Fuel cells,

Danger or challenge?

KULI Meeting
25.6.2003

P. Claassen

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1. Why fuel cells?
2. Fuel cells as primary drive for motor vehicles
3. Motor vehicles - application: APU
4. Further mobile application
5. Fuels and infrastructure
6. Development of costs
7. Influence on the automotive industry
8. Summary

1. Why fuel cells?

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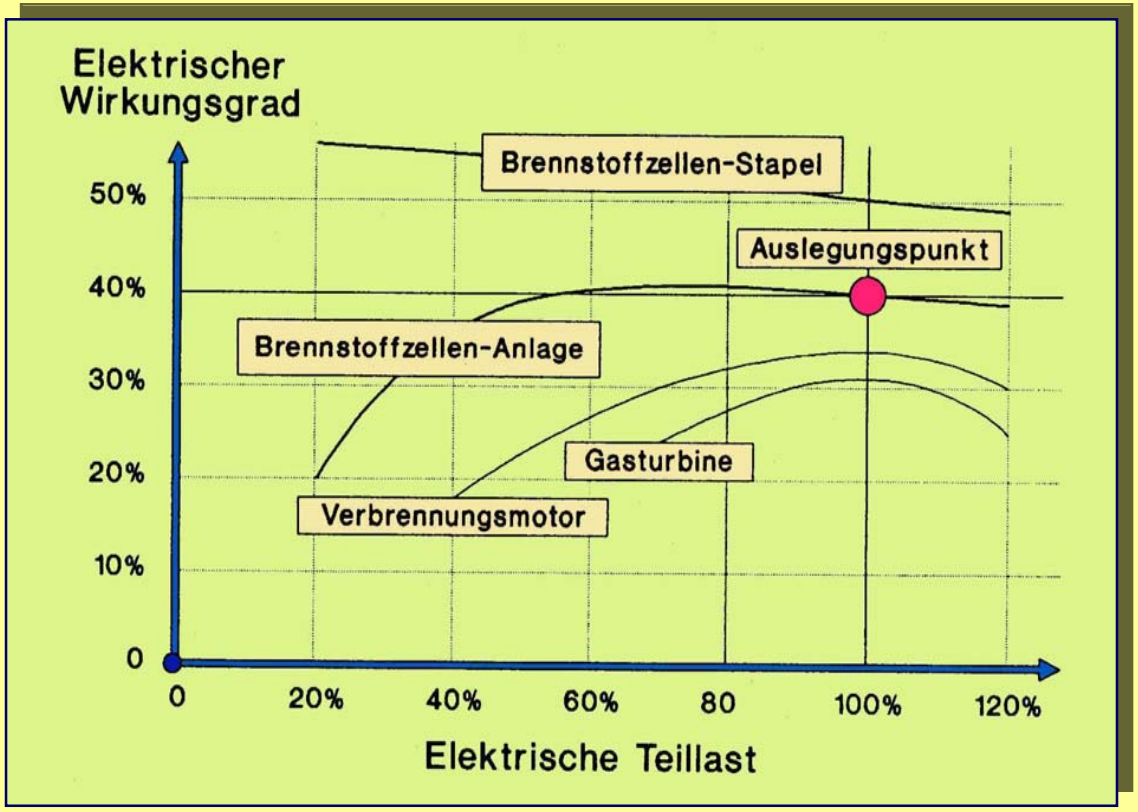
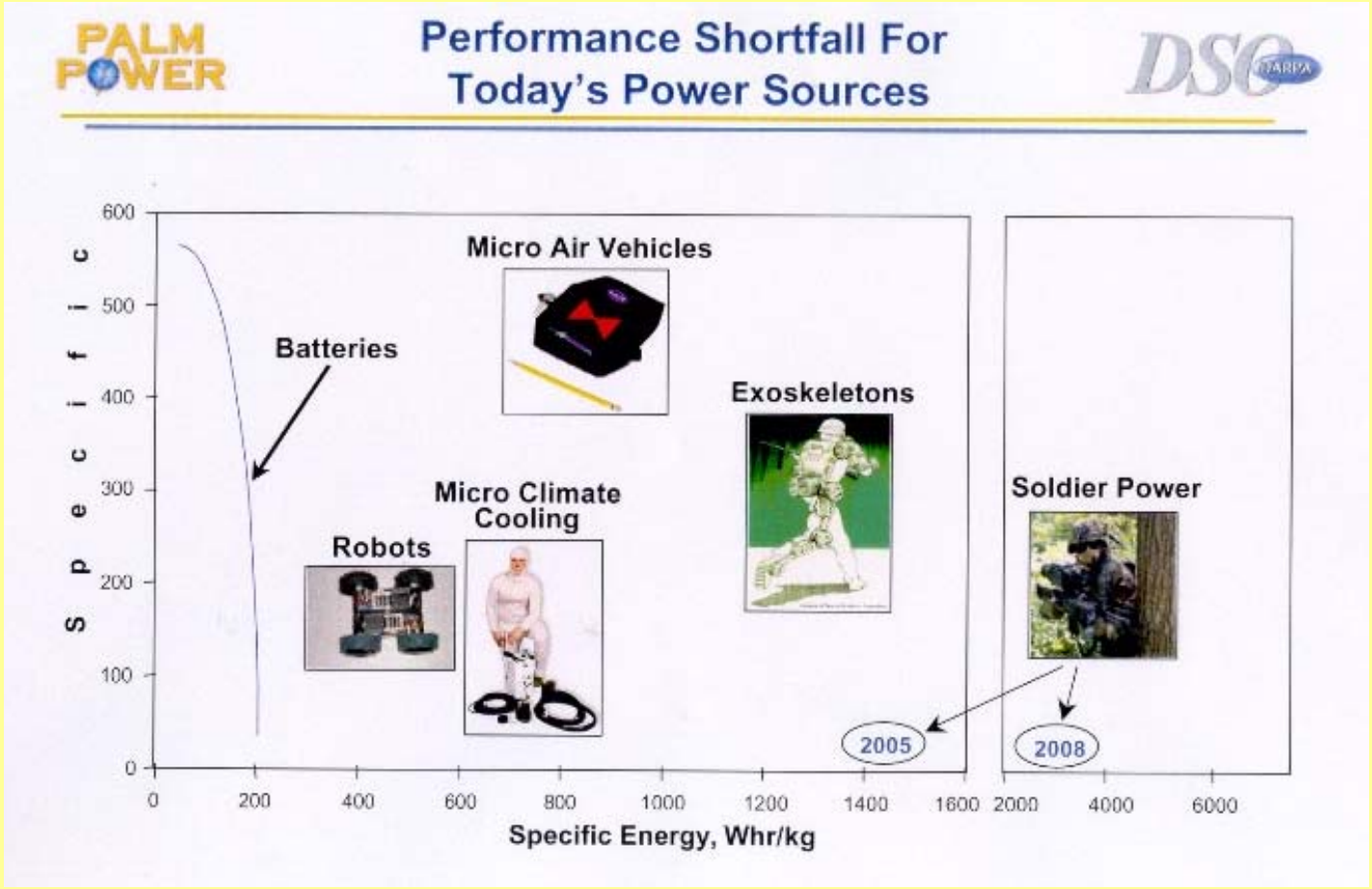
Efficiencies of different drives



