Zentrum für BrennstoffzellenTechnik GmbH

Kunststofftechnik in Brennstoffzellensystemen

Chancen und Herausforderungen

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www.h2fc.center

GKV Tagung, Heidelberg, 13.-14.09.2018

Agenda

Struktur

- Vorstellung ZBT
- Batterie oder Brennstoffzelle? Hauptsache Elektromobilität?
- Brennstoffzelle: Marktsituation und Kostenfragen
- Aufbau von Brennstoffzellensystemen / Technologiestatus
- Kunststoffe im Brennstoffzellensystem

Zentrum für BrennstoffzellenTechnik GmbH: The hydrogen & fuel cell center

Facts

- Established in 2001
- Research and development:
  fuel cells, hydrogen and battery technology
- Focus on industry demand
- Independent service provider and R&D partner
- Share holder: University of Duisburg-Essen
- ~ 90 full time employees + 20 students

Infrastructure:

- 1200 m^2 laboratory
  - Flexible test benches
  - Advanced measurement and analytics
  - Chemical laboratories
- Modern CAE & Simulation tools
- 500 m^2 technical center / production technologies
  - Injection molding/compound laboratory
  - Gasket production site
  - Mechanical workshop

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EUROPEAN UNION
Investing in our Future
European Regional Development Fund

ZBT – The hydrogen and fuel cell center
Our main application targets

ZBT supports the establishment of hydrogen as energy carrier as core vector towards the energy transition and sustainable mobility

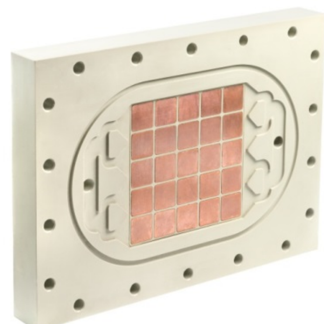
Automotive fuel cells

HRS technologies and quality

Energy conversion

Portable power

Stationary and UPS
Power supply

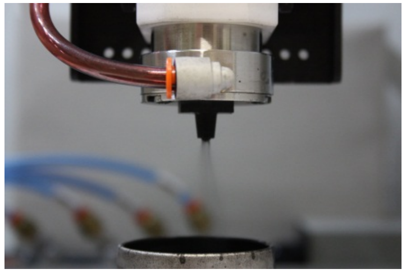


Battery technologies

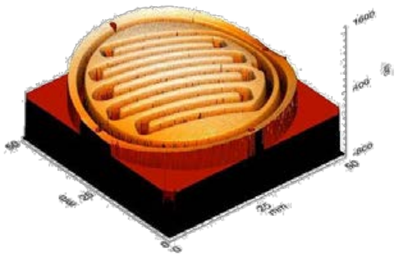
Electrolysis

ZBT – The hydrogen and fuel cell center
Our main working fields & methods

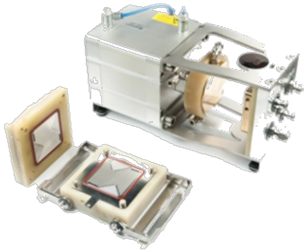
ZBT supports industry on their pathway to commercial products from the invention to the innovation



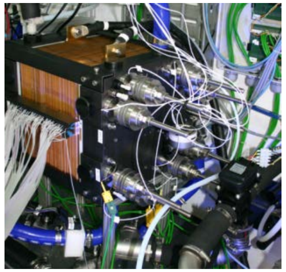
Advanced electrochemistry



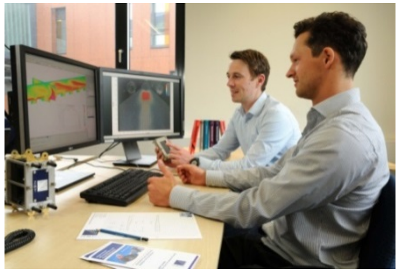
Ex-Situ qualification and QS-methodolgy



In-situ qualification



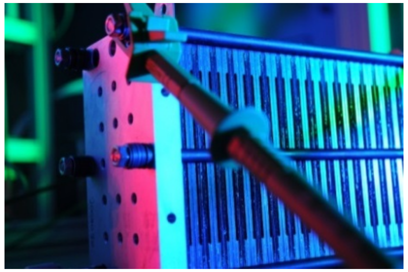
Product near component qualification



Computer aided design (CAD, CAE, CFD)

Production process development

Prototyping and pre-series production



RCS / Norms and standardisation

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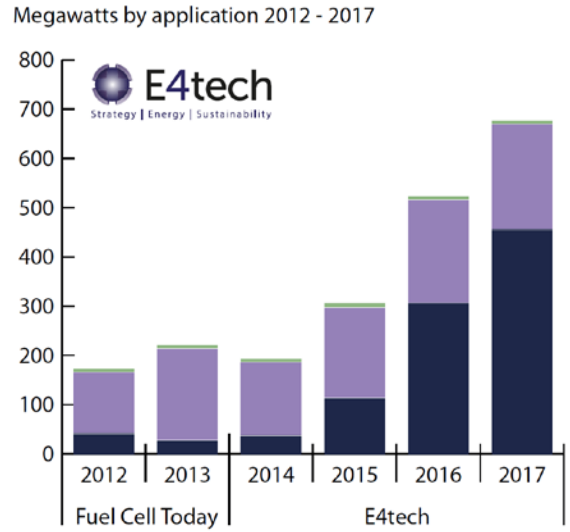
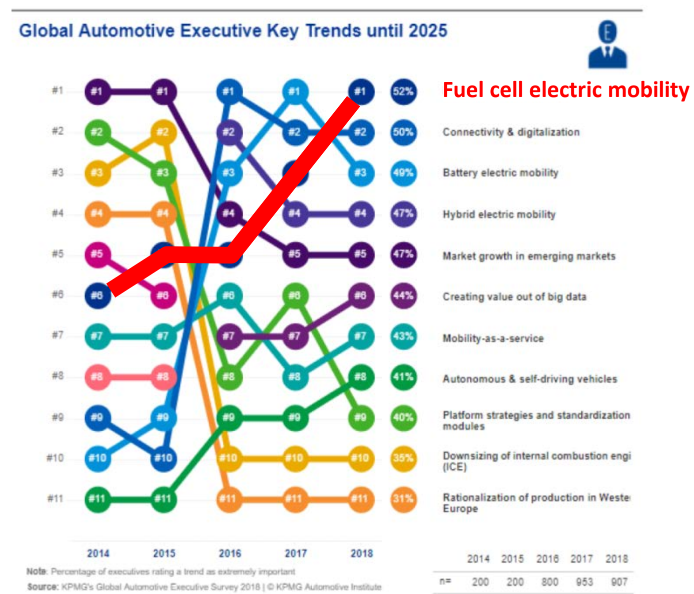
Applications of fuel cells
Worldwide market overview

- More than 260.000 fuel cell µCHP units installed in Japan
- > 235 MW large stationary fuel cells operating in the US
- More than 16.500 fuel cell powered material handling vehicles in the US
- More than 8.500 fuel cell backup power installations
- > 7.000 fuel cell vehicles sold
- Fuel cell vehicle targets
  - Japan: 2025: 200.000 2030: 800.000
  - China: 2025: 50.000 2030: 1.000.000
  - Korea: 2025: 100.000 2030: 600.000
- 500 fuel cell busses currently on the road
- Fuel cell trains already cost competitive with diesel trains on a TCO perspective

