Breaking the Fuel Cell Cost Barrier

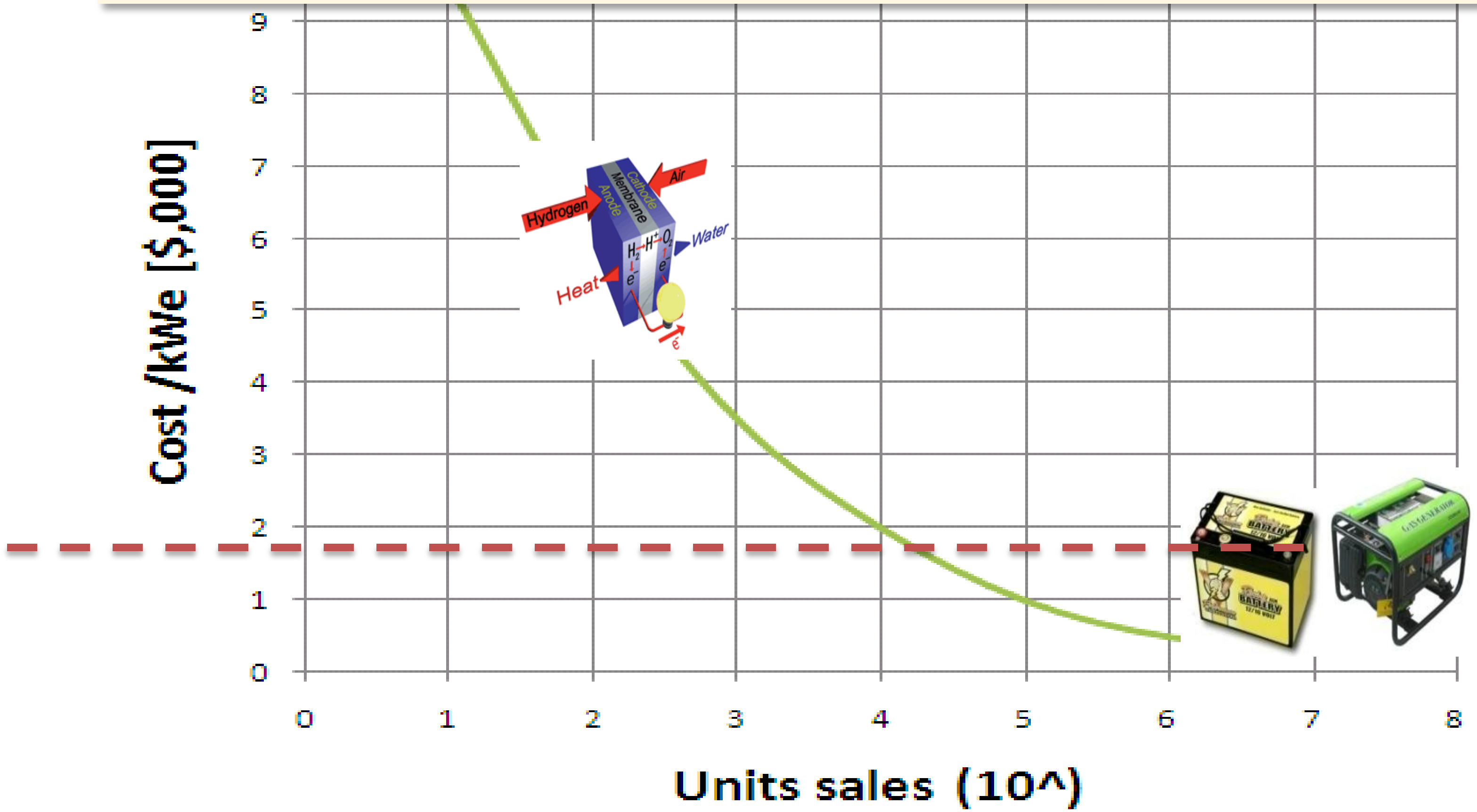
AMFC Workshop

May 8th, 2011, Arlington, VA

Shimshon Gottesfeld, CTO

The Fuel Cell Cost Challenge

CellEra's goal – achieve price parity with incumbents
earlier on in market entry process !



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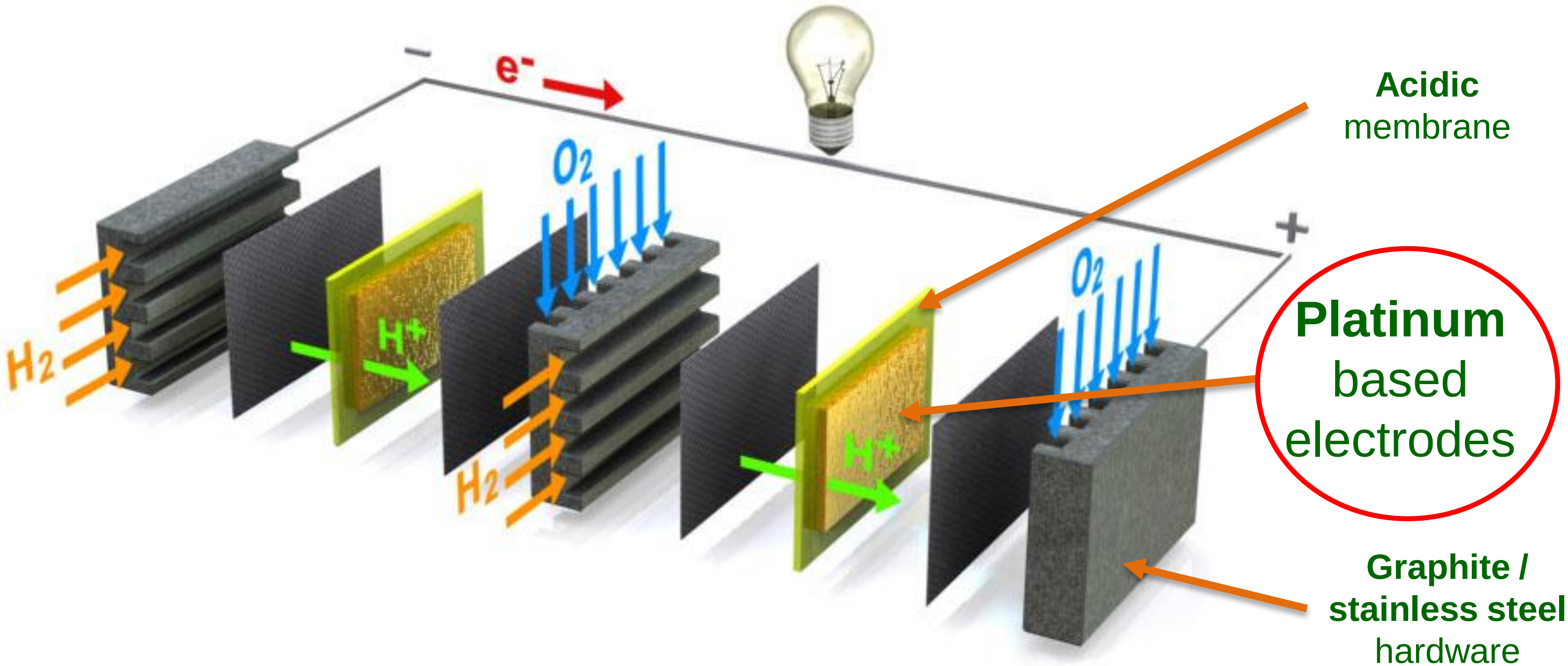
Mainstream Polymer Electrolyte Fuel Cell (PEM) Cost Barriers