Quelle: ZSW

For example: new degrees of freedom via fc



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Advantages of fuel cells

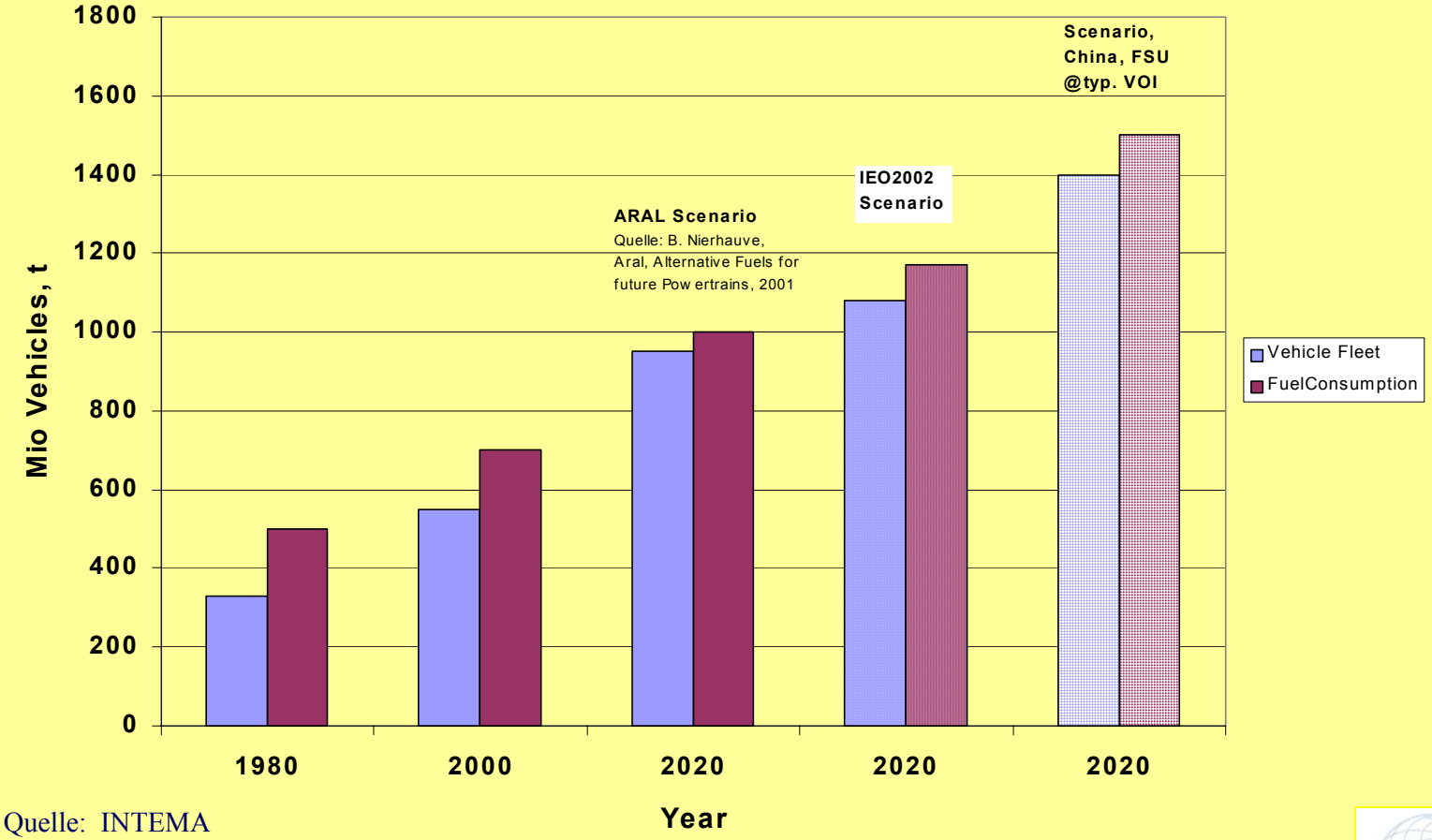
- no noise by the cell itself
- no moving parts, vibration-free
- not limited by carnot-efficiency
- different temperature ranges from 60 to 1000°C
- low emissions
- still sustainable advantages!!!

Disadvantages of fuel cells

- presently too high costs
- inadequate state of development
- sensitivity of certain components (S, CO)

- temporary disadvantages to be solved!!!

