Report back

Technology specific:

Fuel Cells (home scale)

June 2, 2011

ARPA-E strawman for single family systems

Category	ARPA-E's proposed
System rating	7 kWe
Electrical efficiency (@ ≥50% kW rating)	≥ 50%
Cost	$10k CAPEX @ 10,000 units per year
Lifetime	>7yrs

Life-cycle cost + emissions is the critical metric.
Shouldn't assume that efficiency is a proxy for cost.

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Cost Drivers

Major Sources of Costs	Knob
System Design	Reducing complexity (removing components)
Fuel Processor	Not major cost driver
Stack	Manufacturing (enable high throughput) • spray • layer deposition Materials • SOFCs (no ceramics) • Intermediate T (no precious metals) • low T PEM (no carbon to reduce corrosion)
BOP	•Can be addressed with economies of scale (not discussed much)

Operating Temperature


- Are intermediate temperature fuel cells really a pathway towards lower cost?
  - What would be the ideal temperature and why?
  - What effect would this temperature range have on efficiency?

- Does it make more sense to explore bringing the temperature of high temperature fuel cells down, or bringing the temperature of low temperature fuel cells up?

Temperature Range	Advantages/Disadvantages
>250 deg C	• Cheaper materials • No water management • A lot of white space (new electrolytes) • Less clean up than PEM (still need reformer)
~400 deg C	• Chance of reaching 50% efficiency target (not sure how – ZK) • New materials (pyrex supports)
500-600 deg C	• Addresses BOP issues • Need external reformer (all systems below 650C) • Oxidation and carbon removal • Big white space for SOFC
600-700 deg C	• Below coking temperature • Can oxidize CO • Still some materials issues

Impact and Risk

Potential "knobs" to reduce cost (Life cycle cost +emissions)	Impact rank	Risk rank
Radical system design/optimization	High	High
Manufacturing Innovation • Plasma spray • Multilayer deposition	High	Moderate-High
Stack	High	Higher
Materials innovation • Electrolyte • Catalysts and supports • Interconnects	High	High
Fuel processor	Low	Low
PV/hybrid		

Can we do enough to move the needle?

What can be done in fuel cells with a 3yr $30M program?

- Manufacturing
  - Plasma spray
  - Multilayer deposition
- Radically new system design
- Stack
  - zero Pt with novel electrolyte (2-3 kW stack possible with right catalyst)
  - nm scale/Si substrate (SOFC single cell or 2/3 cell stack)

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Fuel Cells (community scale)

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High-level points

- $1500/kWe should be installation price to consumer. ARPA-E should specify some standard profit margin, so cost to manufacture would really be something like $750-800/kWe
- This represents a 3-4x decrease in cost from where SOFCs are today
- 60% efficiencies have been demonstrated at beginning of life. Degradation rate is about 10%, so you would design for initial efficiency that is higher than the rating
- However, efficiency isn't everything. Would be better to focus on lower cost to get people to adopt.
- Do not over define specs, including temperature. State what the targets are and let people give you their best ideas. There are many tradeoffs, and they should think about the integrated system as much as possible.
- Each company is going down a well-defined "stream." Having the ability to explore ideas off-stream via ARPA-E would be valuable.

Bridging the 3-4x cost gap

Innovation	Notes
Reduce size of the stack (same power)	Need new architectures. W/cm^2 is common metric, but really should be W/lb or W/cm^3. A really good design could lead to a standard “box,” which would further reduce cost.
Reduce temperature to enable cheaper materials	Moving from 700 to 600 C would allow cheaper steels to be used. Need to balance lower temperatures with reformer requirements.
Advanced design for manufacturing	One-step forming, one-step firing. Or some new spraying technique that does it all at once. Also need powder manufacturing infrastructure
Increase stack lifetime	60k hours is a challenge. Some think 10 year goal (80k) plus is a good one. Microstructural degradation of electrolyte is big contribution
Volume manufacturing	Important, but not ARPA-E play

Getting a little wild & crazy

Innovation	Notes
Integrate parts of BOS into the stack (fuel cell acts like circuit element)	Can already do this for reforming, what about inverters? Could make each cell look like AC: either pulse fuel or switch b/w anode and cathode. Could also put a FET on each cell to integrate electronics.
High temperature proton conductors	You avoid making water on the anode side, but stability is a problem.
Nanofiber (not nanotube) supported catalysts	Increase surface area and lowers pressure drop. Could be useful for pre-reformer or anode makeup.