Cost barriers deeply embedded in core tech materials



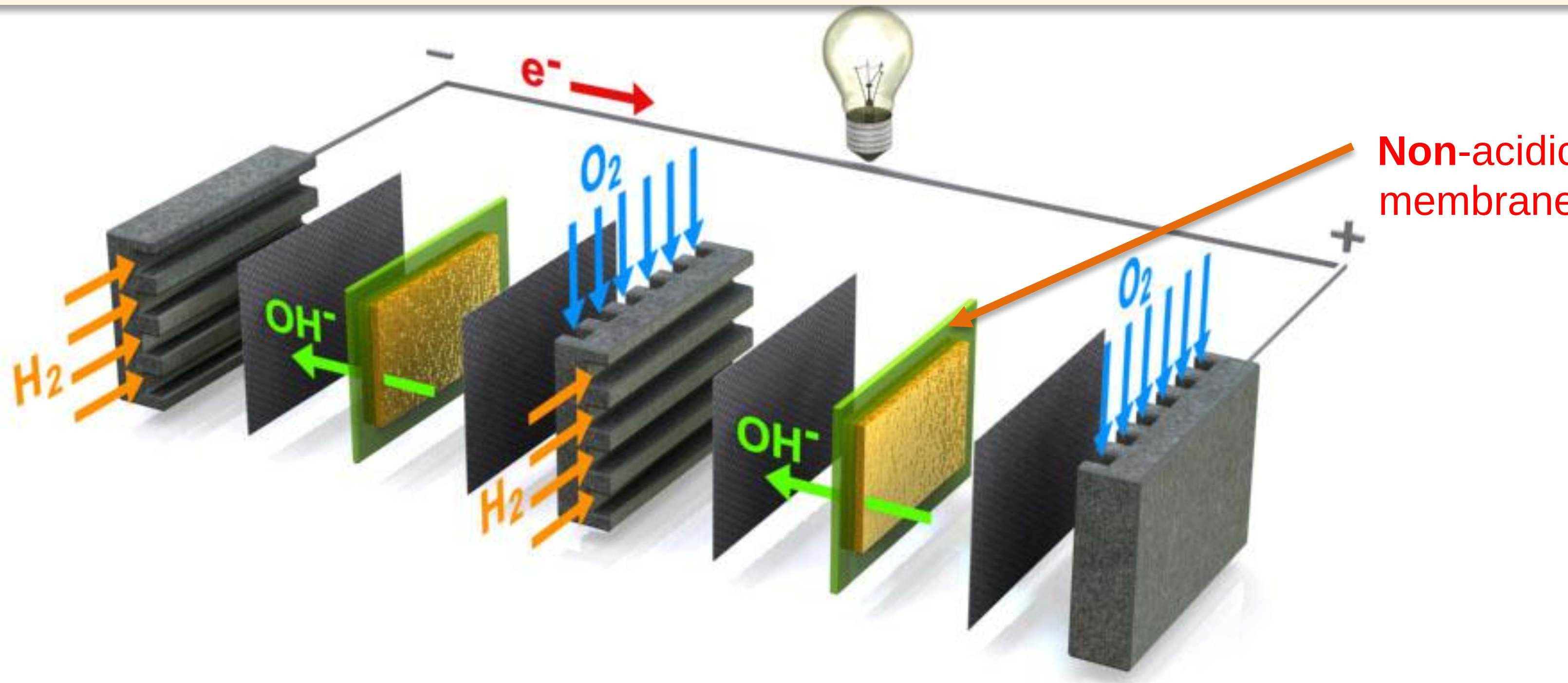
BOM-based cost barriers – 90% of stack cost

Cost volatility - Platinum \$500/Oz - \$2,500/Oz

The possibility of an OH^- ion conducting membrane

A new type of membrane component with potential for strong fuel cell cost cuts was revealed in 2006, but

was accompanied by general industry skepticism



CellEra Took Advantage of this Opportunity

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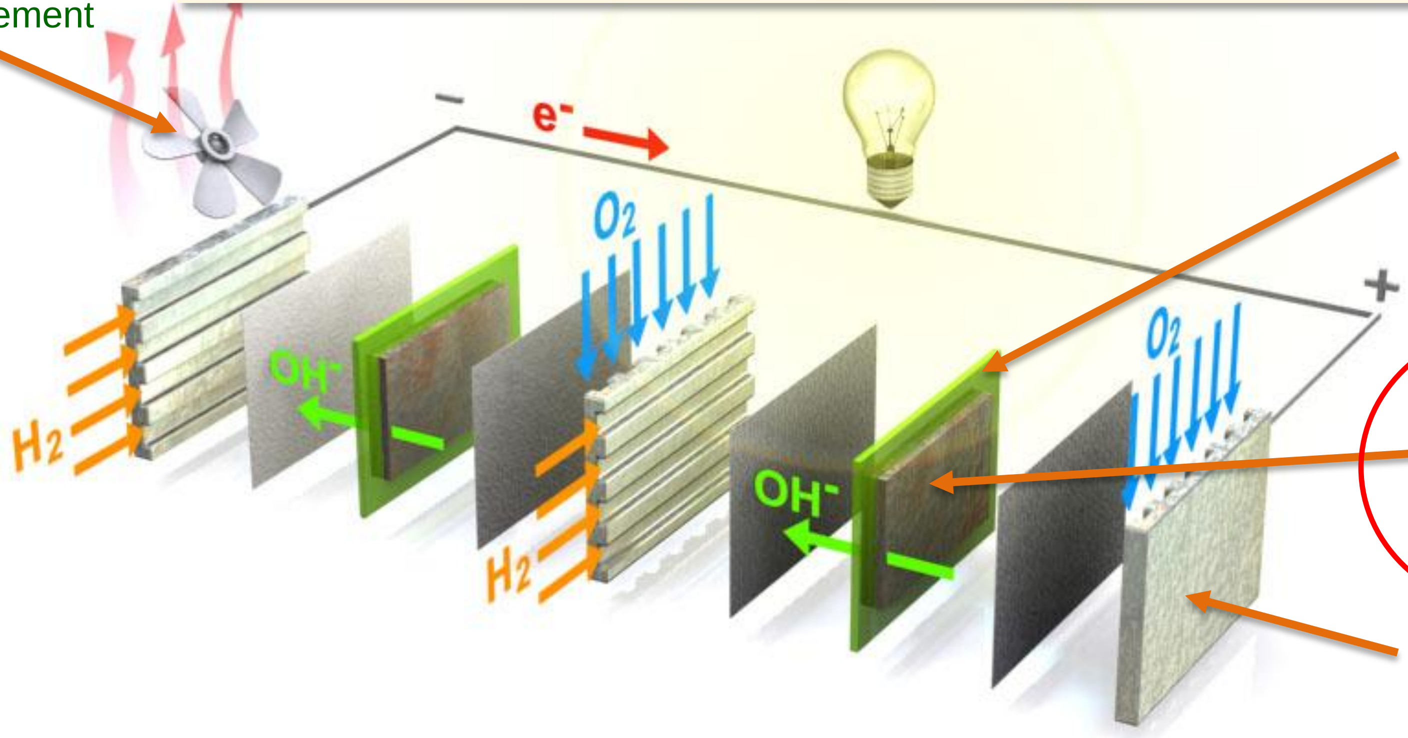
CellEra's Platinum-Free Membrane Fuel Cell (*PFM-FC*)