Scenarios of car distribution



Quelle: INTEMA

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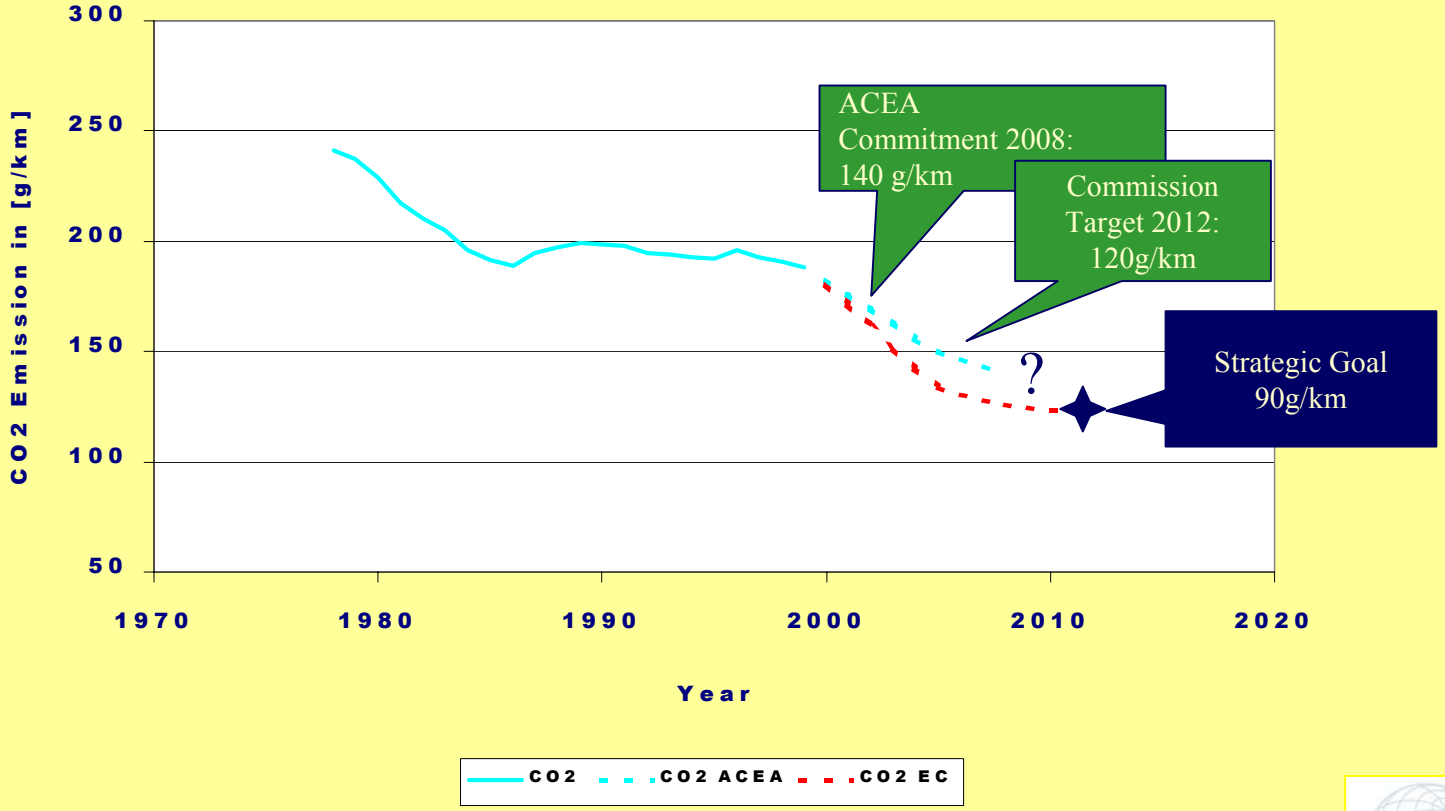
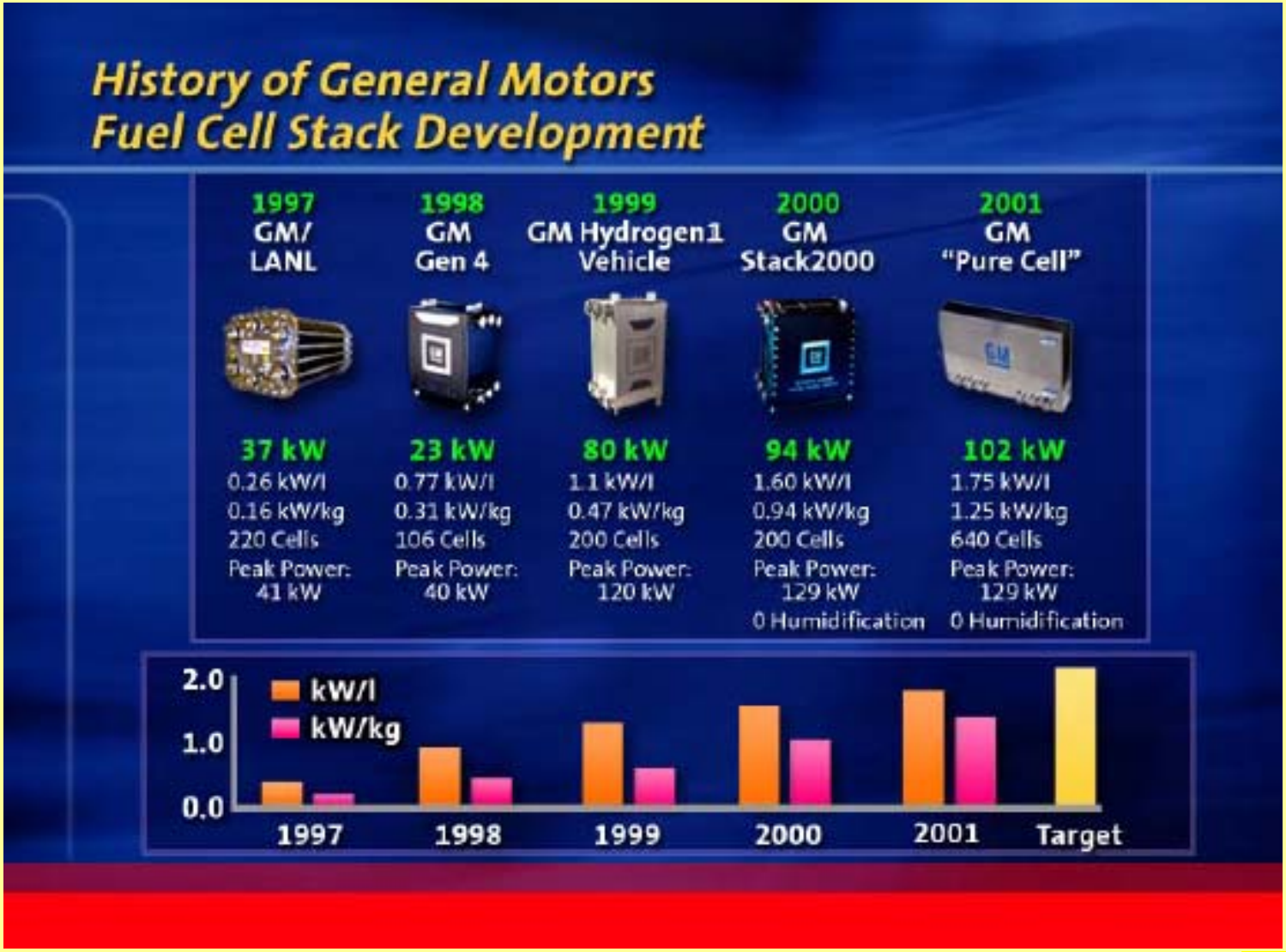
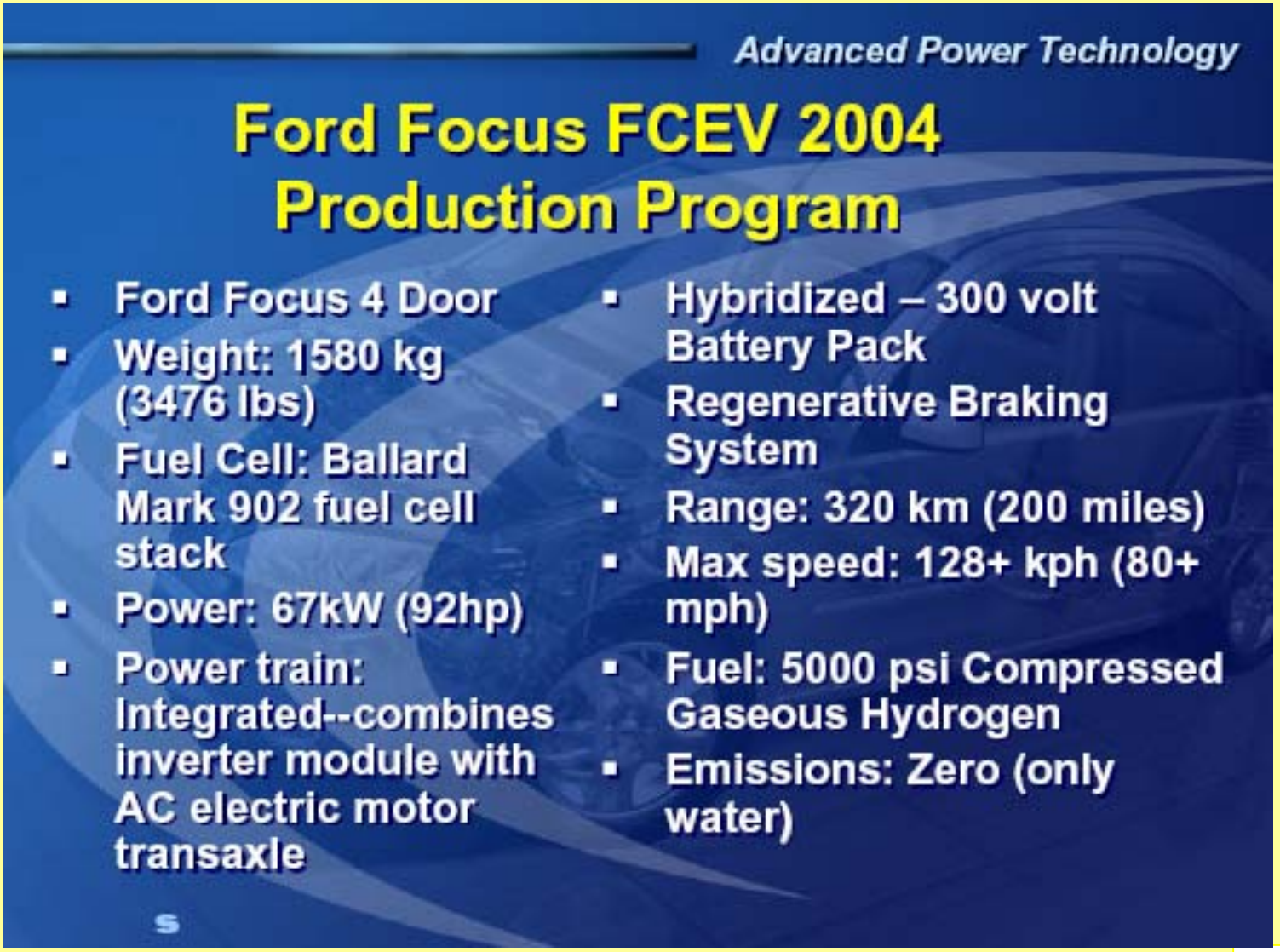
CO_2-Emissions

