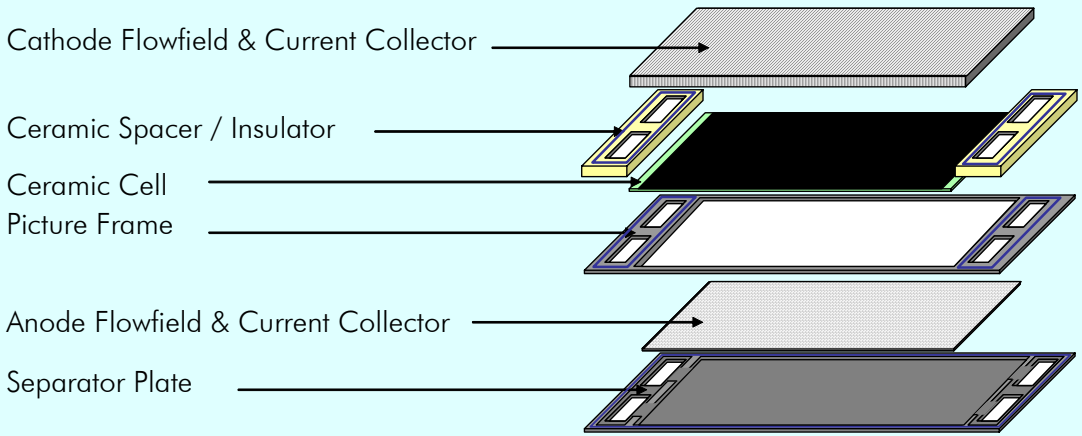


Cell, Stack, and Scale-Up Assumptions[1]

Ceramic Cell Layer Structure



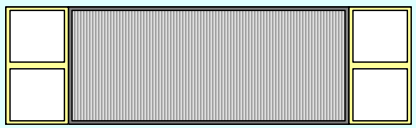
Unit Cell Structure

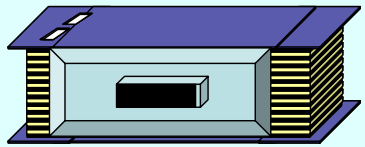


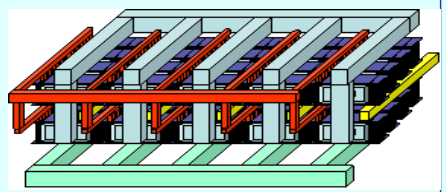
1 Stacks based on planar, rectangular cells shown here; the study assessed three other stack technologies

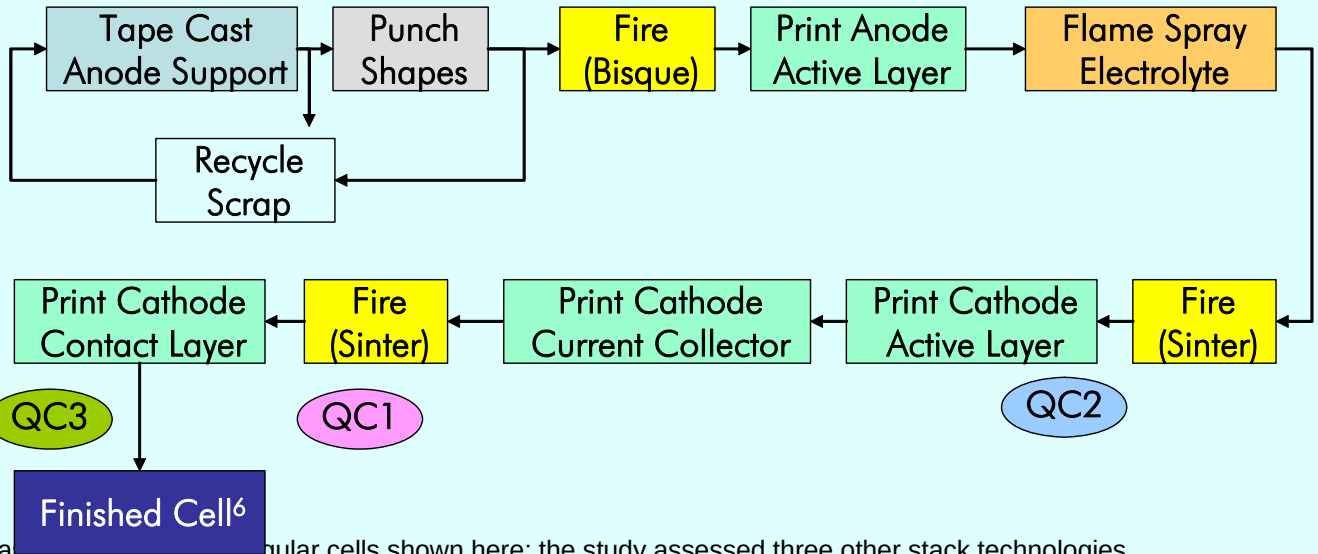
Modular Stack Scale-Up and Manufacturing Approach