Enabler for price parity at volume with lead acid batteries and diesel generators

Facilitated thermal management



Non-acidic membrane

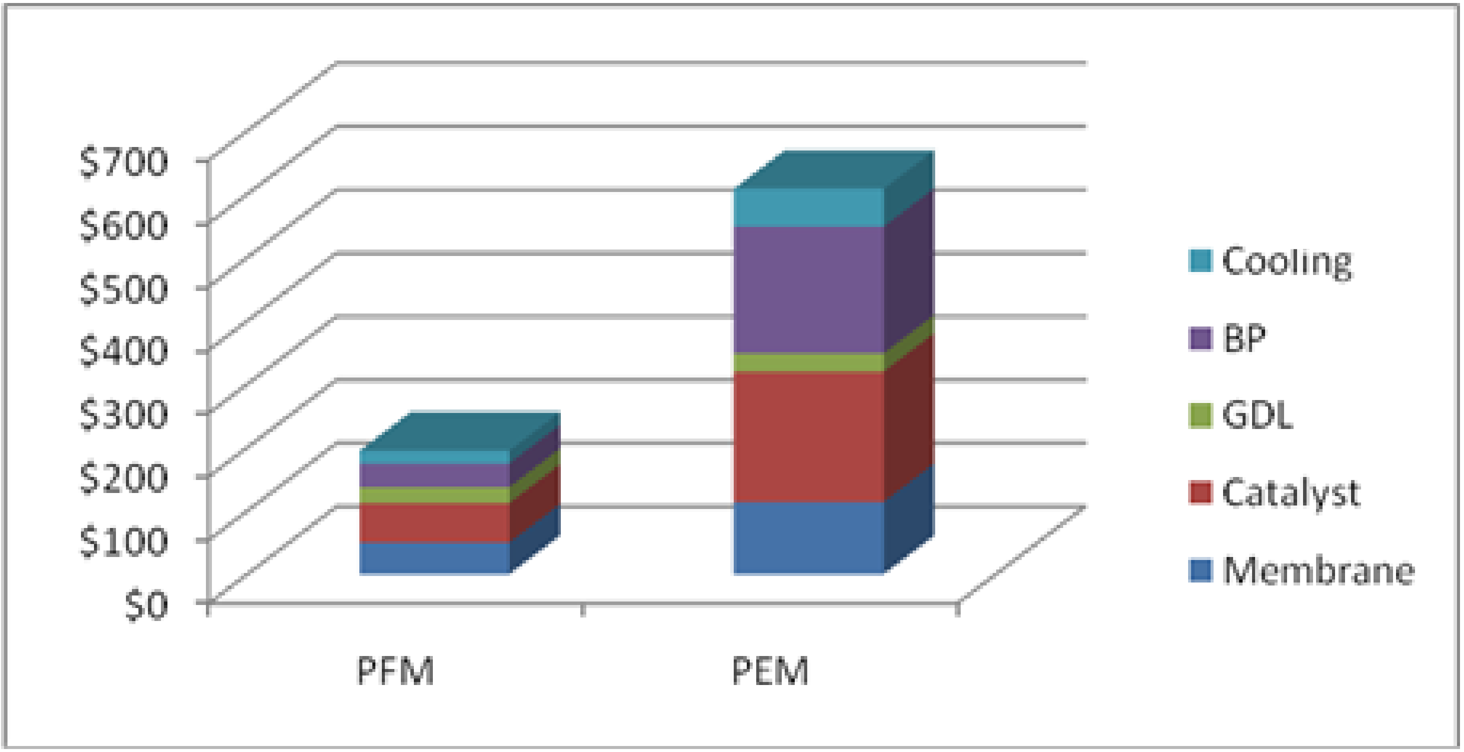
Non-platinum catalysts

Light metal hardware

70% cost savings and above vs. acidic system

PFM vs. PEM stack- Cost Analysis per kW at 10^3 unit volumes

PFM-FC provides cost reductions "across the board"



* The cost of the PFM-FC will come down to the target 40 $/kW in large volume transport applications assuming AMFC operation at 80 degC

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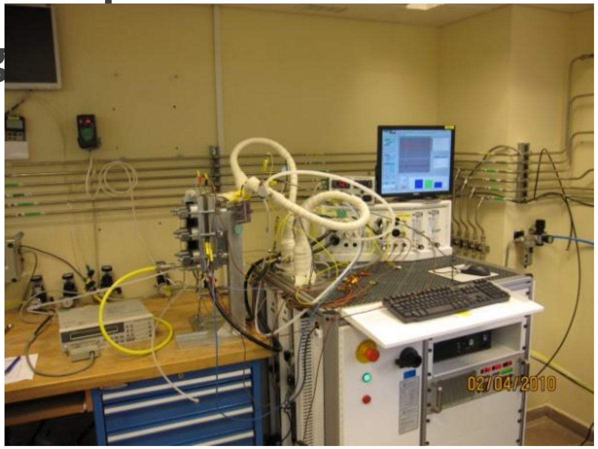
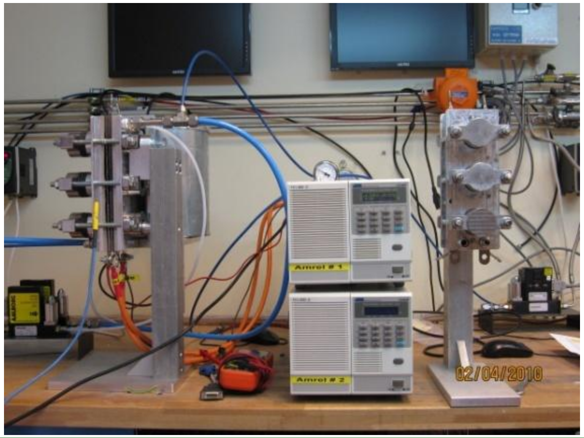
CellEra Tech. Development timeline – Q3 '09