Example: Germany New Car Sales



2. Fuel cells as primary drive for motor vehicles




Advanced Power Technology
Ford Focus FCEV 2004
Production Program
Ford Focus 4 Door
Weight: 1580 kg (3476 lbs)
Fuel Cell: Ballard Mark 902 fuel cell stack
Power: 67kW (92hp)
Power train: Integrated--combines inverter module with AC electric motor transaxle
Hybridized – 300 volt Battery Pack
Regenerative Braking System
Range: 320 km (200 miles)
Max speed: 128+ kph (80+ mph)
Fuel: 5000 psi Compressed Gaseous Hydrogen
Emissions: Zero (only water)

Environmentally Conscious

Natrium.

Environmentally Conscious

Natrium – the testbed vehicle.

- 54-gallon tank
- 300 mile range
- From 0 to 60 mph in 16 seconds
- Top speed of 80 mph
- Fuel economy (gasoline equivalent) of 30 mpg
- 40 kW Lithium-ion battery pack
- 35 kW AC motor (80 kW Peak)

3. Motor vehicles - application: APU

Product: Vehicle-APU

APU replaces:

APU - benefit for users

- Independent vehicle heater and air condition
- improved cold start
- decreased power needs
- total availability of all systems without running engine
- decreased fuel needs (up to 1/3 savings)

Comparisions of APU efficiencies

	Efficiency (% LHV)	CO2 - Emissions (kg /kWh)
• Fuel cells	~ 40	0,68
• Diesel - APU	< 30	0,9
• Trucks at idle	~ 11	2,4

