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Techno-Economic Analysis of SOFC-TE Hybrid Power Generation Systems

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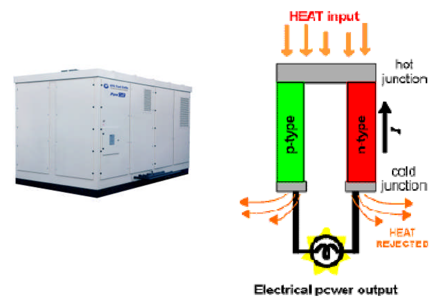
Introduction and Background



Goal:

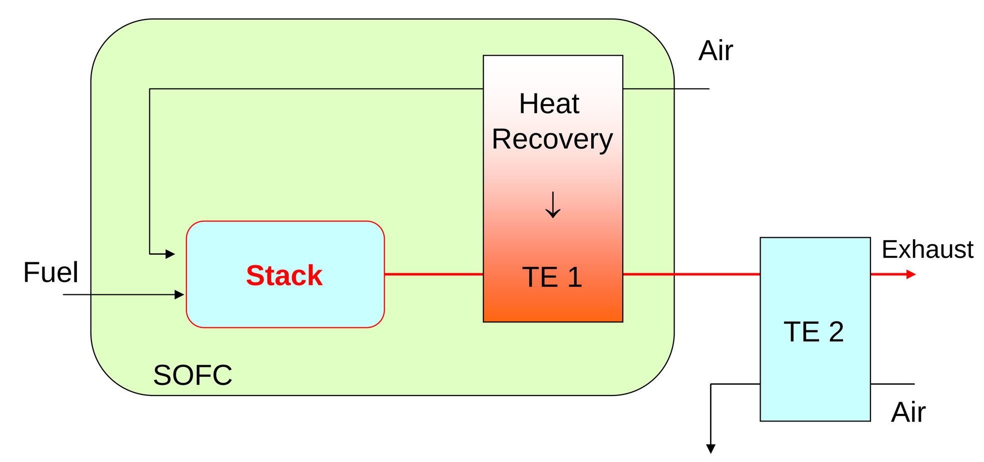
- Combine TE and SOFC
- Net power Efficiency: ≥ 65%
- Factory Cost: ≤ $400/kW
- Life: 10 years/40,000 hours

Scope:

- Application: 200 kW Plant in the year 2011
- Number of units/year: 2.5GW market (Unit size: 5-200 kW)
- Fuel: Coal gas

Baseline system

- Simple, ambient pressure, standalone 10kW SOFC
- Efficiency: 45%
- $400/kW (SECA, Phase III goal, 2011)
- No reformer, no sulfur trap
- With cathode recirculation
- Anode recycle



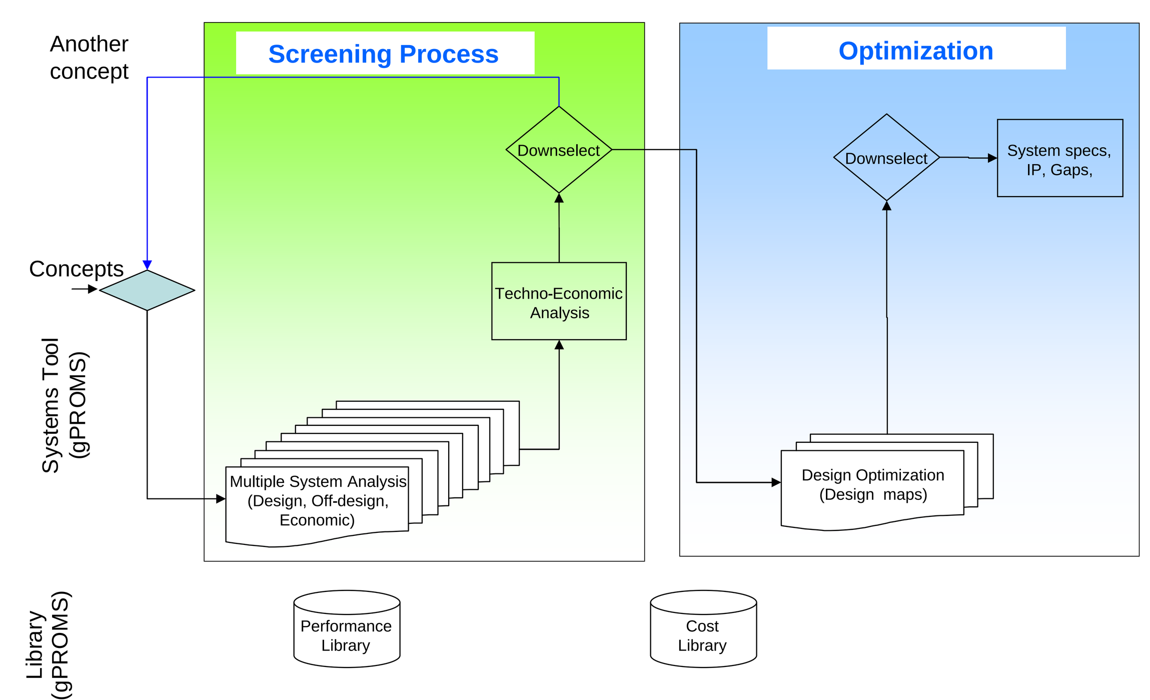
Specific Objectives:

- To understand the factors affecting the system performance and cost
- To find the best system integration concept for SOFC-TE
- To create development strategy for the identified system concept

Approach

- Generate system integration concepts
  - *Different configurations to combine SOFC and TE*
  - *Trade-off between component performance and cost*
- Benchmark thermoelectric materials for system integration
  - *Identify TE materials potentially used for the hybrid system*
- Develop modeling tools to analyze system performance and cost
  - *Lumped modeling of major component physics*
  - *Cost modeling as a function of component size and sales volume*
- Down-select the best system concept
  - *Use system efficiency and cost as the down-selection criteria*
- Identify the barriers and enablers for developing the best concept

SOFC-TE Modeling Tools and Process



Cost Models:

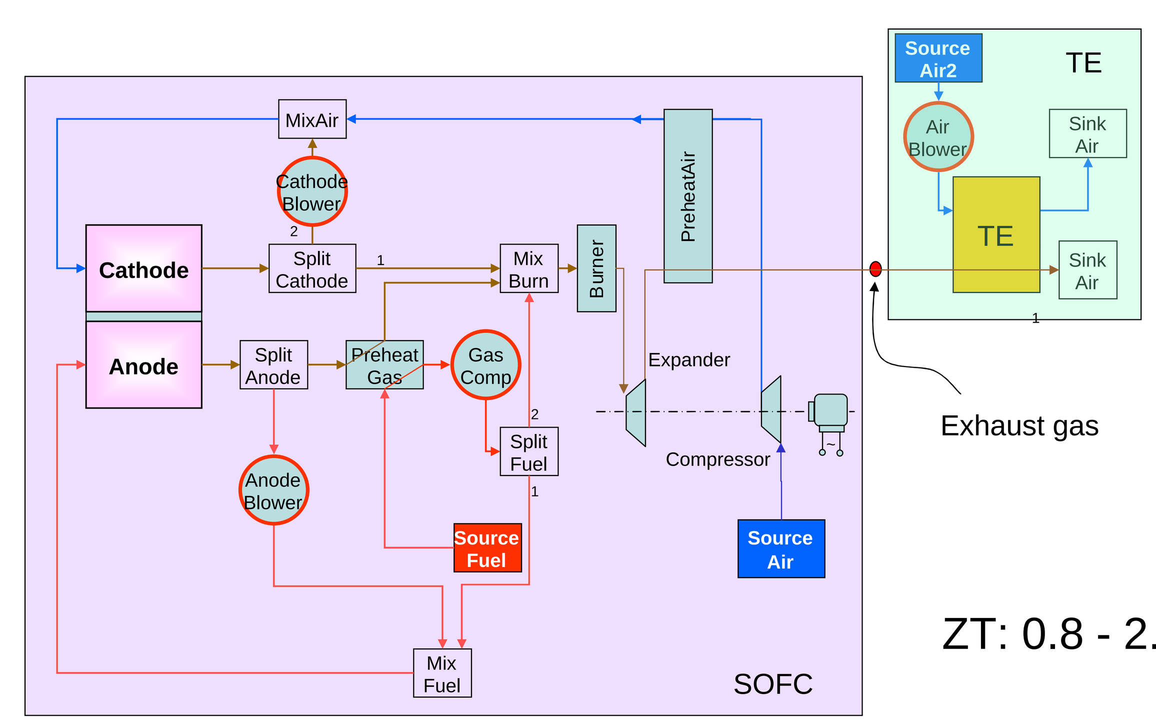
- SOFC-CHP cost modeling equations used as baseline
- Calibrated to match the published cost data from DOE (ADL report)
- Considered volume effect to non-generic components such as turbine
- PCS cost regression based on solar PV PCS cost and size data