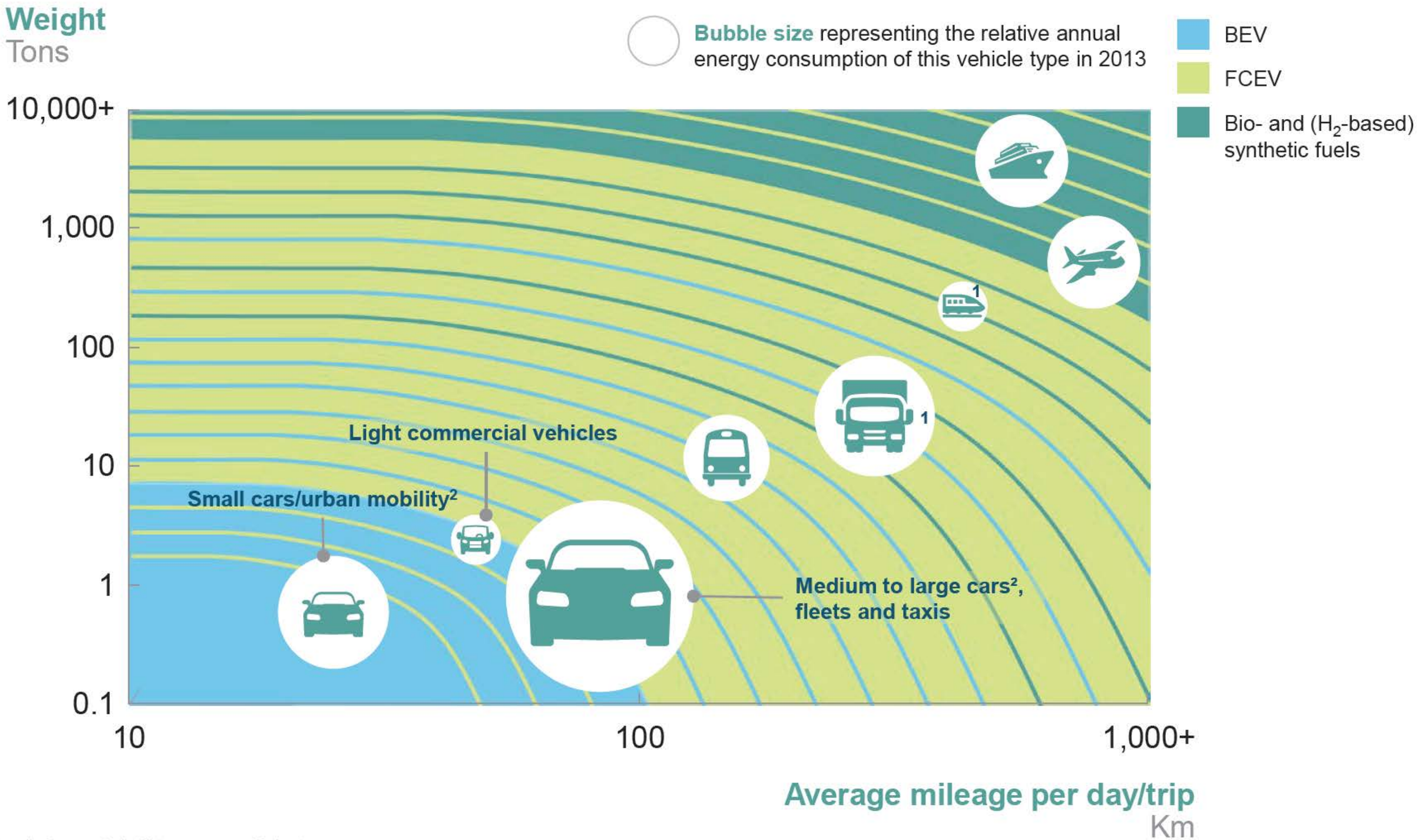


Toyota:
>30.000 FCV/a in 2020:
~3.500MW



Sources: DOE, http://www.ace.or.jp/web/works/works_0090.html, Hydrogen Council 2017, e4tech, KPMG

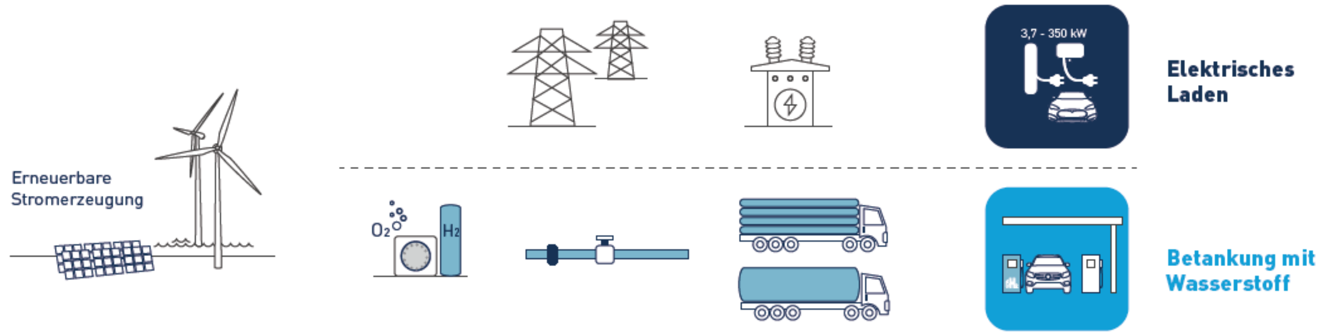
Powertrain technology options for different transport modes

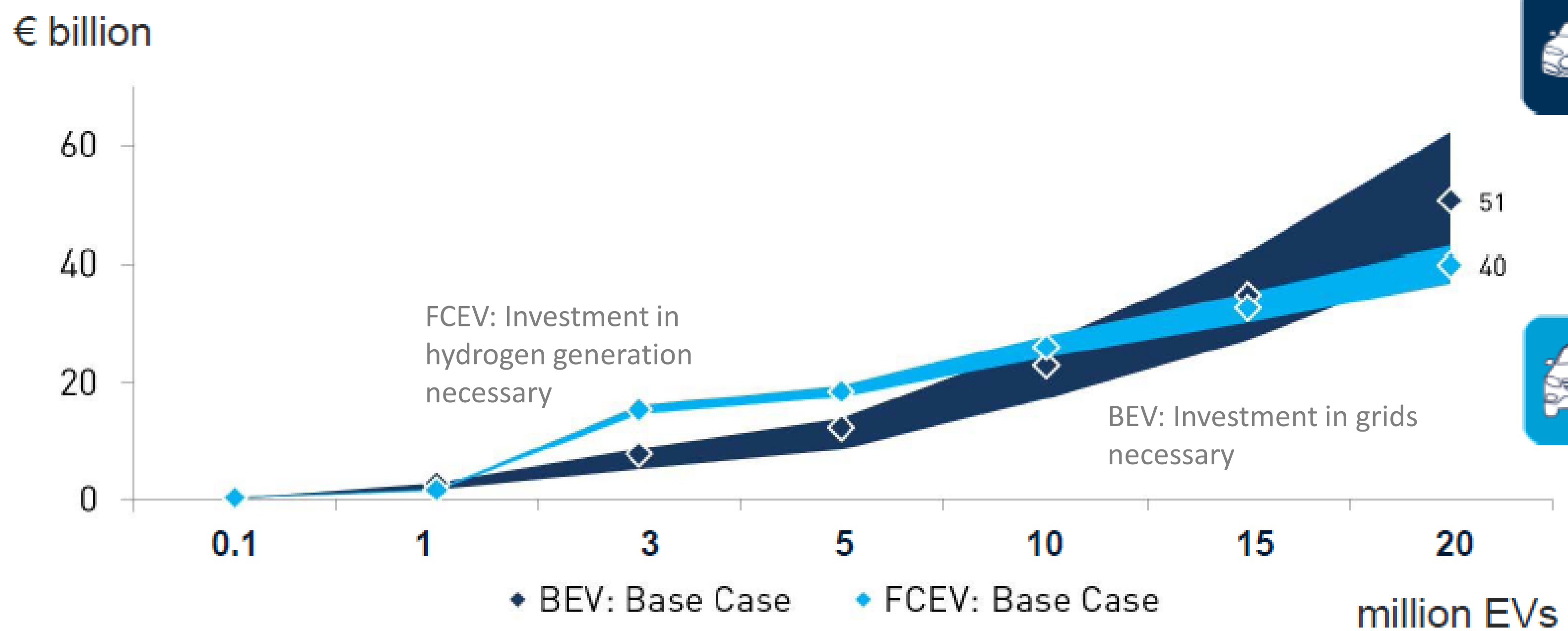


1 Battery-hydrogen hybrid to ensure sufficient power
2 Split in A- and B-segment LDVs (small cars) and C+-segment LDVs (medium to large cars) based on a 30% market share of A/B-segment cars and a 50% less energy demand

Source: Daimler, Honda, Hyundai, Toyota, BMW, Kawasaki, Alstom, Shell, Total, Linde, Air Liquide, Anglo American, Engie, Hydrogen Council 2017
Pictures: Toyota, Alstom, e4ships, ecowatch.com, DLR, Airbus

Automotive fuel cell systems: Feasibility of infrastructure scenarios





Sensitivity:

Top // larger batteries with 100 kWh dominate in the long run (base case +100 kWh)
Bottom // no fast charging at 350 kW in cities

Top // base case +20% investment in stations
Bottom // base case -20% investment in stations

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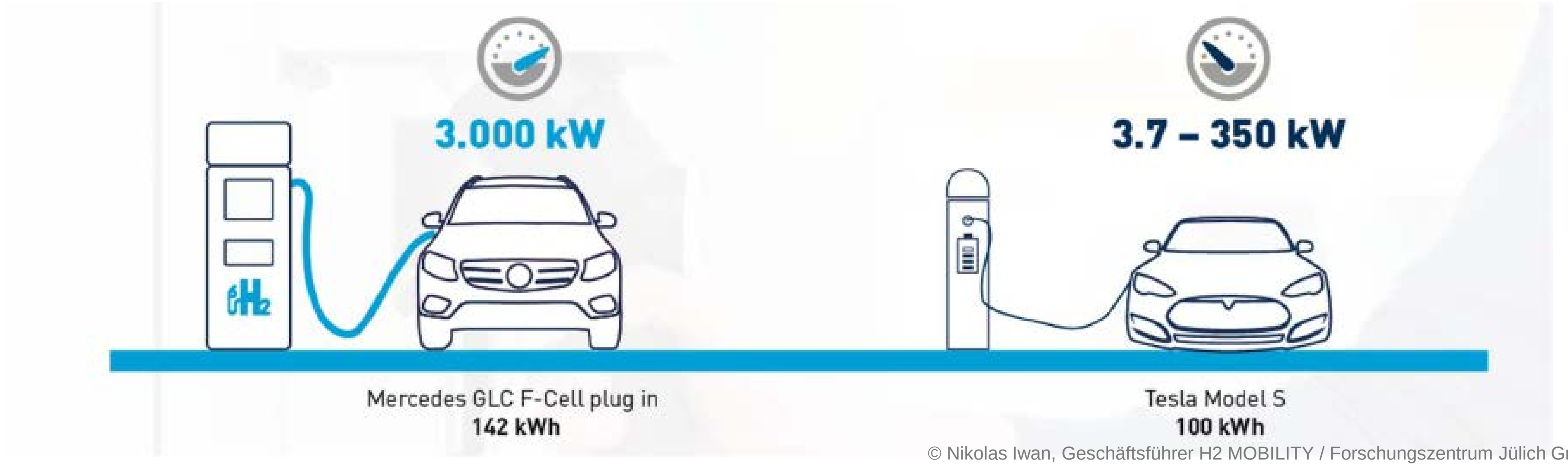
http://h2-mobility.de/news-und-infos/vergleichende-infrastrukturanalyse/