4. Further mobile applications

Application
lift truck

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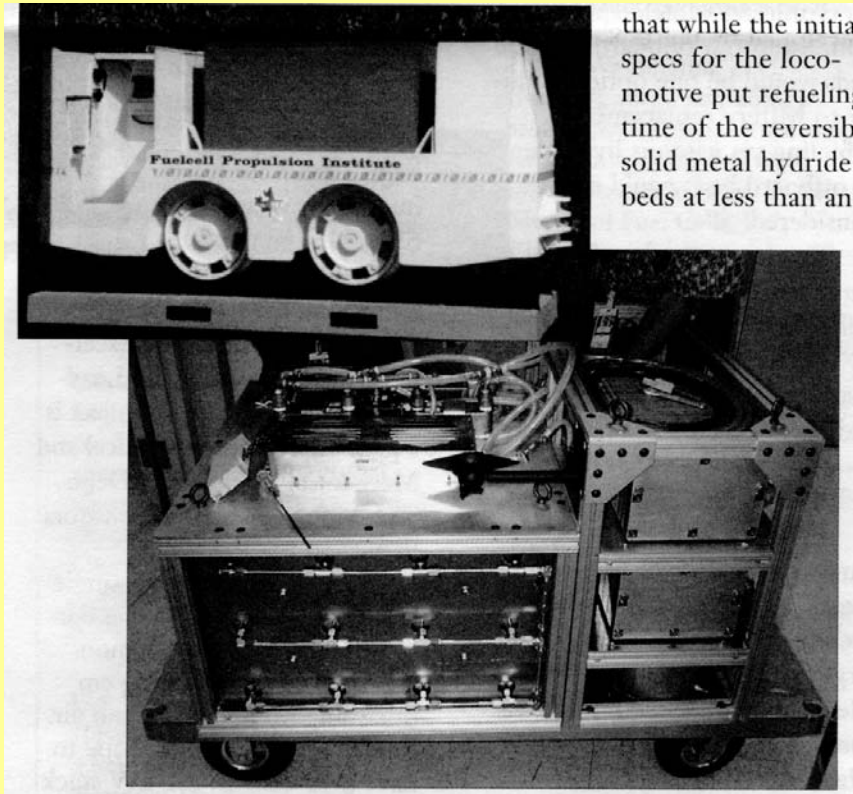
Application mining



that while the initial specs for the locomotive put refueling time of the reversible solid metal hydride beds at less than an

Prototype of 4-ton mining locomotive is integrated with 14-kW PEMFC and metal hydride storage system. (Source: Fuel Cell Propulsion Institute)

Application boats

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PEMFC - Application Notebook

FhG ISE

3 cell PEMFC
(Corresponds to: 1,5 V, 16 Ah)

Application modelling

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5. Fuels and infrastructure

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Fuel savings - cars

Vehicle/Driveline Type	Fuel Economy EDC [l/100km]	Engine Efficiency	Vehicle Efficiency	Acceleration Time 0-100km/h [s]	Fuel Consumption Reduction	
Zafira 2002 PFI Gasoline	8,15	21%	18,20%	11,6	0%	Baseline
Zafira 2010 Gasoline CD	7,66	22,50%	19,40%	11,6	-6%	
Zafira 2010 DI Gasoline CD MTA	6,59	25,20%	22,60%	11,4	-19%	
Zafira 2010 DI Diesel CD MTA	6,16	28,50%	25,50%	11,8	-24%	
Zafira 2010 DI Gasoline HEV	5,19	32,90%	30,90%	8,8	-36%	
Zafira 2010 DI Diesel HEV	5,18	34,80%	32,60%	9,4	-36%	
Zafira 2010 CNG ICE	7,00	25,80%	22,90%	11,4	-14%	
Zafira 2010 CNG HEV	5,42	33%	31,80%	9,1	-33%	
Zafira CH2 FC	**3,59**	56,60%	44,30%	10,7	**-56%**	
Zafira LH2 FC	**3,51**	56,60%	44,30%	10,4	**-57%**	
Zafira CH2 FC HEV	**3,31**	55,60%	48,90%	9,5	**-59%**	
Zafira LH2 FC HEV	**3,24**	55,60%	48,90%	9,3	**-60%**	

