AUTOMOTIVE FUEL CELL COOPERATION

Automotive Fuel Cell Stack Technology Status, Plans, Outlook

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AFCC: ***The Centre for Fuel Cell Stack Development for Daimler AG and Ford Motor Company***

DAIMLER

Ford

Who is AFCC?

AUTOMOTIVE FUEL CELL COOPERATION

- **The** fuel cell stack development centre for Daimler and Ford
  - Fuel cell stack technology and product development
  - Prototype manufacturing

- Joint-venture private company, located in Vancouver, Canada

- Ownership structure
  - 50.1% Daimler AG
  - 30.0% Ford Motor Company
  - 19.9% Ballard Power Systems (financial investor only)

In the 2015 timeframe, our fuel cells are a zero-emission, reliable, affordable, mainstream automotive propulsion technology.

Status vs DOE Goals

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Characteristic (Stack Only, inside a target fuel cell vehicle)	**Units**	**2015 DOE**	**AFCC 2009 Technology Capability**
Energy efficiency (b) @ 25% rated power	%	60	57-61
Energy efficiency @ rated power	%	50	50-53
Power density	W / L	650	2000-2500
Specific power	W / kg	650	1000-1500
Cost (c)	$ / kWe	30	75-80
Transient response (10-90% of rated power)	Seconds	1	1
Cold start-up time to 50% of rated power			
@ -20C ambient temp	seconds	30	30-60
@ + 20C ambient temp	seconds	5	5
Start-up and shut down energy (d)			
from -20C ambient temp	MJ	5	<5
from + 20C ambient temp	MJ	1	<1
Durability with cycling	Hours	5,000 (e)	3,000-5,000
Unassisted start from low temperatures (f)	C	-40	-30

AFCC 2009 technology capability is based on our latest Generation 2 and Generation 3 fuel cell full size stacks that are operational on fuel cell stack test benches, and are also installed and operating in Daimler prototype vehicles

Notes (reference DOE definition)

- a. Targets exclude hydrogen storage, power electronics and electric drive
- b. Ratio of DC output energy to the lower heating value of the input fuel (hydrogen).
- c. Based on 2002 dollars and cost projected to high-volume production (500,000 systems per year)
- d. Includes electrical energy and the hydrogen used during the start-up and shut-down procedures
- e. Based on test protocol to be issued by USDOE in 2007
- f. 8-hour soak at stated temperature most not impact subsequent achievement targets