Automotive fuel cell systems: Feasibility of infrastructure scenarios



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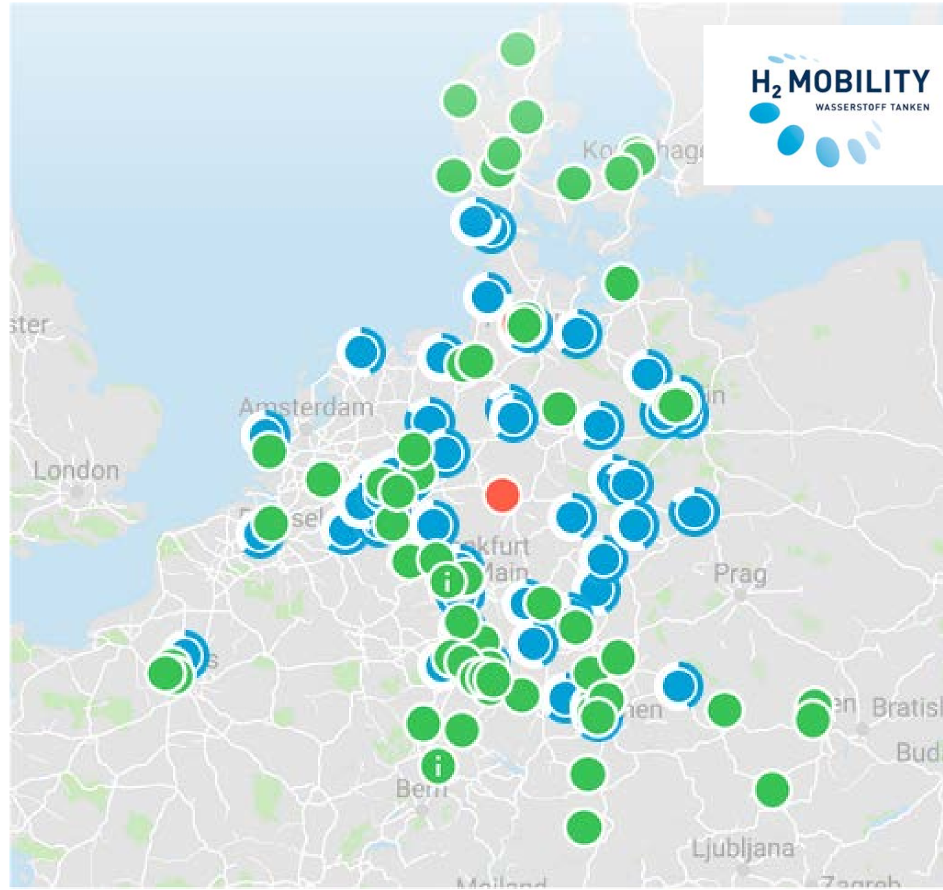
https://www.linkedin.com/pulse/five-teslas-waiting-line-supercharger-david-wenger/

Automotive fuel cell systems: Setup of hydrogen refuelling stations in Germany

H2 MOBILITY

- Air Liquide, Linde, OMV, Shell, TOTAL and Daimler – the companies behind H2 MOBILITY are sharing their skills to advance the hydrogen infrastructure.
- Status August 2018: 46 Stations in operation (Germany)



64 8 In Betrieb 51 In Realisierung

Automotive fuel cell systems: OEMs pushing for market introduction

Toyota:

- 500 fuel cell developers
- 150M€ investment in additional manufacturing capacities
- Further fuel cell activities Toyota Group: Busses (Hino), forklifts (Toyota Industries), CHP (Aisin Seiki), refuelling stations (Toyota Tsusho)

Tokyo/Japan:

- Tokyo: 330M€ for 6.000 FCVs/35 stations in 2020
- Tokyo: 100.000 FCVs/100buses/80 stations in 2025
- Subsidies: Government 2 Mio Yen / Tokyo 1 Mio. Yen

Hyundai:

- 2013 to 2015: 1.000 ix 35 FCVs

Honda:

- Market introduction of new FCV in 2016 in Japan, USA and Europe

Cooperations:

- GM/Honda
- Toyota/BMW and Toyota/Mazda
- Daimler/Ford/Nissan
- VW/Ballard





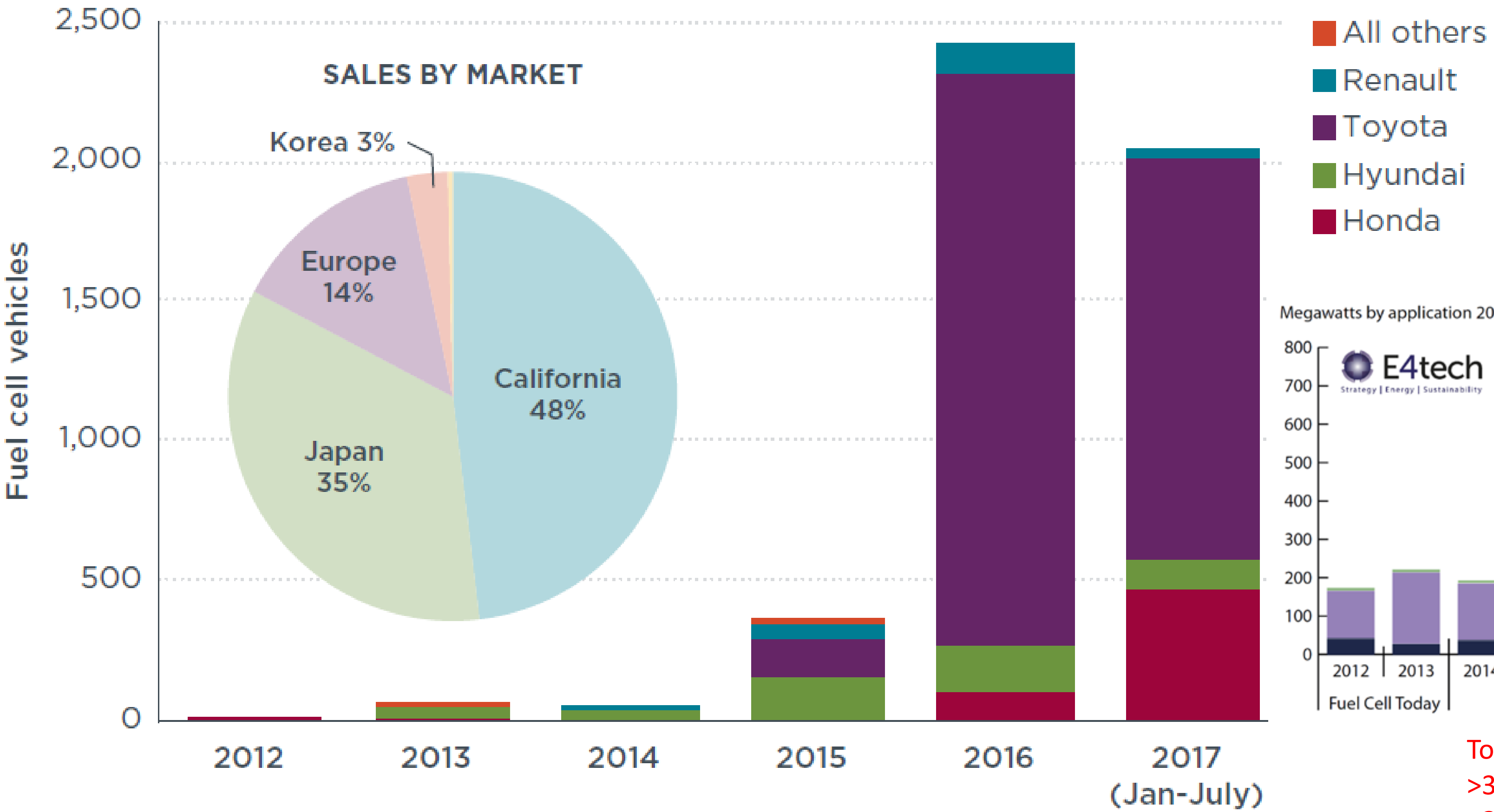


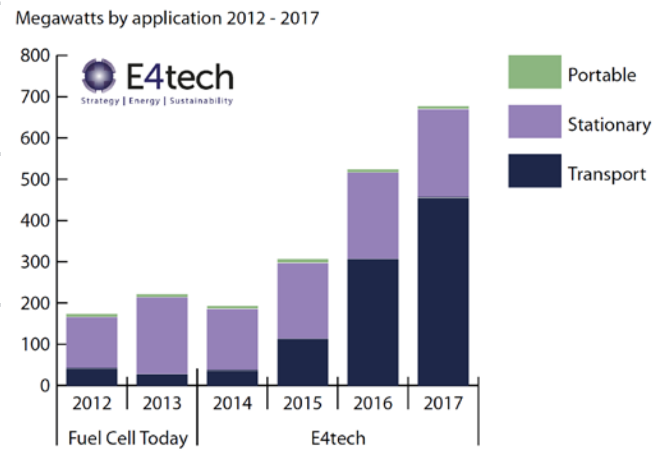






Quellen: Toyota, Honda, Hyun dai, Daimler, GM, VW, BMW, Lexus, Evobus, Hino, Tata, vanHool





Toyota:
>30.000 FCV/a in 2020:
~3.500MW

Figure 1. Fuel cell vehicle deployments for 2012 through mid-2017, by company and locale.