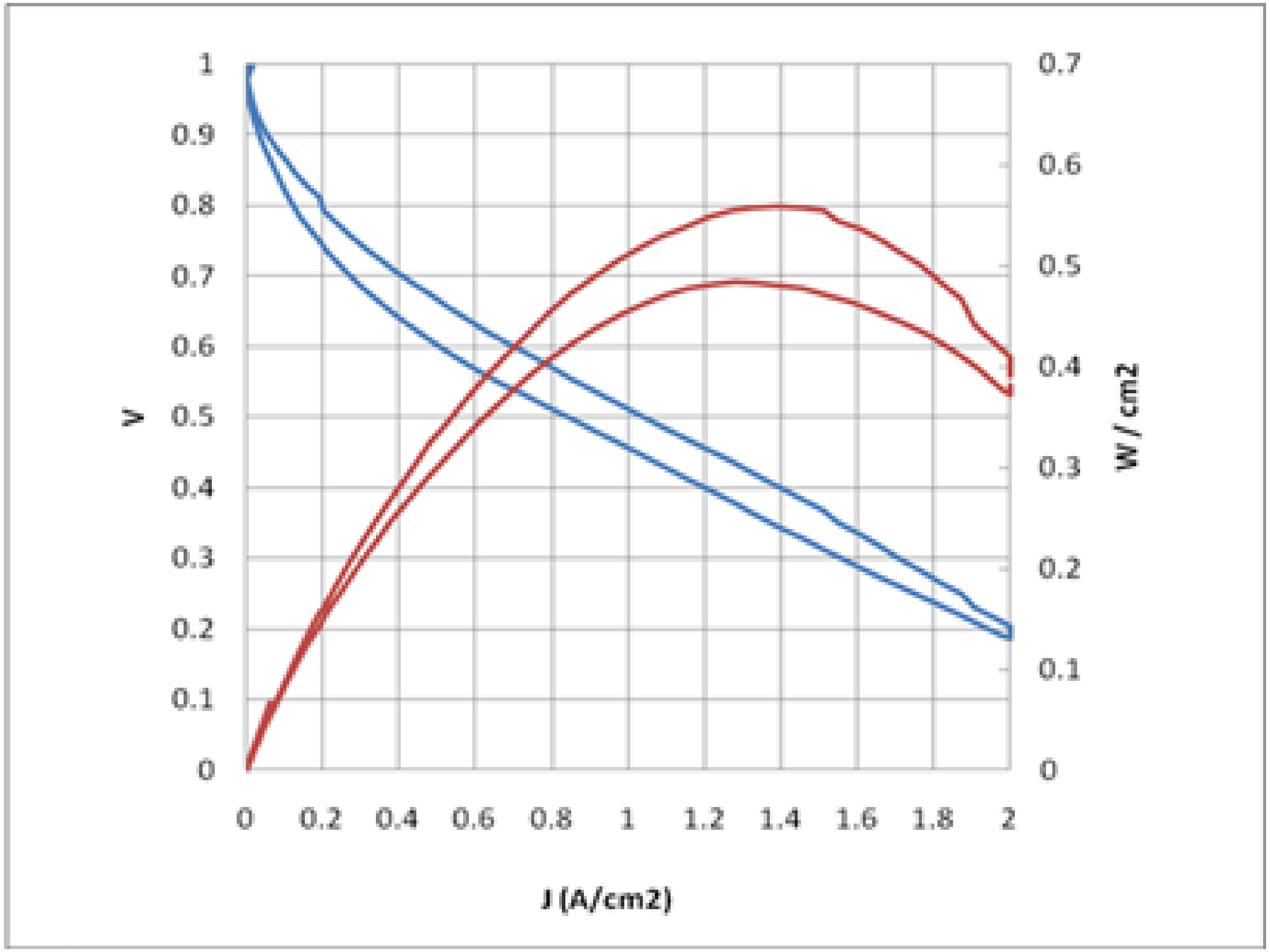
- CCM fabrication scaled up to **100 cm2* – moved from manual to semi-automated fabrication** * present CCM has 265 cm2 active area
- Work initiated on scalable AMFC stack design & development
- Lab upgraded for stack level fabrication and testing





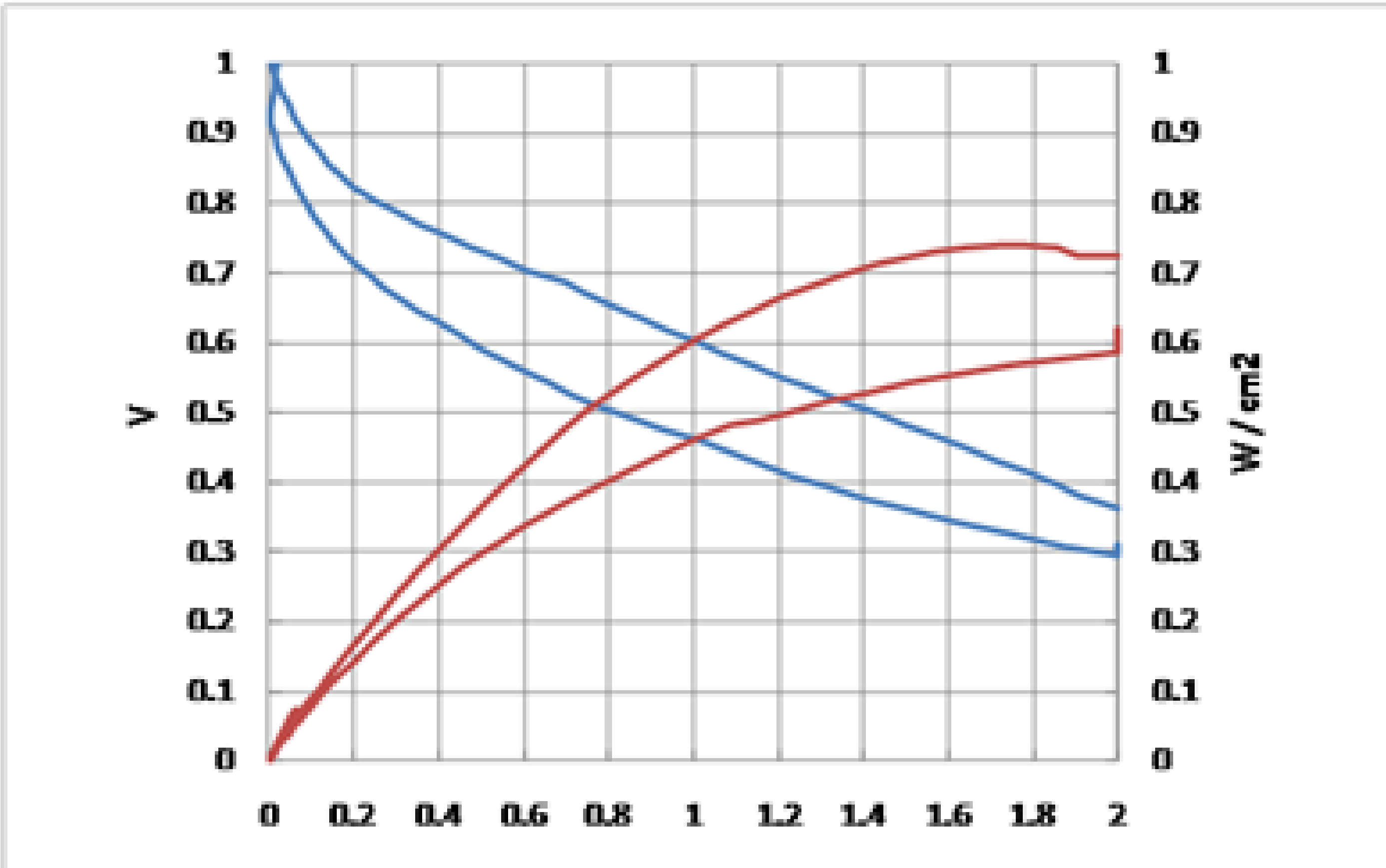
Cellera's AMFC :
Hydrogen/Air, 2/2 bar, 80 deg C* (Dec. 2010)