Unit Cell	Stack Module	Stack
1800 cm^2 (92% active) 834 W @ 0.7V	60 Unit Cells 50 kW @ 42V	40 Stack Modules 2 MW @ up to 1680V





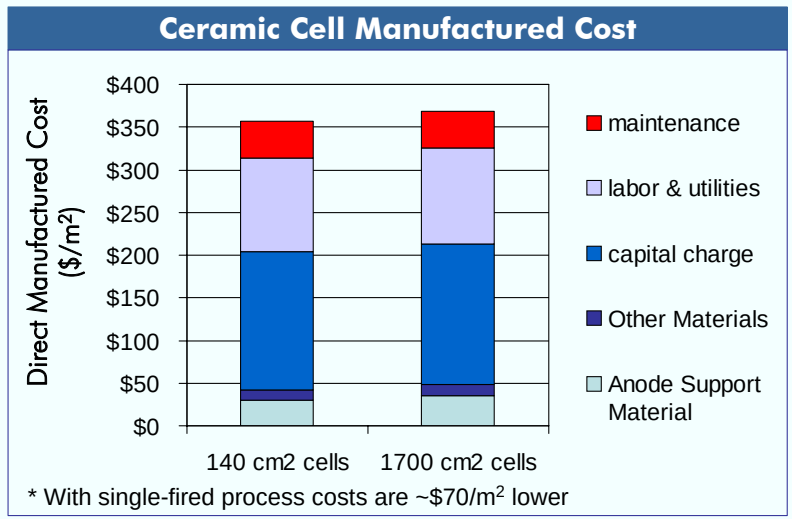




1 Stacks based on planar, rectangular cells shown here; the study assessed three other stack technologies

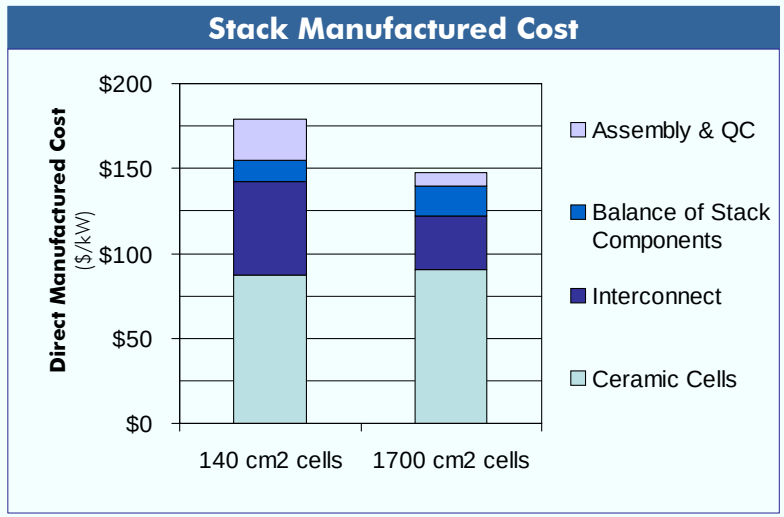
Anode material and fabrication dominate ceramic cell baseline cost