Source: USDOE Fuel Cell Technical Plan, 2007

Fuel cell achievements and challenges

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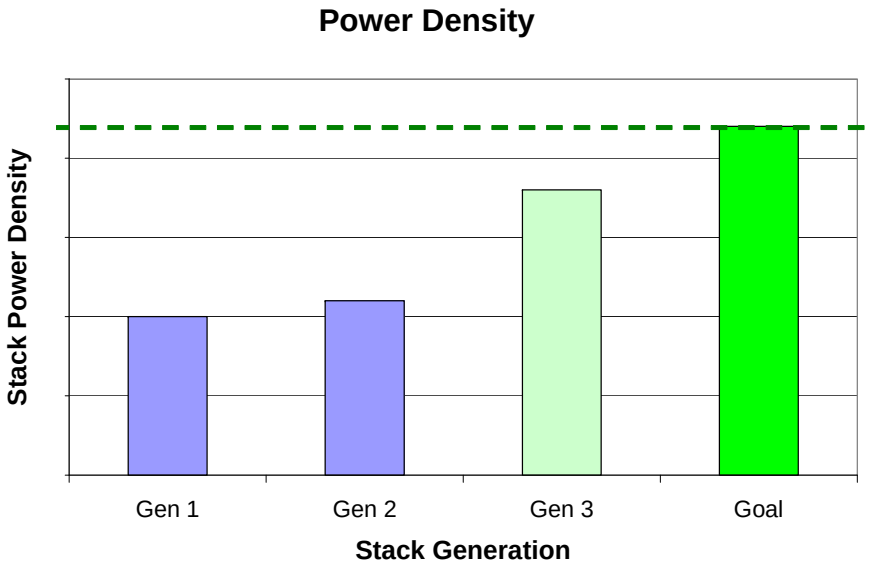
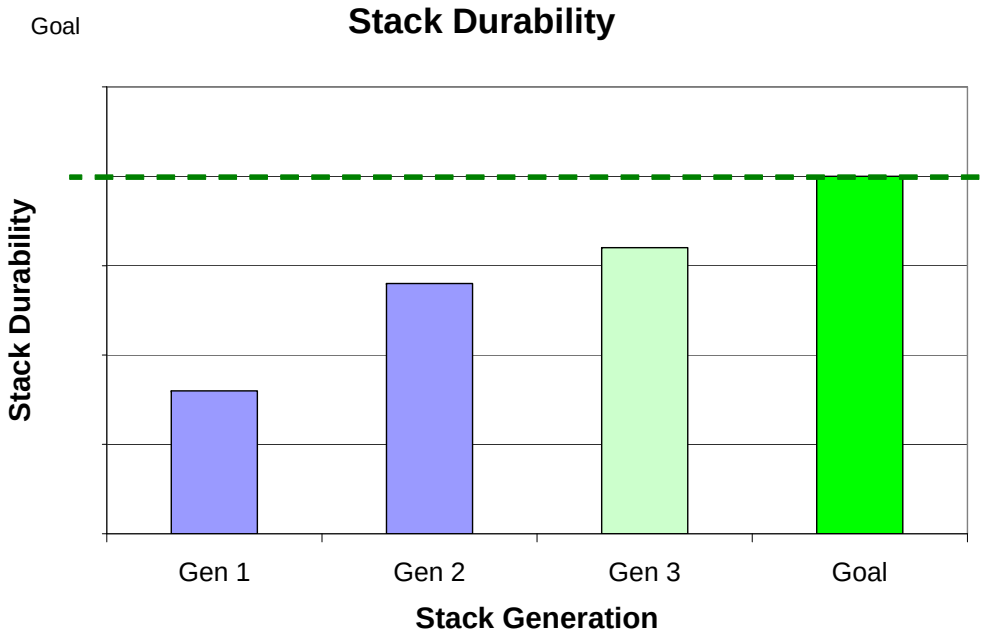