* short term test



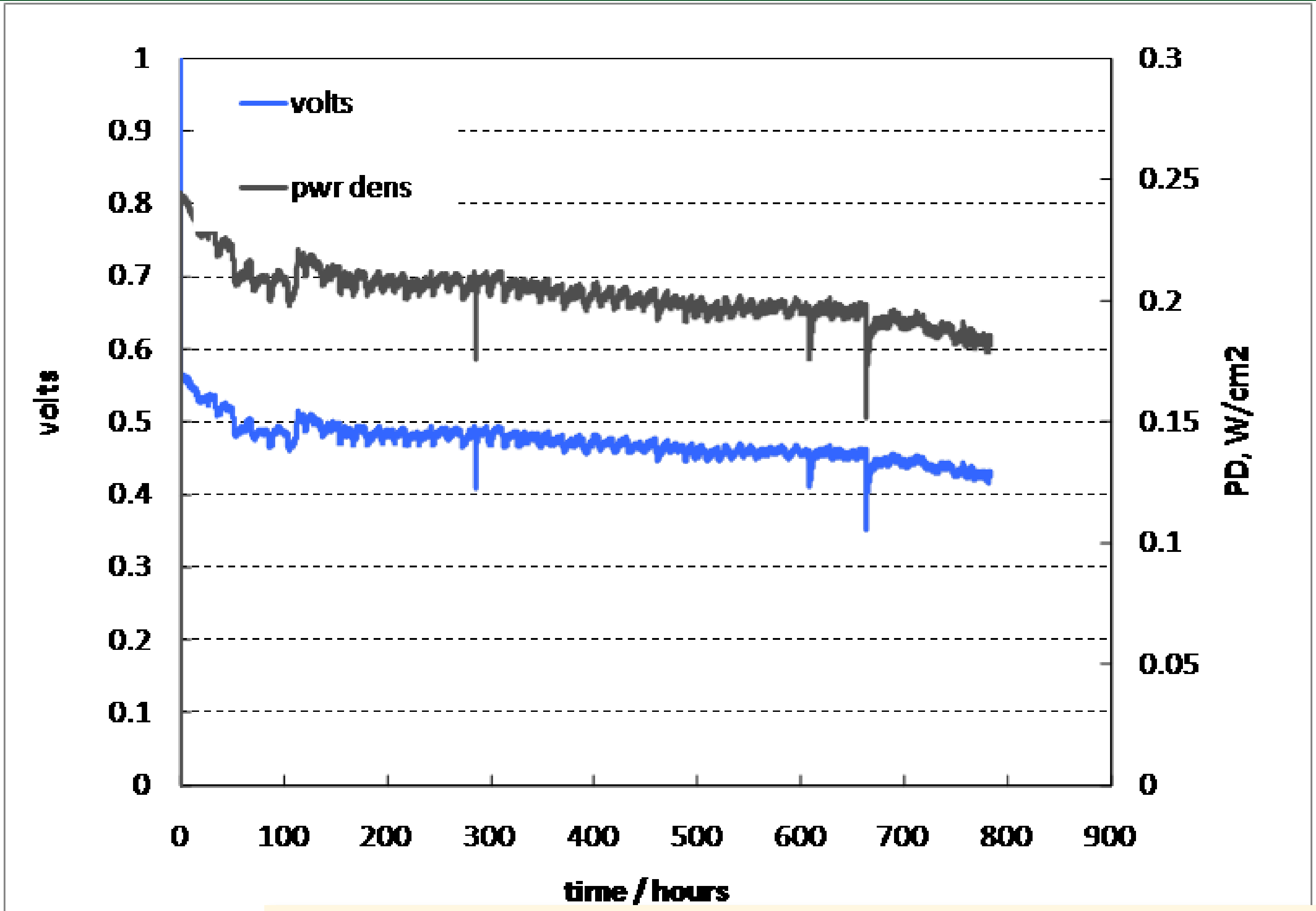
Cellera's AMFC :
Hydrogen/Oxygen, 2/2 bar, 80 deg C* (Dec. 2010)

* short term test



Operation on oxygen not presented here to suggest a technical option—only demonstrate that Tokuyama membrane and recast ionomer conductivities and water mobilities enable to reach these currents and Pmax at 80º

5 cm^2 H_2/air AMFC power variation with time at constant current of 0.4A/cm^2 ,cell T =60^{O}C . (Jan. 2011)



Pseudo–linear rate of power loss shown here is 40 microvolt/hour

While still lagging behind demonstrated stability in PEMFCs, this is 2 orders of magnitude improvement over the 2008 status

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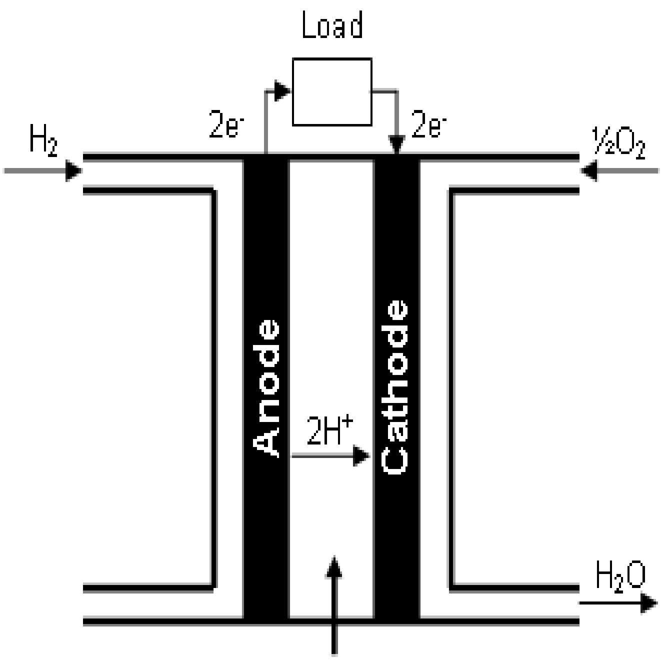
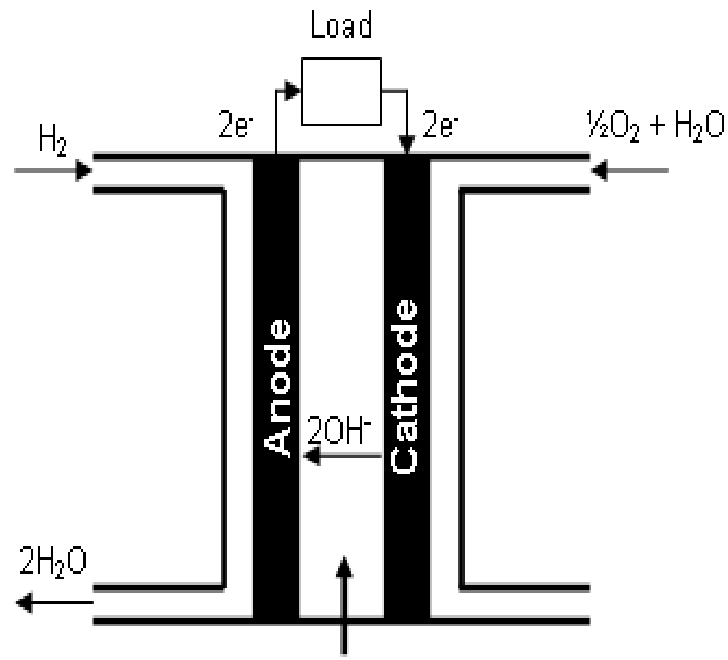
Processes in PEM and AEM Membrane Fuel Cells