Source: Developing hydrogen fueling infrastructure for fuel cell vehicles: A status update, ICCT Briefing October 2017

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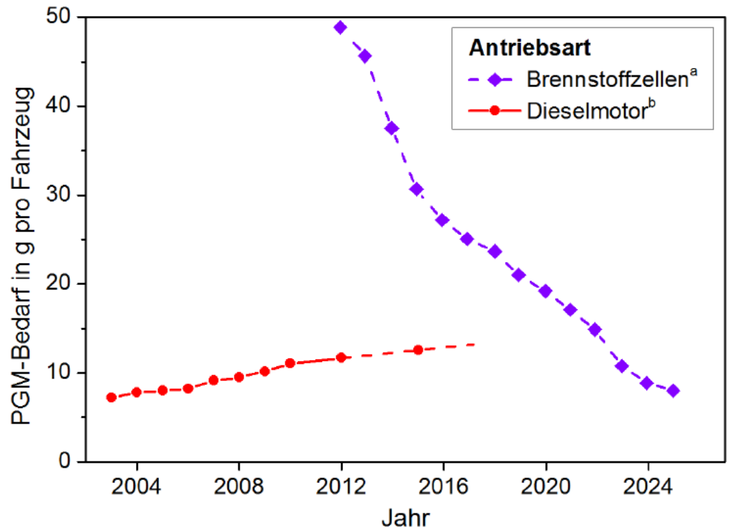
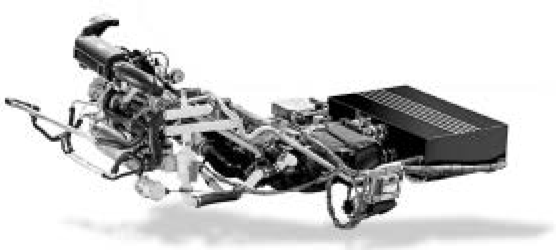
New Powertrains require new materials: Platinum is no longer a show stopper for FCEVs



[a]: The impact of widespread deployment of fuel cell vehicles on platinum demand an price, Intern. Journal of Hydrogen Energy 2011, 36, 11116-11127

[b]: Global PGM Outlook, RBC Capital Markets 2013, http://www.resource-capital.ch/fileadmin/research/fremde/Heinz_Isler_Juli2013/Global_PGM_Outlook_RBC_28.6.13.pdf

Source: DLR, Prof. Friedrich, Batterie oder Brennstoffzelle – was bewegt uns in Zukunft?, 2014



2010: Underfloor package
206 g Platinum
4 kW / m² active area
Screw compressor

2017: Compartment package
20 g Platinum
9 kW / m² active area
Electric turbo charger with turbine

Source: Daimler

- Platinum loading of automotive fuel cell stacks could be reduced by more than **90%** in the latest fuel cell vehicles compared to 2010 technology status
- Current fuel cells require not much more platinum than catalytic converters of a conventional car
  - Daimler GLC: 20g
  - GM lab system: 12g
  - Catalytic converter diesel: 6-8g
- Development continues to further reduce platinum demand
- Platinum is no longer a show-stopper for FCEVs

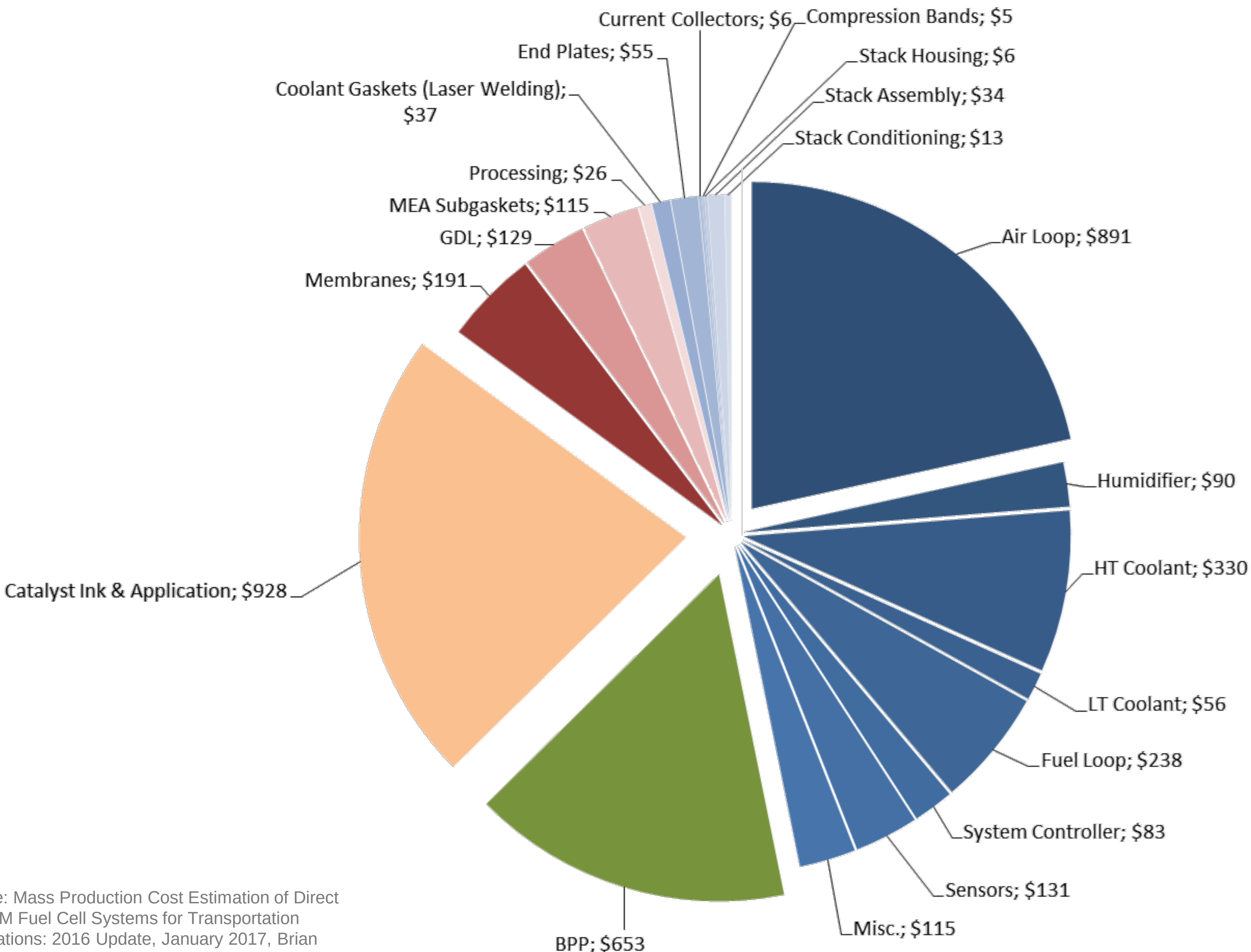
New Powertrains require new materials: Critical raw materials with high supply risk have to be evaluated

Raw material	Main producers (2014-2015)	Main sources of imports into the EU (mainly 2012)	Substitutability index	End-of-life recycling input rate
Critical raw materials used in Li-ion batteries				
Cobalt	Democratic Republic of Congo: 51 % China: 6 % Russia: 5 % Canada: 5 % Australia: 5 %	Russia: 96 % (cobalt ores and concentrates) USA: 3 % (cobalt ores and concentrates)	0.71	16 %
Natural graphite	China: 66 % India: 14 % Brazil: 7 %	China: 57 % Brazil: 15 % Norway: 9 %	0.72	0 %
Silicon metal	China: 68 % Russia: 8 % USA: 5 % Norway: 4 %	Norway: 38 % Brazil: 24 % China: 8 % Russia: 7 %	0.81	0 %

- Massive increase in Li-Ion battery production will require sufficient raw material supply
- Some of these materials have a high economic importance while at the same time have a high supply-risk and are termed "critical raw materials (CRM)"
- Li-Ion battery materials cobalt, natural graphite and silicon metal are listed as CRMs by the European Commission
- Detailed JRC Science for Policy Report available

Source: JRC Science for Policy Report Lithium ion battery value chain and related opportunities for Europe

Automotive fuel cell systems:
US DOE automotive fuel cell system cost analysis: Overview



Source: Mass Production Cost Estimation of Direct H2 PEM Fuel Cell Systems for Transportation Applications: 2016 Update, January 2017, Brian James, Strategic Analysis