- Anode material, capital, and labor & utilities costs are the main ceramic cell cost components
- Based on ~400 mW/cm^2 peak power the cost of cells is around $90/kW
- Scale-up from 140 to 1700 cm^2 cells:
  - Active cell area increases from 84% to 95% in scale
  - Increased manufacturing losses offset gain (Assuming same # of defects per unit area)



Ceramic cell anode material and fabrication dominate overall baseline stack cost*

- Ceramic cell cost dominates stack cost, though interconnect and stack conditioning & QC also contribute significantly
- Based on 400 mW/cm^2 active area stack cost are around $180 per kW for small cells (current state-of-the-art)
- At the stack level, cell scale-up provides advantages:
  - Cell cost increases slightly
  - Cost of QC, IC, and BOS strongly reduced
- This supports system costs of $400 - $600/kW

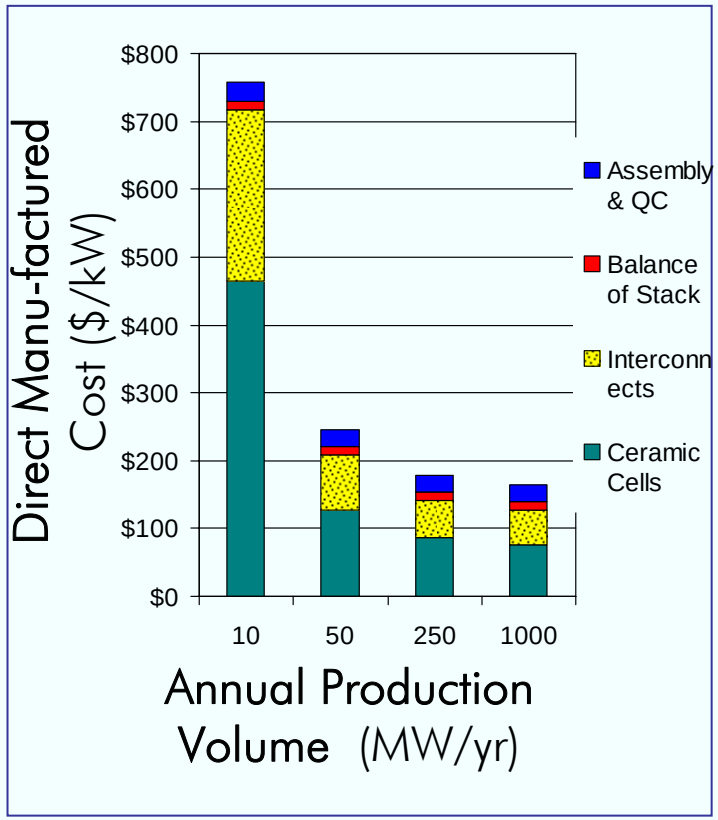


* Stack insulation and manifolding are not included

Impact of Production Volume

Production volume has a critical impact on SOFC stack cost, especially if production volume is lower than 50MW/yr

- At low volume, fixed costs are high due to poor utilization of capital and labor:
  - Affects mostly ceramic cell and IC
  - BoS can be outsourced and QC requires many parallel units, even at low production volume
- Above 50-100 MW, the benefit of production volume increase diminishes as equipment scale-up and utilization are mostly optimized



Conclusions

High production volume cuts SOFC stack cost more effectively than scale-up

- The study suggests that the manufactured cost of planar anode-supported SOFC will likely be below $200 per kW in high volume production
- If production volumes are lower than 50 MW/yr (vs 250 MW/yr) stack cost may be more than $750/kW
- Cell scale-up has the potential to reduce stack cost by ~25%

Acknowledgements &References

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