Gen 3: Full scale running prototypes

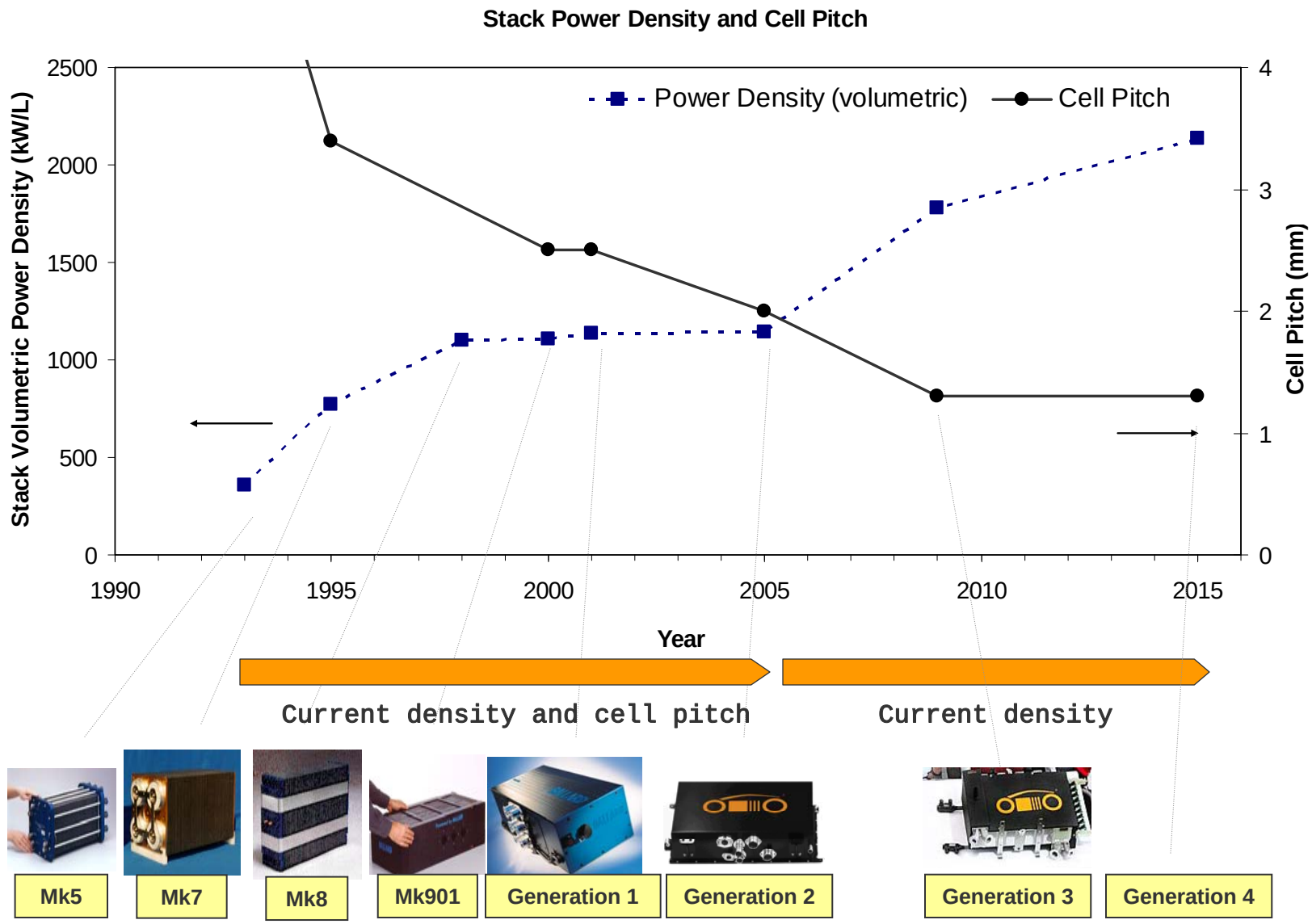
Gen 2: On road 2009

Gen 1: 3 million miles

Daimler, Ford, Honda vehicles



Power Density Progress



For fuel cells we know how to get the cost down

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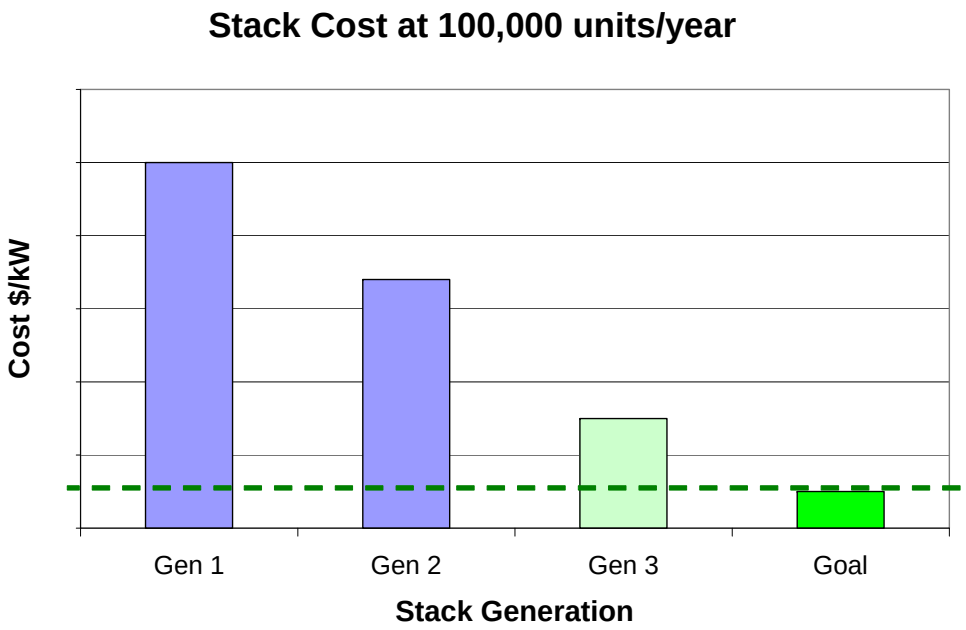
Goal: Competitive to the incumbent technologies