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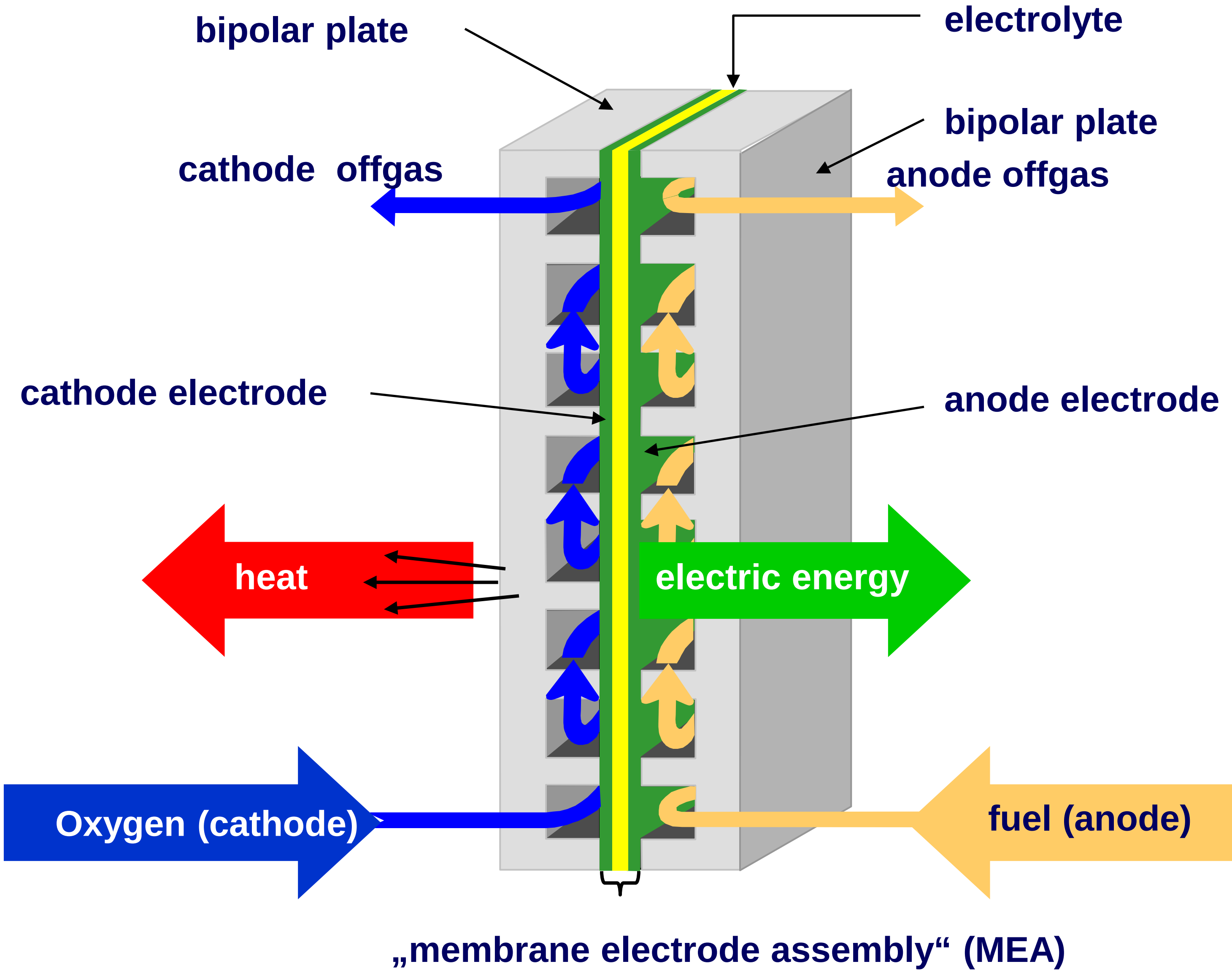
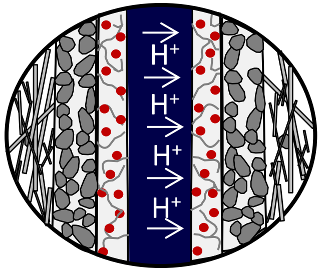
Fuel cell basics: fuel cell
Schematic layout



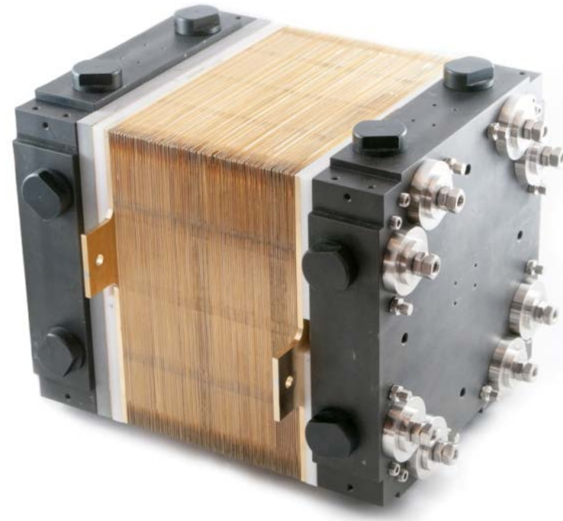


source: VKA, RWTH-Aachen

Fuel cell basics:
ZBT fuel cell stacks

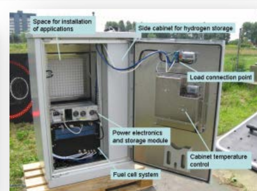




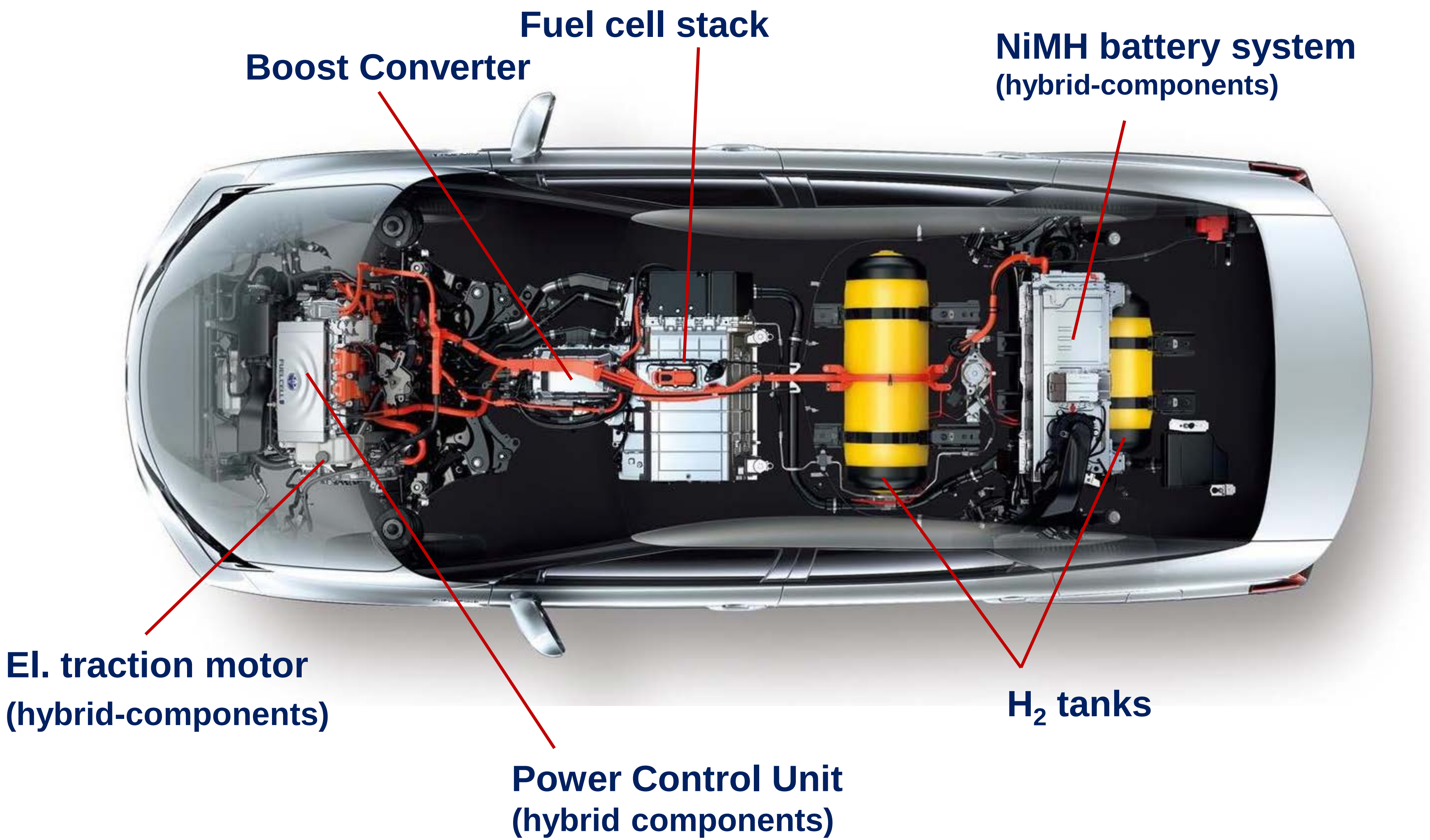


Typ	Portable	APU / light drive	UPS / stationary	Light traction	Range extender
Power range	<10 W	<1 kW	1 - 4 kW	1 - 10 kW	10 - 40 kW
Construction	Grafite AC	Grafite AC/LC	Grafite AC	Metal LC	Metal LC