Proton-Exchange Membrane Fuel Cell
[PEM-FC]



Anion-Exchange Membrane Fuel Cell

Anode: $H_2 + 2OH^- = 2H_2O + 2e$

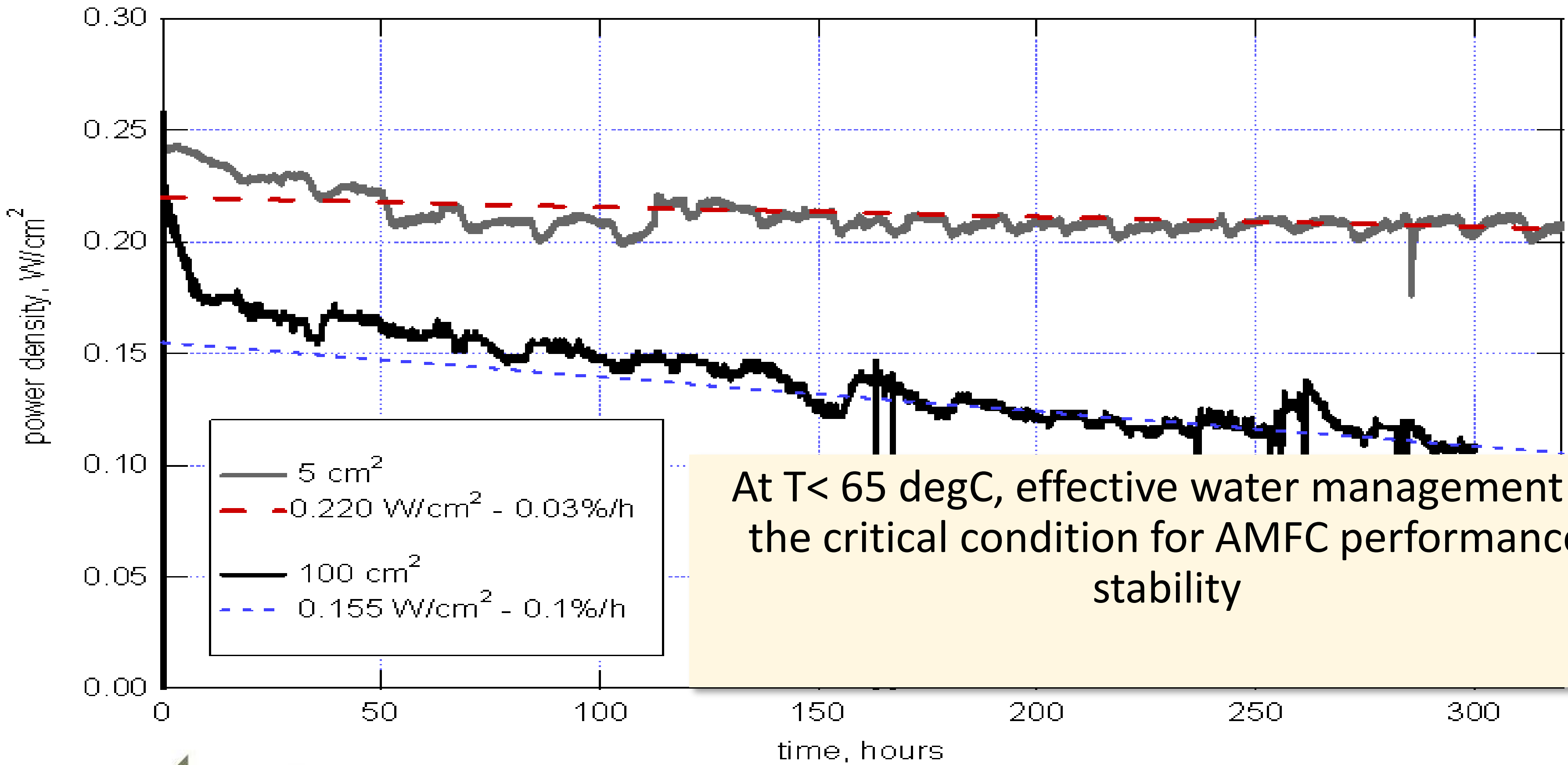
Cathode: $2e + 0.5O_2 + H_2O = 2OH^-$

cell: $H_2 + 0.5O_2 = H_2O$

*** Water is generated at the anode**

& <u>*is consumed*</u> at the cathode at half the generation rate

AMFC power loss under ideal and less ideal water management conditions

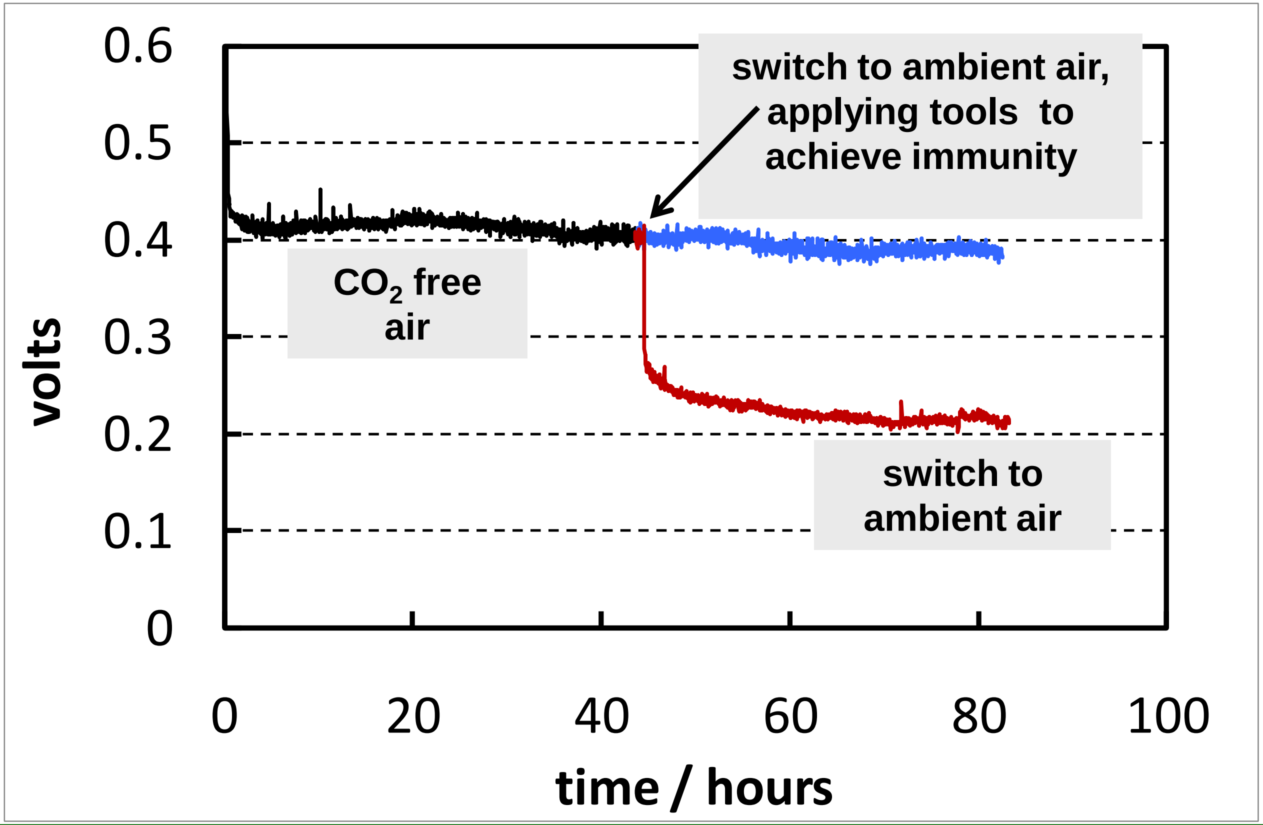


At T< 65 degC, effective water management is the critical condition for AMFC performance stability