No	Component	Equation	Scale Var	Unit	Life	Production Volume	Note
1	Stack (SOFC)	$=0.35P(28.18(N_cell/P)+120.4)*((290.94-30.198*LOG(P))/130)*(	DC pow	kW	5	2.5GW total capacity	
2	Turbine	$=272*(P/1.3)^0.95*(Vol/Vol0)^(-0.1278)	Shaft pow	kW	5	50000 for 5kW SOFC	1
3	Air compressor	$=60*(vdot/27.75)^0.703	vdot	CFM	3		2,3
4	Cathode Blower	$=100*(vdot/27.75)^0.703	vdot	CFM	2.5		3
5	Anode Blower	$=100*(vdot/27.75)^0.703	vdot	CFM	2.5		3
6	Pressure vessel	$=5P(P/200)^(-.25)*(Vol/Vol0)^(-0.1278)*((PR-1)^0.5	P, PR	kW/1	3	50000 for 5kW SOFC	
7	Air preheater	$=158*(Mdot/0.028)	Mdot	kg/s	5		3
8	PCS	$=(290.94-30.198*LOG(P)) *P	AC pow	kW	5		4
9	BOP	$=85*P/5.6	DC pow	kW	10	50000 for 5kW SOFC	
10	Insulation	$=54*P/5.6	DC pow	kW	10	50000 for 5kW SOFC	
11	Burner	$=42*(Mdot/0.028)^0.55;	Mdot	kg/s	5	50000 for 5kW SOFC	
12	TE blower	$=60*(vdot/27.75)^0.703					3
13	TE	$=($TE_mat+TE_hot+TE_cold+$TE_ass)*(1+overhead_ratio)	weight	kg	20		5

*: For the notes, please see the Cost Modeling Additional Notes in the Backup Slides