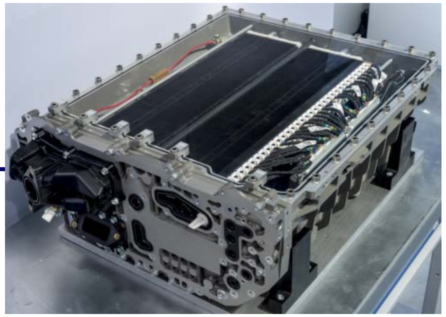


Technology benchmarking: Toyota Mirai
Powertrain configuration



Quelle: Toyota

Technology benchmarking: Toyota Mirai
Specification fuel cell stack



PEM fuel cell stack

- 114 kW (3.1 kW/l)
- 37 l / 56 kg
- 370 cells
- 102 g/cell; 1,34 mm cellpitch
- No cathode humidification
- -30 °C freeze start

Boost converter

- 650 V output voltage
- 4 phase, water cooled
- 13 l

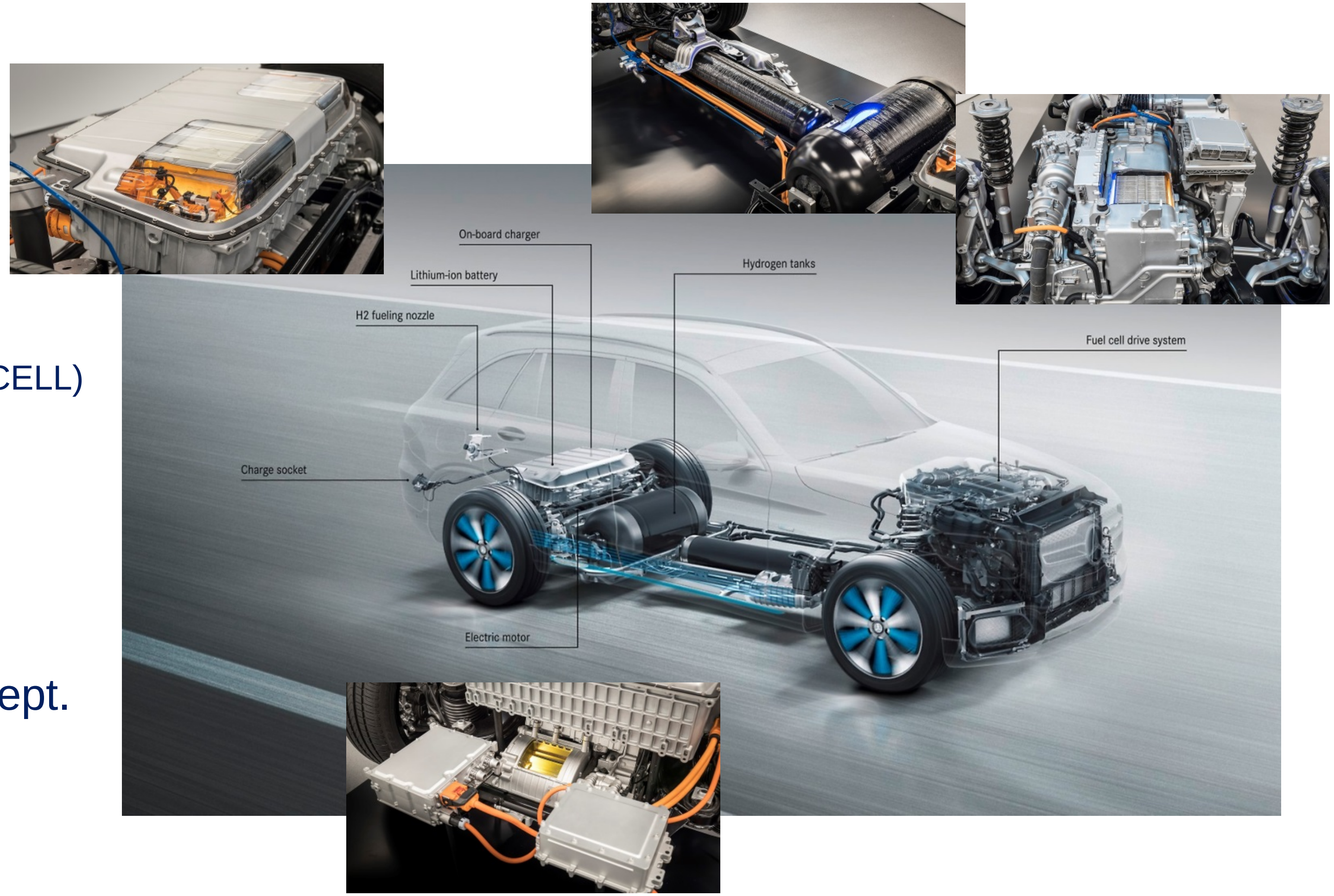
Quelle: Toyota

BOP components

- H_2 recirculation pump

Automotive fuel cell systems
Technology benchmark Daimler GLC F-CELL

- Stack
  - 400 cells
- H2 Storage
  - 700 bar / 4,4 kg
  - 3 mins refuelling
- FC System (comp: A-class F-CELL)
  - 30 % more compact
  - 40 % more drive power
  - 90 % less platinum
  - 25 % less weight
  - Fits into conv. Engine dept.
- Li-Ion Pack
  - 13,8 kWh
- Drive train:
  - 350 Nm torque / 147 kW / 200 PS
  - 437 km @ H2 (NEDC in Hybrid Mode) + 49 km electric (NEDC in Battery Mode)



23-7-18 https://www.daimler.com/innovation/case/electric/fuel-cell-hydrogen-electromobility.html

Automotive fuel cell systems
Technology benchmark Daimler GLC F-CELL

- Development and Pre-Series
  - Nucellsys Nabern / MB Tech center Sindelfingen: FC Unit and Hydrogen storage
- Series Production
  - Produced at MB Bremen
  - EDAG Bremen supports on drive system integration
  - Daimler Untertürkheim: FC System
  - MB Mannheim: Hydrogen tank system
  - MB Fuel Cell (Vancouver): Stack
  - Accumotive Kamenz: Lithium ion battery

23-7-18 https://www.daimler.com/innovation/case/electric/fuel-cell-hydrogen-electromobility.html

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Sealings for fuel cells: Functions, features and requirements

Primary sealing functions:

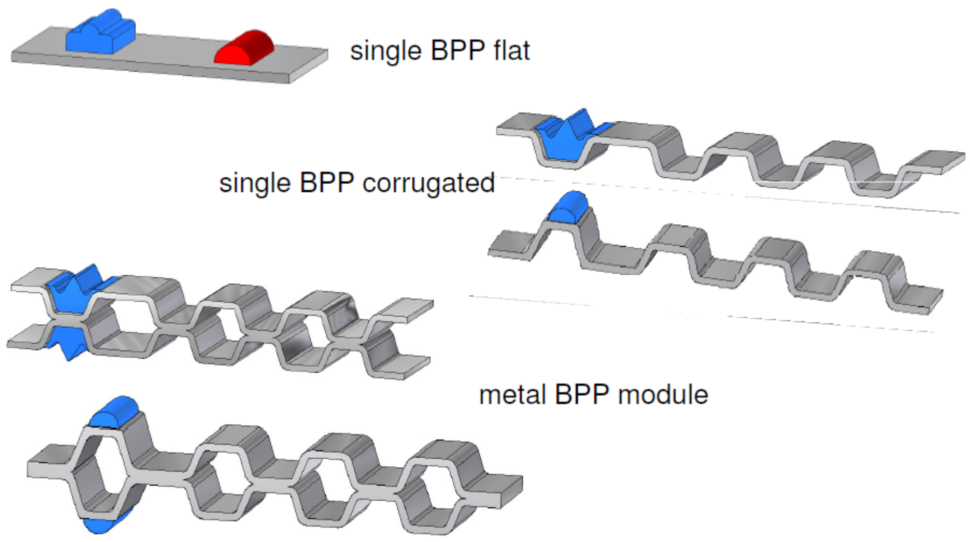
- Prevent leakage
- Prevent cross-over
- Compensate manufacturing tolerances, thermal expansion & distortion

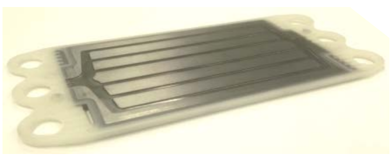
Requirements:

- Electrical isolation
- Electrochemical inertness
- Withstand fuel cell environment
  - Humid & acidic conditions
  - Temperature

Additional features:

- Ease/robustness of assembly
- Reduction of parts or process steps
- QA ability



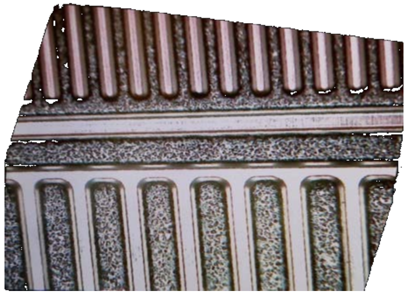


Injection molded seal (ZBT)

Dispensed seal (ZBT)

Screen printed seal (ZBT)