Complete CO_2 immunity Achieved in Cellera's Stack

- Switching from CO_2-free air (<1 ppm) to ambient air (~400 ppm CO_2) results in ~50% loss of performance (red curve) at 60 degC
- CellEra system tools eliminate this loss , to give performance equivalent to CO_2-free air (blue curve) with no scrubbing solutions

- Operation at Tcell = 80^{0}C with no treatment required upstream the cathode inlet looks possible (next slide)



Higher cell T will further facilitate achieving CO_2 –free performance with direct feed of ordinary air

P_{air} / $P_{air\ w/o\ CO2}$ (exptl. results)

50^0C		80^0C	
0.6V	20%	0.6V	40%
0.5V	33%	0.5V	70%
0.4V	50%	0.4V	**80%**

Anode carbonate decomposition process:

(1a) ($-NR_4$+)(HCO_3-) + ½ H_2 = H_20 + CO_2 + e + ($-NR_4$+)

(1b) ($-NR_4$+) + OH- (from cath.) = ($-NR_4$+)(OH-)

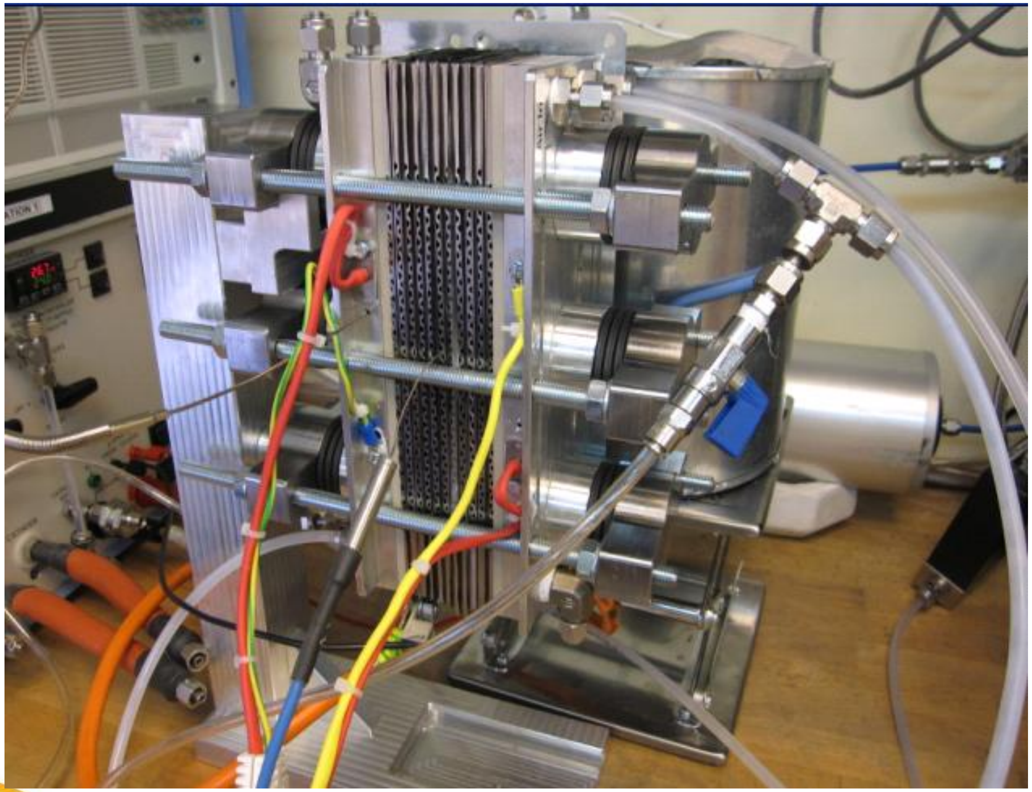
Steady state anode carbonate concentration, is given by :

[(NR_4+)(HCO_3-)]$_{an}$ (V,T) = [dNco$_{2,cath}$/dt] /$k_{(1a)}$ (V,T)

*High $k_{(1a)}$ (V,T) at T_{cell} =80^0C ensures effective "electrochemical purge" of CO_2

Cellera Tech. Development timeline – Q4 ‘09

- Short stack fabrication and testing begun
- design based on cabinet dimensions defined by Commscope
- Aluminum hardware, transverse air cooling

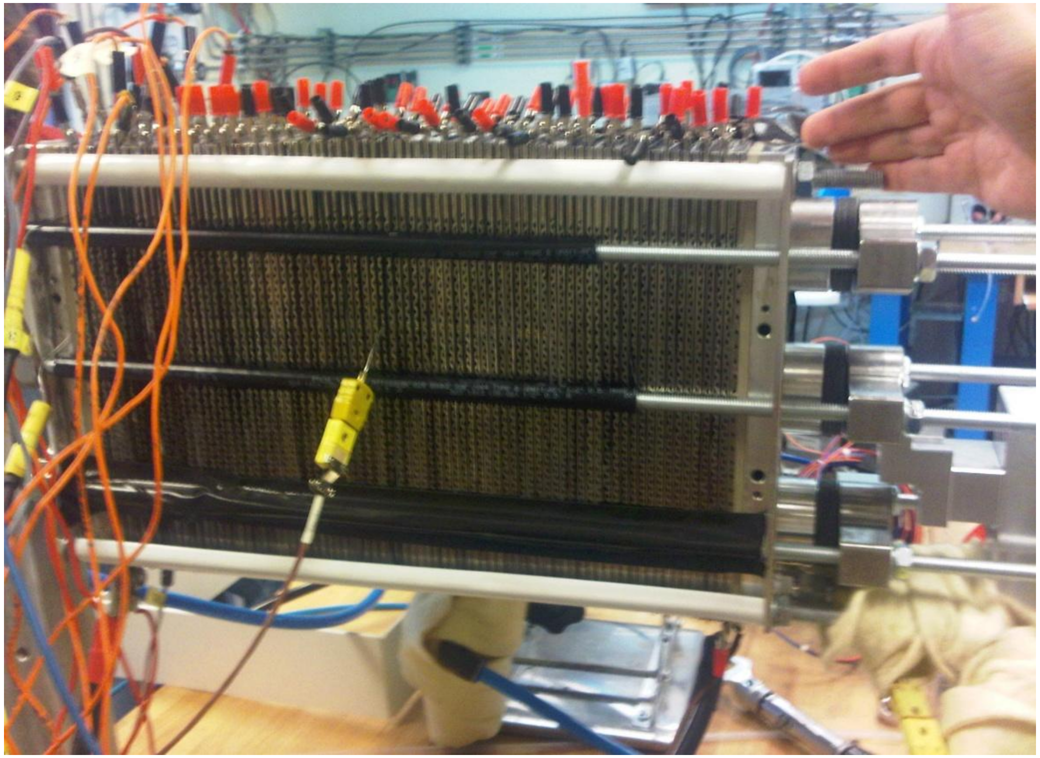


CellEra Tech. Development timeline – Q3 ‘10

- First kW level AMFC stack*

Stack built of surface coated aluminum and runs on:

- **Ambient air**
- **No added electrolyte**
- **No added water**
- **No CO_2 “scrubbing”**
- **Four 9’s H_2**
- **Cooling by fan**



*** demonstrated at Andrew/Commscope, Richardson, TX**

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The Near Term Market

near-term opportunities in lead acid battery and diesel gen set replacement

- ✓ **Critical power (annual $3 billion lead acid battery market)**
  - ❑ Backup power for telecommunications
  - ❑ Affordable, clean and compact, time- extended backup solution
  - ❑ 10X energy density versus lead acid, highly scalable solution

- ✓ **First Cellera/Commscope product pursued:**

❑2kW net AMFC stack to fit in Commscope's transciever cabinet
❑price parity with 8 hr lead-acid battery solution ($0.3/Wh) targeted
❑Joint development and go-to-market agreement
❑Project selected for BIRDF funding, www.birdf.com

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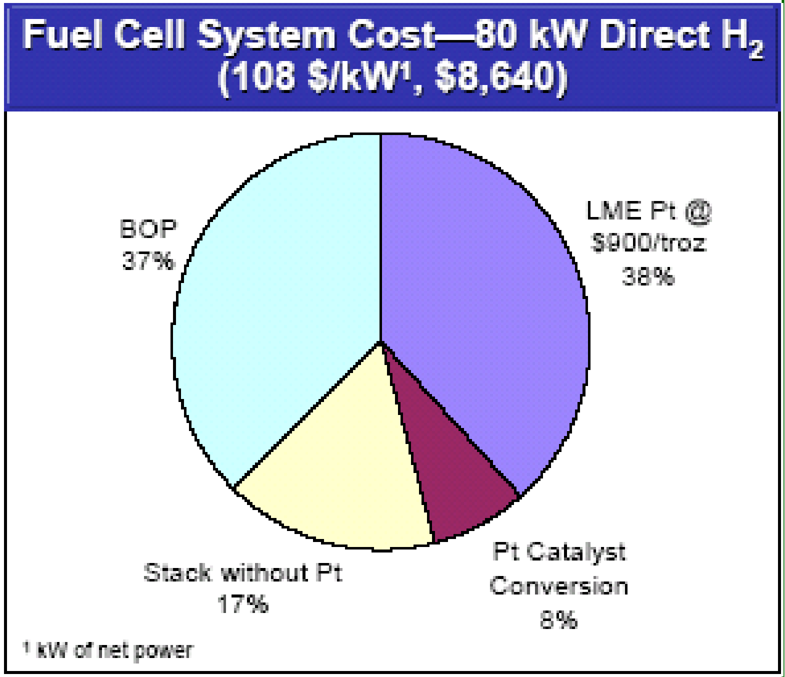
The Market Opportunity – Automotive

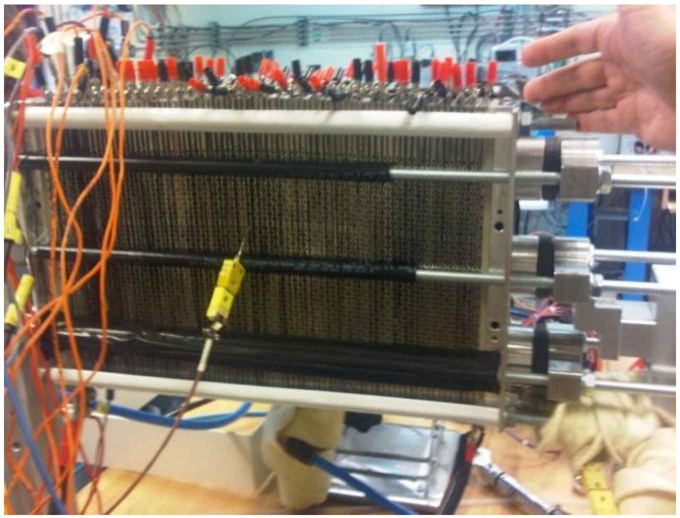
- ✓ Transportation
  - ❑ Longer term, but largest opportunity
  - ❑ At high volume, large fraction of cost is Pt related
  - ❑ 1st application - EV Range extension



Source: NREL, 2009

Achieved in under 3 years, $4 million

BIRD Foundation



✓World's first kW-scale PFM-FC working prototype (first achieved Q2-2010)

✓Joint development and go-to-market agreement with global communications-infrastructure solutions provider as launch partner

✓Fast-growing industry interest in AMFCs revolving around our recent achievements

Global Cleantech 10 100
cleantech theguardian

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Co-operations and Formal Collaborations

CommScope

AMMINEX

CellEra Technologies

Automotive OEM
funding contract being finalized

TOKUYAMA

Electrocatalysis R&D Center
funding contract being finalized

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Cellera intends to develop and fabricate PFMFC stacks, leveraging the capacity and knowhow of supplier and user partners

Materials

TOKUYAMA
& possible others

+ Catalysts Suppliers

FC "Engines"

Major SI's / OEM's

CommScope
& possible others

Automotive OEM

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Technology and Business Development

- Cellera is targeting a first, H2/Air, 2 kW AMFC stack product for back-up power application

  Cellera's AMFC technology focuses on operation with no Pt catalyst and no liquid electrolyte

- Cellera's first stacks are designed to be used in a power system co-developed with Commscope (Richardson, TX) , a company supplying a range of telecom products including back-up power systems for cell phone towers

- Cellera is pursuing further widening of the field of AMFC product applications, including applications for transport , based on cooperation with an OEM in the relevant sector

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Summary: (1) Technical Insights

- ***On some common concerns regarding AMFCs:***

Concern 1: Chemical stability of the ionomer is poor and is severely limiting cell life

Observation: Cell life demonstrated under load for >10^3 hours, with the keys for longer life being good quality MEA and cell T < 65 degC

***AEM and ionomer technology developed to-date by Tokuyama could serve well for a 1st generation AMFC stack*

Concern 2: The conductivity of OH- ions in a membrane is well below that of protons, hence performance hit expected

Observation: Cell HFR with Tokuyama materials = 0.2 ohmcm^2 at 60 degC (at full hydration)

Concern 3: Replacement of Pt will incur significant performance loss

Observation: Initial cell performance is comparable with non-Pt catalysts and stability mostly depends on CCM structure and effective water management

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Summary: (2) requirements of further development

Closing the performance gap vs. PEMFCs will mainly require:

- Higher-temperature (80 degC) membrane and ionomers of high water mobility, including under partial hydration conditions

  *Operation at such higher temperature will facilitate achieving full CO_2 tolerance w/o any need of upstream sequestration

- Low cost , non-Pt anode catalysts operating at overpotential < 50mV at the design current density and exhibiting good long term stability

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Acknowledgements

The $$

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Thank You!

Shimshon Gottesfeld, CTO
(US) 1 518 786 88898
(Israel) +972 542 526 373
shimshon@cellera.biz