- Volume increase, economies of scale" (4-5x)
- Technology improvements (3x)
- Supplier development
- Manufacturing technologies
- New, cooperative business models



Magnitude of the task: factor 15

Cost driven development goals

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Stack

- reduce Pt loading from 0.5 - 1 mg/cm2 to 0.2 - 0.3 mg/cm2
  - develop improved cathode catalyst material and application technology without negative impact on lifetime
- reduce active stack area
  - increase catalyst activity at full and part load while reducing Pt loading
  - improved plate technology
  - improved GDL technology
- reduce bipolar plate cost through high volume manufacturing technologies (metal plates or carbon plates)
- improve membrane performance under dry and hot conditions to accommodate reduced/eliminated humidifier system concept
- improve unit cell/ flow field concept to accommodate reduced/eliminated hydrogen recirculation system concept

Fuel cell component priorities

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	Technology Area	Driver	Criticality	Understanding	Opportunity
1	Catalyst	Carbon supported Pt	9	High	Low
1	Catalyst	New High Activity Catalyst	9	Low	High
1	Catalyst	Less Platinum	8.2	High	Med
2	FCS	Efficient Air Compressor Technology	7.2	High	Med
2	FCS (vehicle)	Less Gross Power	6.6	High	High
2	Membrane	Conductivity @ <20% RH	6.6	High	Low
1	Catalyst	Pt Dissolution Resistant Catalyst	6.3	Med	Med
2	Membrane	Low N2 Cross over membrane	6.3	Med	Low
2	FCS	Less Expensive Humidifiers	6	Med	High
3	GDL	Improved GDL Pore Structure	5.4	Med	High
4	GDL	GDL low Cost Substrate Materials	5.4	Med	Med
3	GDL	Maximize GDL Stiffness	5.4	Med	Low
4	Membrane	Fundamentally less expensive polymers	5.1	Low	High
3	Plate	Improved Plate Formability	5	High	Med

These areas of research and development need to be the focus.

1 •New durable high activity catalysts.

2 •Enable low cost system

3 •Enable high current density via plate and GDL

4 •Lower cost cell materials

Fuel Cell Component Supply Base

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- Many components are novel (catalyst, membrane, plates, GDL)
- Component suppliers are investing significant resources in development
- Significant investments required for scale-up
- Some synergy and leverage with non-Automotive
- Hard for component suppliers to make a strong business case for investment with uncertainty in volumes, infrastructure, and policy (energy and environment)
  - Strong government signals can help immensely

Other applications

- Primary path is automotive – highest volumes and hardest requirements

- Long history of successful application of automotive fuel cells to other applications – buses, forklifts, heavy hybrid

- Optimization of hybridization and operating conditions can greatly extend fuel cell stack durability by a factor of 3+, enabling use of low cost automotive fuel cells in buses etc.

Key Messages

- Fuel cells work fine - #1 focus is now on cost reduction, and we know how to get there
- Partnering is key to success
- Strong government signals supporting fuel cells can spur the needed industry investment for commercialisation