Quelle: GM WTW Studie auf www.lbst.de

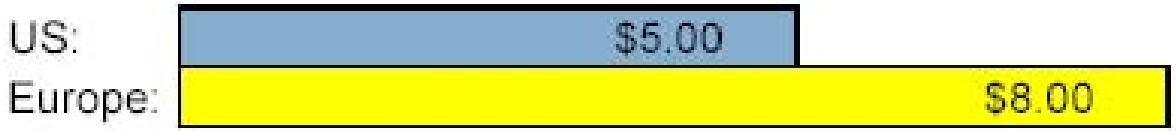
Hydrogen Cost at Pump

Cost Comparison for 100 km

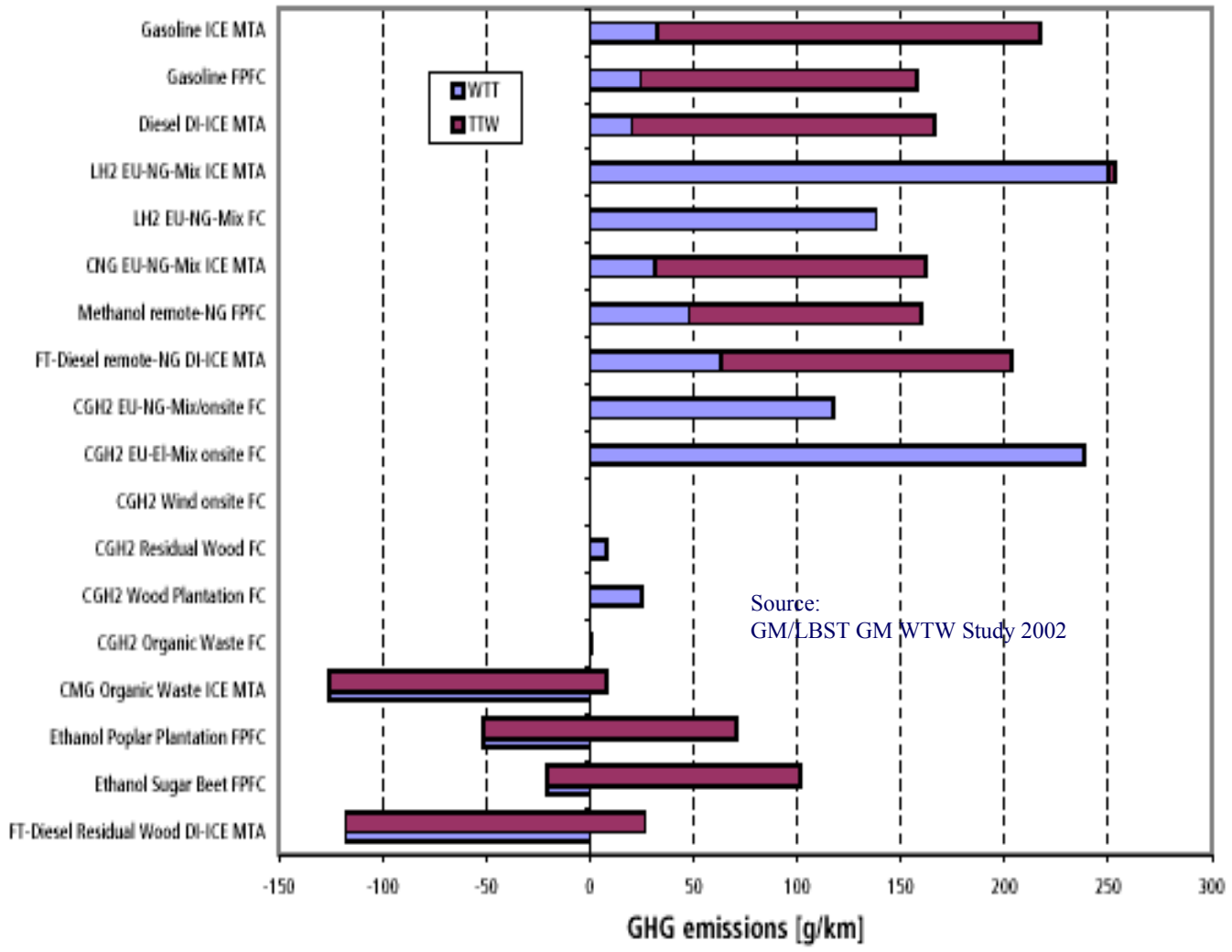
Gasoline

Hydrogen

Current GM purchase price (untaxed) :

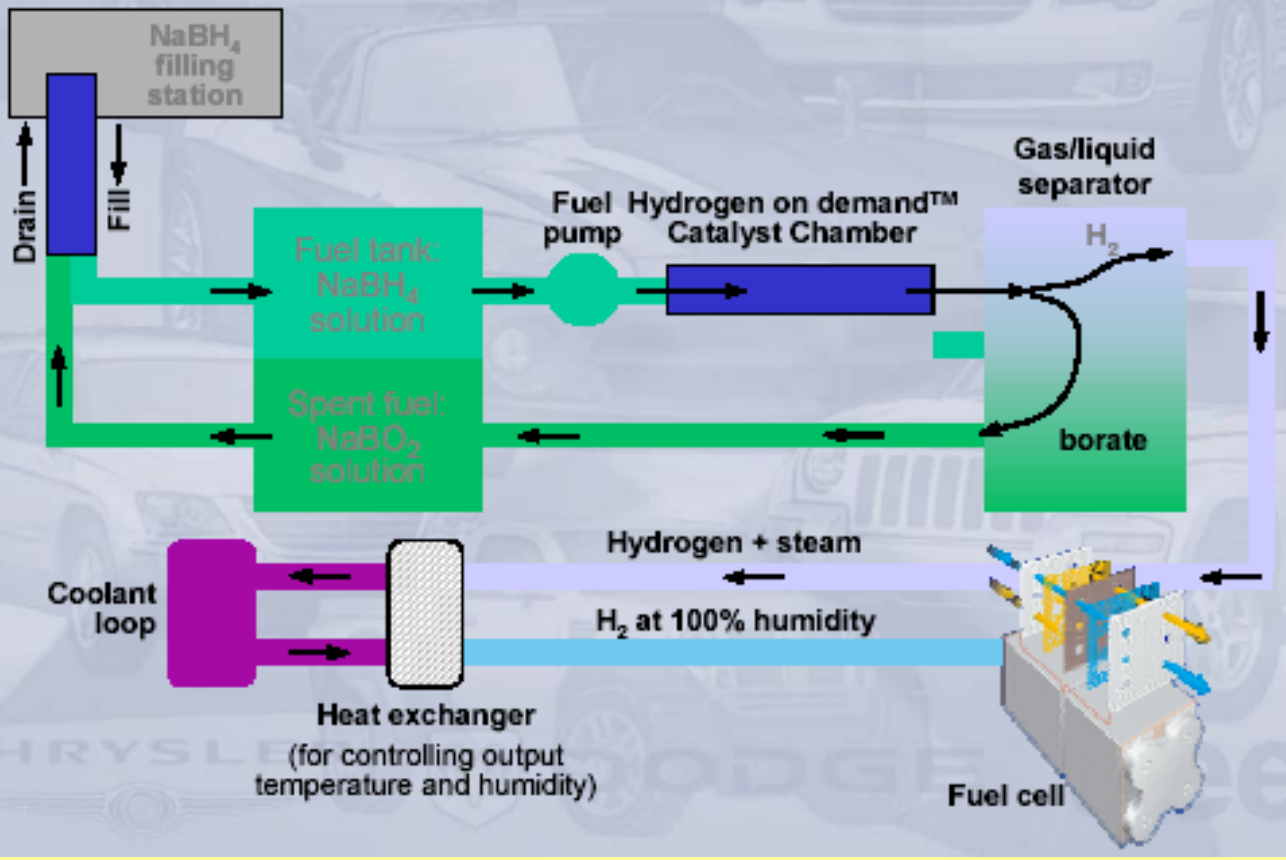


High likelihood for further cost reductions exists


Gasoline ICE MTA
Gasoline FPFC
Diesel DI-ICE MTA
LH2 EU-NG-Mix ICE MTA
LH2 EU-NG-Mix FC
CNG EU-NG-Mix ICE MTA
Methanol remote-NG FPFC
FT-Diesel remote-NG DI-ICE MTA
CGH2 EU-NG-Mix/onsite FC
CGH2 EU-El-Mix onsite FC
CGH2 Wind onsite FC
CGH2 Residual Wood FC
CGH2 Wood Plantation FC
CGH2 Organic Waste FC
CMG Organic Waste ICE MTA
Ethanol Poplar Plantation FPFC
Ethanol Sugar Beet FPFC
FT-Diesel Residual Wood DI-ICE MTA
WTT
TTW
-150
-100
-50
0
50
100
150
200
250
300
GHG emissions [g/km]
Source:
GM/LBST GM WTW Study 2002

Environmentally Conscious

Hydrogen on demand™ – Schematic.