Cost efficient production technologies for fuel cells
Project Low Cost Bip: Bonding of metallic bipolar plates



Bonding of metallic bipolar plates requires:

- Minimum hydrogen diffusion
- High electric conductivity
- Media compatibility
- Minimization of contact area and bonding height
- Application suitable for high-volume production
- No effects on fuel cell degradation

Project partners:

VOLKSWAGEN AKTIENGESELLSCHAFT

GRAEBENER MASCHINENTECHNIK www.graebener-maschinentechnik.de

ZBT

Jowat Klebstoffe

HARDO

ifs

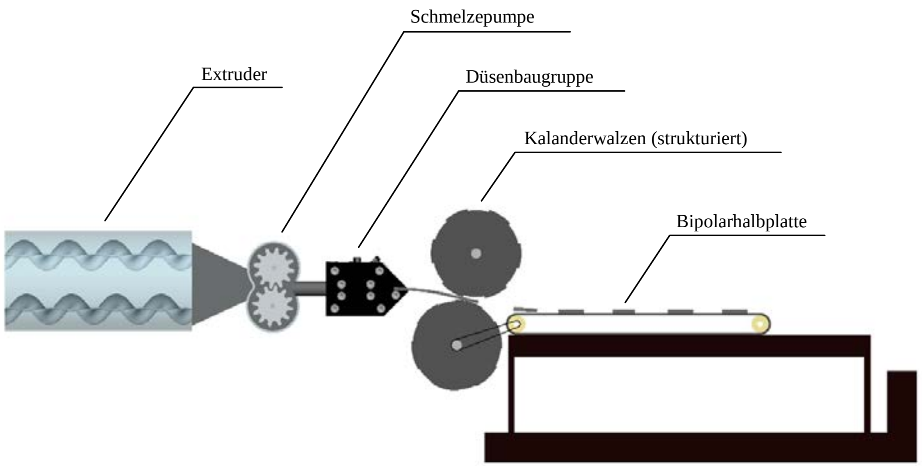
Gefördert durch:

Bundesministerium für Wirtschaft und Energie

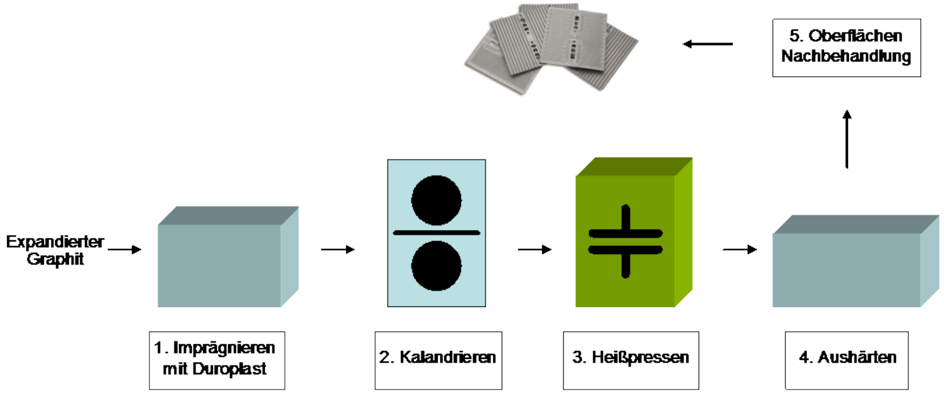
aufgrund eines Beschlusses des Deutschen Bundestages

ZBT stack development: Bipolar plates
Development of graphitic bipolar plates

- Development of thin, flexible graphite foils for high power density applications
- Integrated, fast production process
- Homogenous material with superior electrical and thermal properties
- High corrosion resistance of graphitic material



→ combines advantages of metallic and graphitic materials



source:GrafTech International. adapted

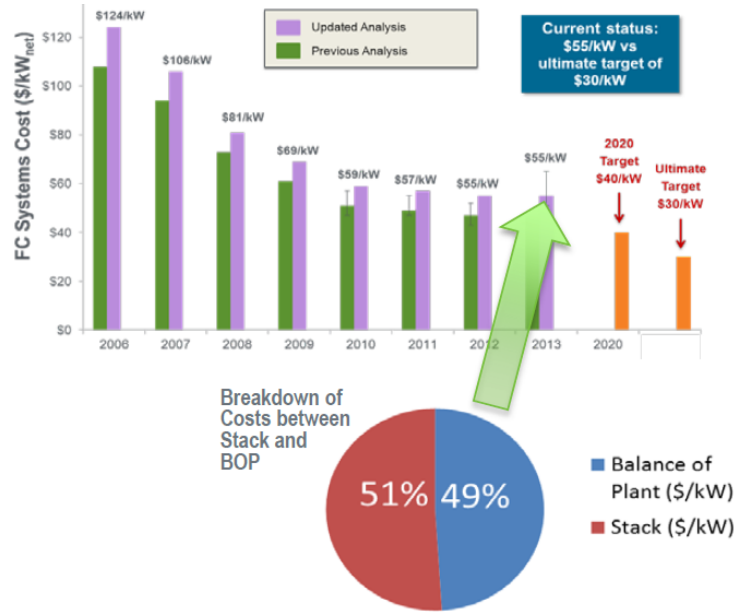
Degradation of fuel cell stacks: System components

Source: National Renewable Energy Laboratory (NREL) U.S Department of Energy

- System components: Air compressor, coolant pump, H_2 recirculation pump, valves, tubes (hoses), sensors, gaskets (seals), etc.
- Different types of materials, different requirements for the materials (anode, cathode, cooling)

Degradation of fuel cell stacks: System components

- **Balance of plant (BOP) costs have risen in importance with decreasing stack costs.**
  - **Decrease overall fuel cell system costs by lowering BOP material costs.**



- **System contaminants have been shown to affect the performance/ durability of fuel cell systems.**
  - **Increase performance and durability by limiting contamination related losses**

Extremely extensive and complex

Examples of common additives in automotive thermoplastics:

- Glass fiber
- Antioxidant
- UV Stabilizer
- Flame retardant
- Processing aids
- Biocides
- Catalysts
- Residual polymer
- Residual solvents

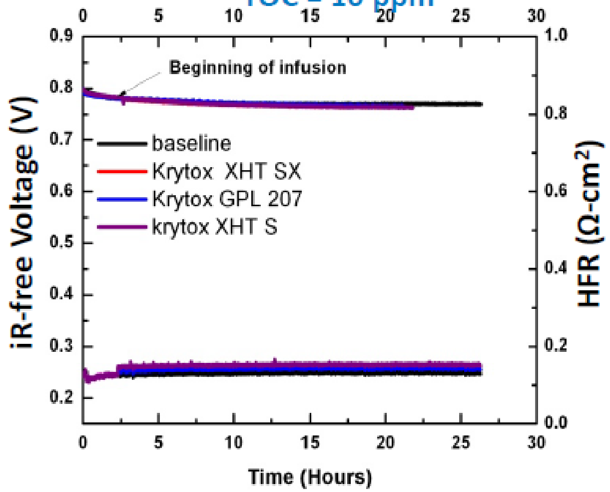
Record Source: http://www.hydrogen.energy.gov/pdfs/13012_fuel_cell_system_cost_2013.pdf

NREL fuel cell contaminant database: In-situ testing

In-situ infusion screening for impact on fuel cell performance (at 0.2 A/cm²)

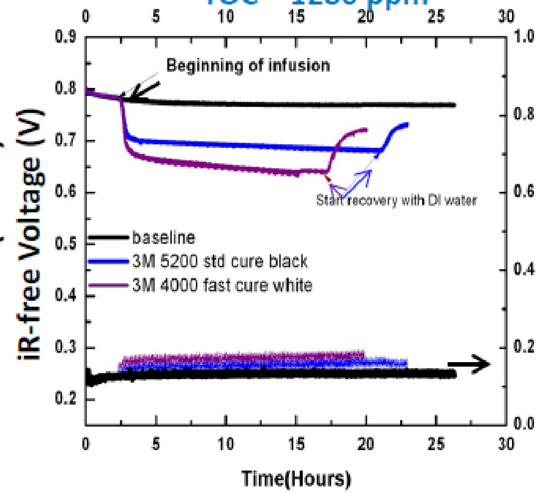
PFAE/PTFE example

TOC = 10 ppm



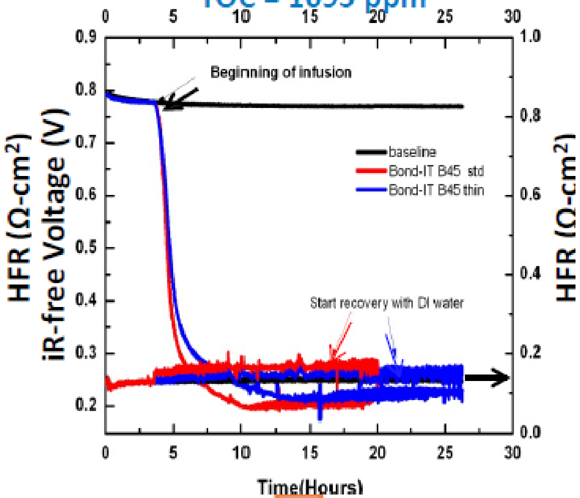
Urethane example

TOC = 1280 ppm



Epoxy example

TOC = 1695 ppm



Material Classification by Result

clean

Contaminates, partially recovers

Contaminates, Does not recover

System contaminants can have an adverse effect on fuel cell performance, but the effect is complex. Some contamination are recoverable while others are not.