Results

Best Concept: SOFC + 1TE + 2 Compressors



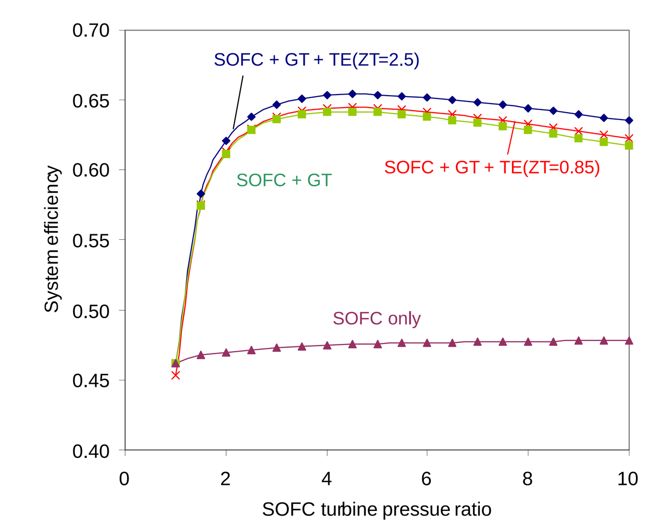
ZT: 0.8 - 2.5

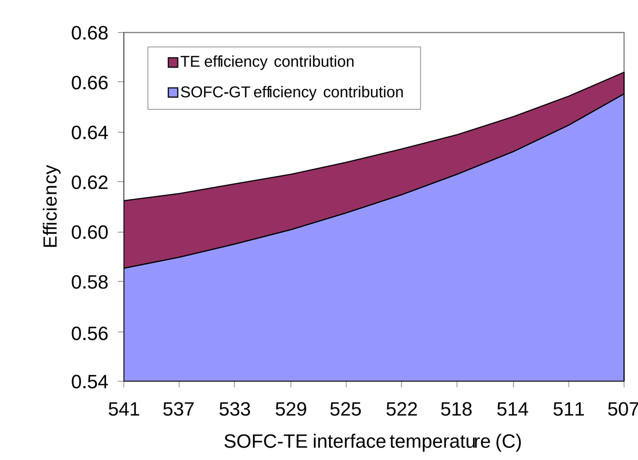
Air preheater: another TE potentially

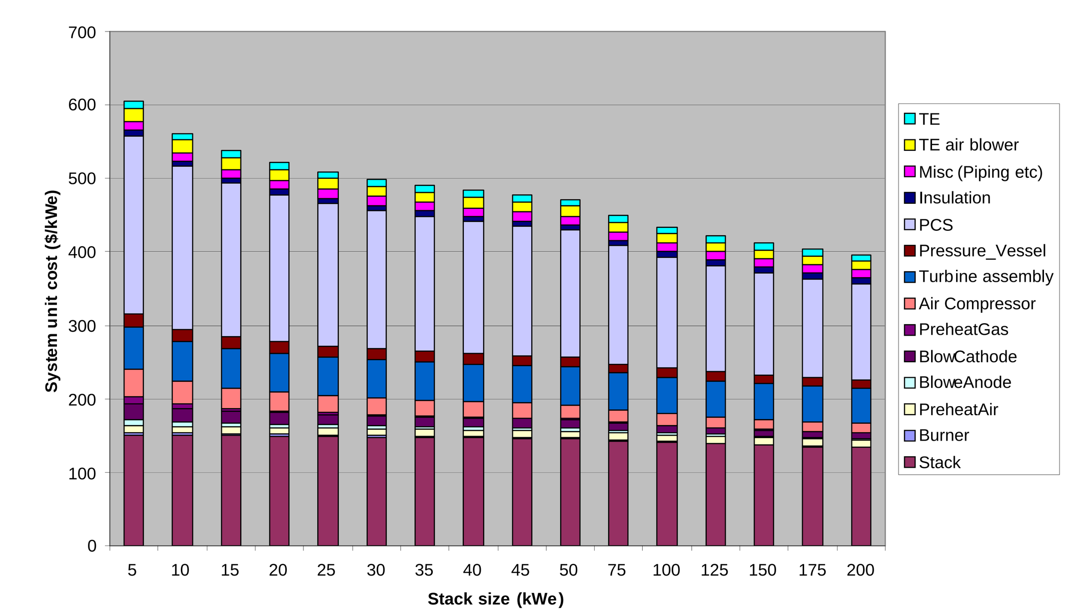
- Cold inlet: after air compressor
- Hot inlet: after expansion

➔ Limited power generation

System Performance:







Future Development

	Ambient Pres SOFC-TE	Pressurized SOFC-TE
Application	Commercial / small SOFC	Large utility power generation
Major advantages	Heat recovery and flexibility	High efficiency
System efficiency	51%	65%
TE efficiency addition	6% point	1% point
No. of TE generators	2	1
CHP Potential	Yes	No

Conclusions

- To meet the 65% efficiency and $400/kWe cost target, a pressurized SOFC-TE is identified as the best system
- The best system pressure ratio is approximately 4.0
- TE contributes approximately 1-2% of system efficiency in the optimal SOFC-TE configurations
- Optimal SOFC-TE system provides little CHP potential due to limited waste heat
- TE has better value as a bottoming cycle generation device for small size (200kW and below) and ambient pressure SOFC.
- Ambient system is also better for CHP