Fuel - Infrastructure

- Changeover of 33 % of petrol stations in NY, Massachusetts, California:

  - **to hydrogen** **ca. 1,4 Mrd US$**
  - **to methanol** **ca. 0,4 Mrd. US$**

Quelle: ZSW

6. Development of costs

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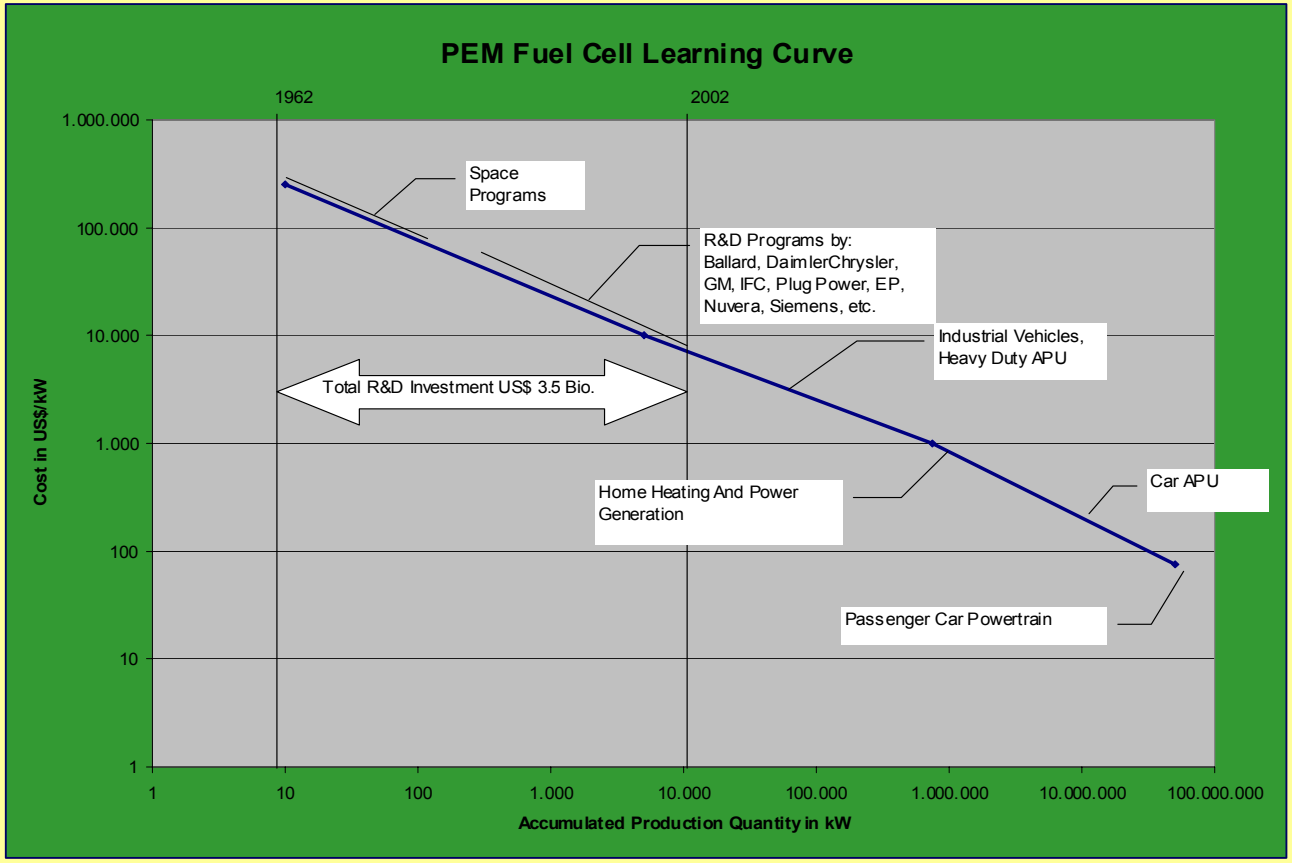
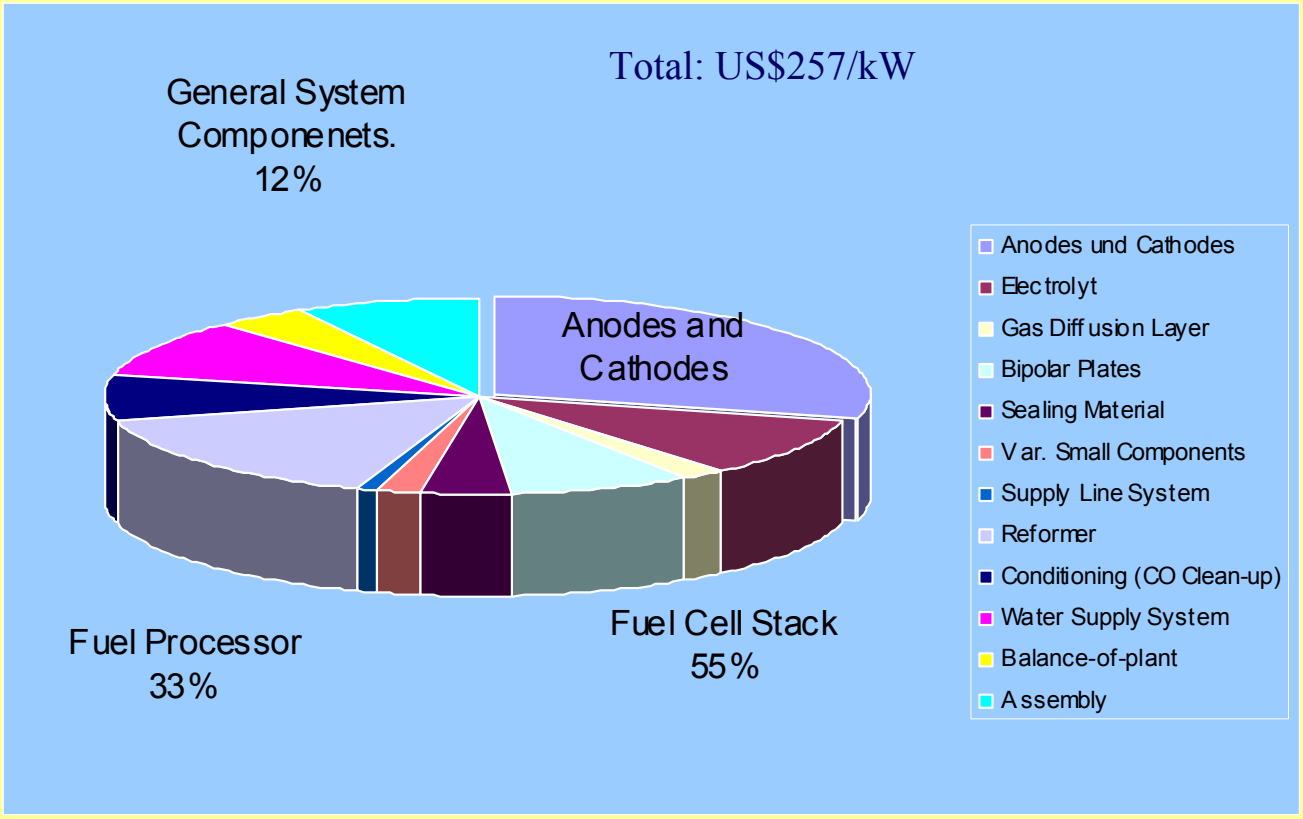
PEM Development of costs Extrapolation