Source: National Renewable Energy Laboratory (NREL) U.S Department of Energy

BMWi project VALIDATE: Motivation and goals

Motivation:

- Materials used in system components can lead to power losses of fuel cells
- The current material selection is restricted
- Uniform test methods for the qualification of new materials for fuel cell applications are missing

Project goals:

- Qualification of materials for fuel cell applications
- Expansion of usable materials
- Standardize test methods for materials used in fuel cell systems

System Contaminants Originate From the System Itself

Source: National Renewable Energy Laboratory (NREL) U.S Department of Energy

VOLKSWAGEN AKTIENGESELLSCHAFT

SGS

INSTITUT FRESENIUS

ZBT

Supported by: 03ET6057

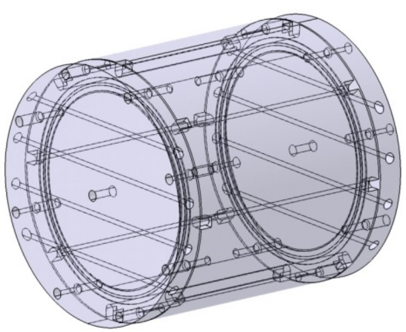
Federal Ministry for Economic Affairs and Energy

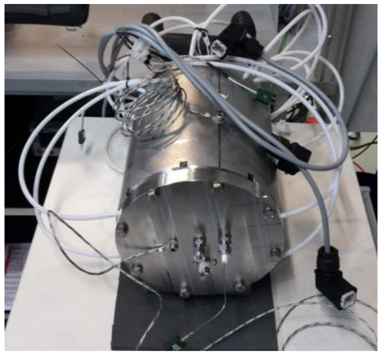
on the basis of a decision by the German Bundestag

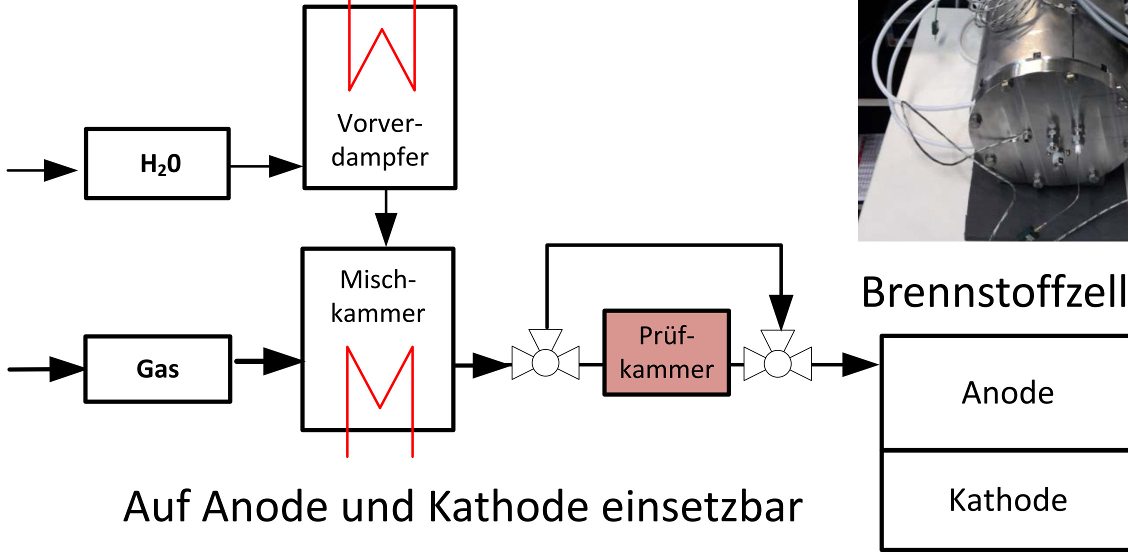
Prüfkammer

Messungen an Testzellen mit vorgeschalteter Prüfkammer für Materialproben

- Einsatz vor Anode oder Kathode
- Möglichkeit zum Bypass
- Temperierkammer für Betrieb < 200 °C
- Kammer kann mit unterschiedlichen Gasen (Luft, H_2, …) bei unterschiedlichen Temperaturen, Drücken und relativen Feuchten bis zur Betauung beaufschlagt werden
- Medienberührenden Teile sind ausschließlich Edelstahl 1.4571 und PTFE
- Aufnahme unterschiedlicher Testmaterialien (Metalle, Kunststoffe, …)
- Anzahl der Proben ist flexibel
- Testkörper hat „Knochenform“







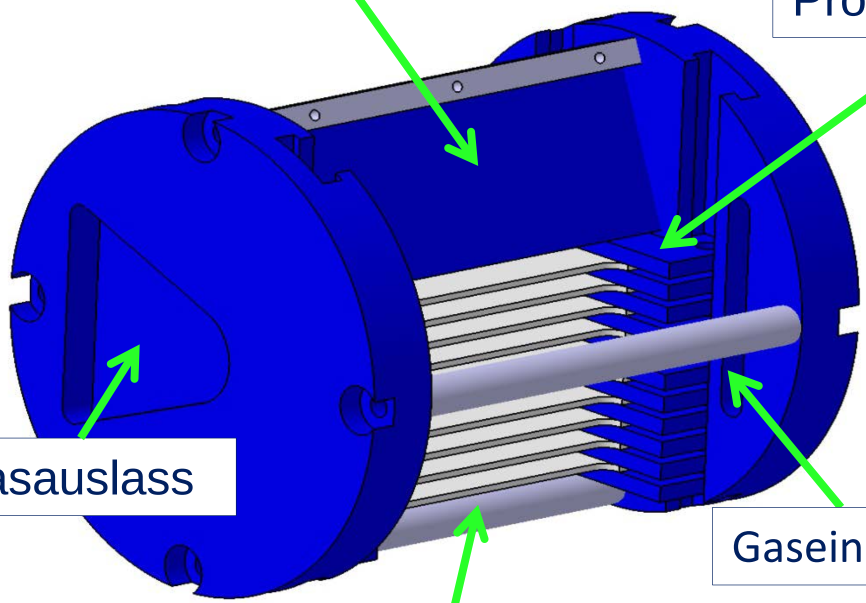
Prüfkammer

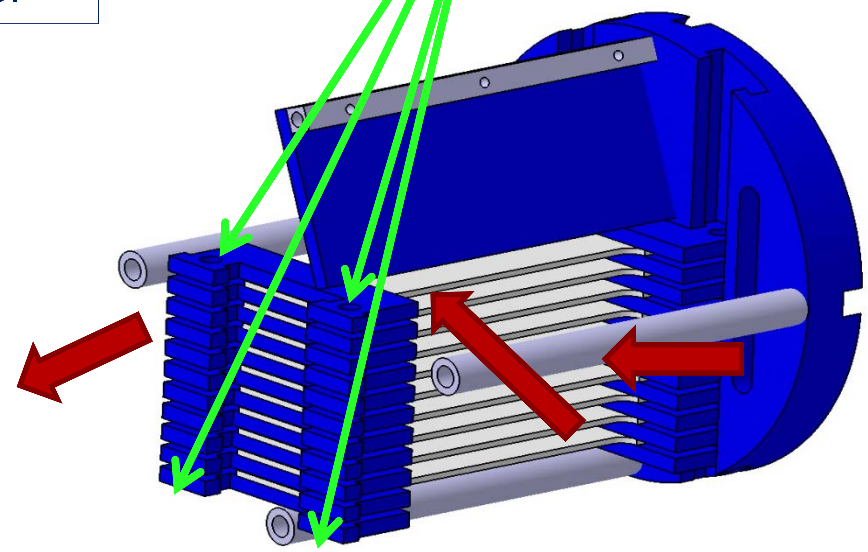
Innerer Aufbau der Prüfkammer

Verschluss des Gasbypasses nach Anzahl und Materialstärke der Proben anpassbar

Fixierung der Probekörper

Nach Einlegen der Proben werden die Probenhalter zusammengeschraubt, um die Proben zu fixieren





Gasauslass

Gaseinlass

Mechanische Kopplung von Boden und Deckel

Das Prüfgas wird Z-förmig durch die Proben geleitet, um die Oberfläche aller Proben möglichst gleichmäßig anzuströmen

Future targets for fuel cell systems

Cost reduction → mass production

- Cheaper materials
- Cheaper production methods

Stability of components → energy supply

- No harmful content in materials
- Long lifetime in fuel cell environment

Optimized performance → new applications

- Weight reduction of system components
- Volume reduction of system components

→ Fuel cell specific material development is opening fuel cells for special applications like aeronautics, logistics, portable devices etc.

Sources: FEV, ZBT, DLR / Hy4

Summary

- Electromobility will be batteries (BEV) and hydrogen fuel cell (FCEV / HEV)
- Fuel cell vehicles are ready for series production, ramp up in progress
- Costs must be further reduced
- Expensive system components have to be replaced by cheaper ones
- New materials have to be tested for use in fuel cell systems to prevent increased degradation
- We support suppliers and OEM on issues like
  - Stability
  - Producablity
  - Efficiency
- Join us for the next steps: New improved materials for next generation fuel cells

Thank you for your attention!

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