Quelle: INTEMA, H. Wancura

Costs of a Fuel Cell System

(50kW, 500.000 units per year)



Source: A. D. Little, Cambridge, MA

Preview to market launch

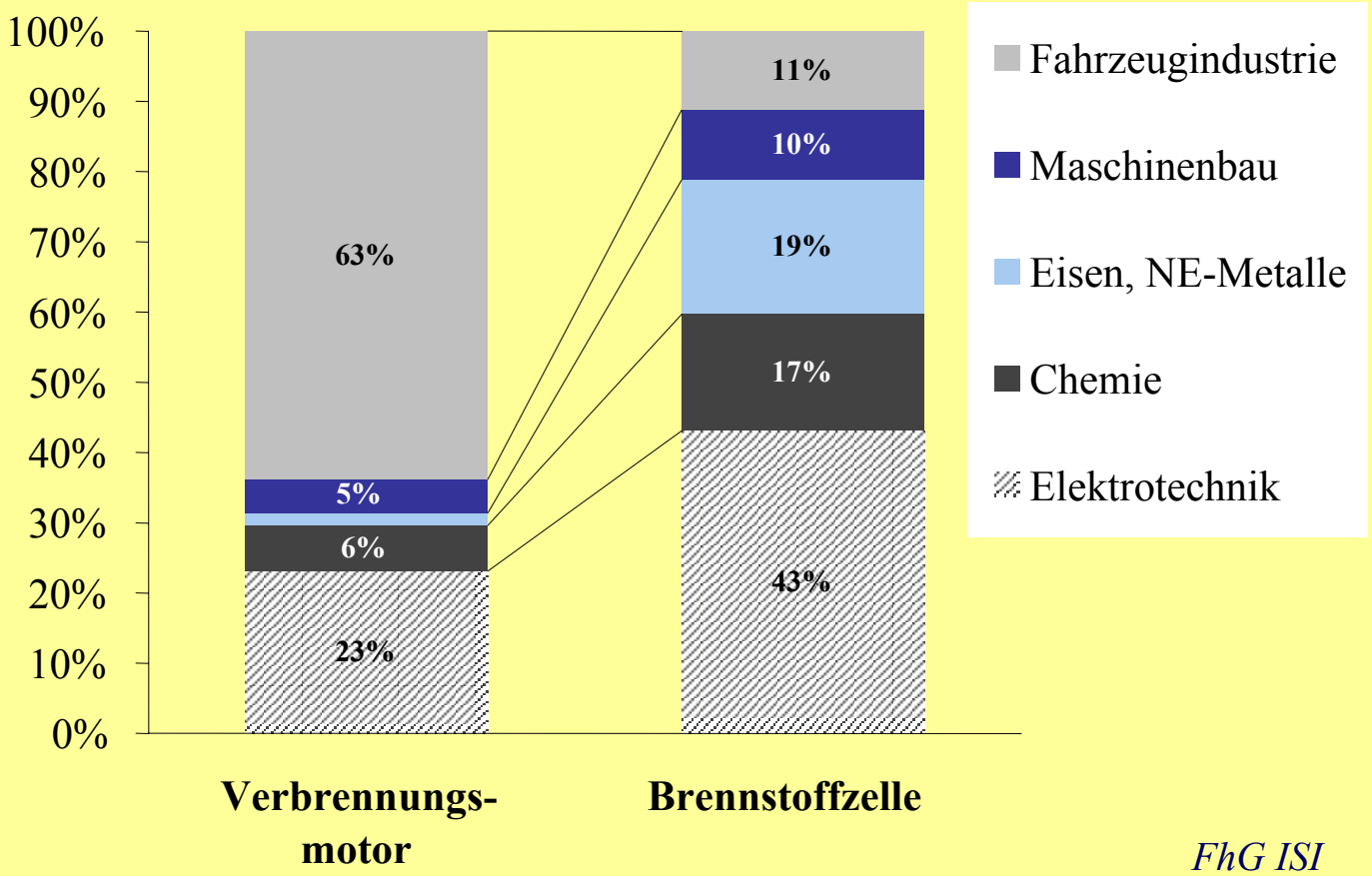
Portables: 2005 already mass production at market, if fuel infrastructure problems are solved

APU: RR , Maybach etc. already offer fc, 2005 - 2008 Launch for heavy duty trucks.

Pkw: 2003/5 first fc‘s launched, e.g. Honda has insert an advertisement at LH-flightjournal: 2008 - 2010 mass production

7. Influence on the automotive industry

Change of supply industry



FhG ISI


Repackage Vehicle Around Fuel Cell Powertrain
GM
AUTONOMY

8. Summary

Executive summary

- Fuel cells will always offer highest efficiencies
- Costs are steadily decreasing
- Present uncertainty belongs to low maturity of technology