

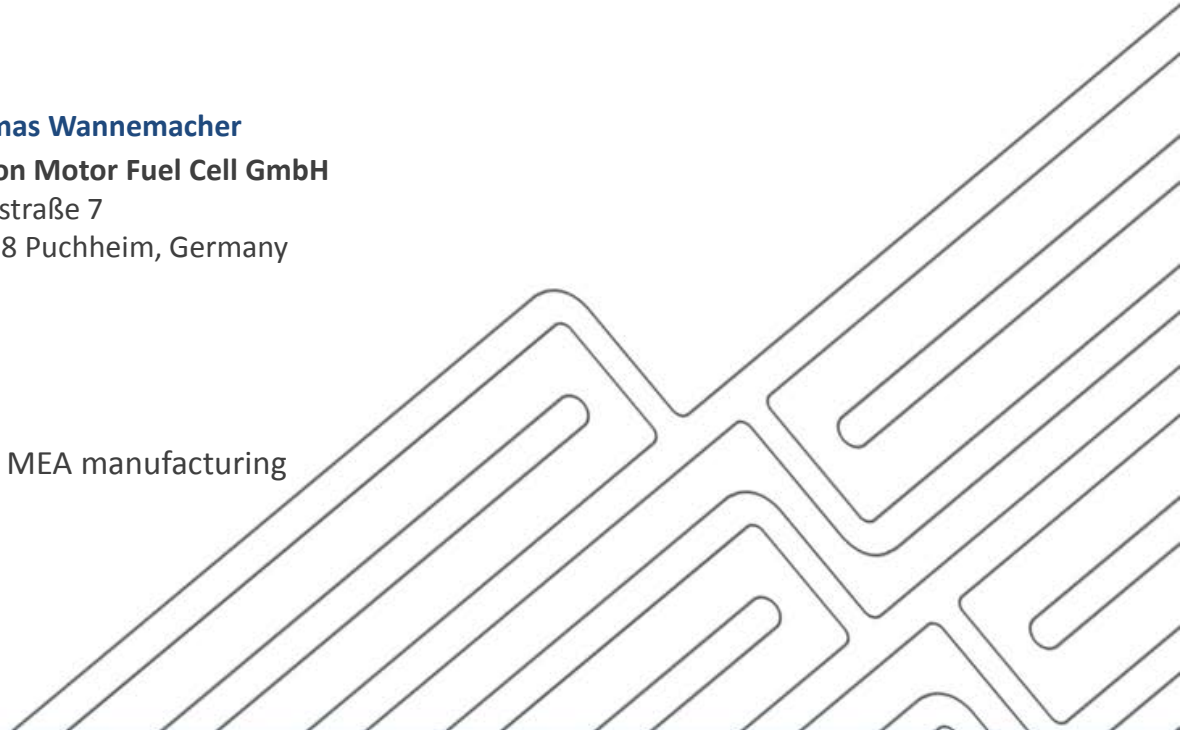


Challenges in Quantity & Quality for an SME in the Ramp-up of Fuel Cells



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FCH JU Workshop on PEMFC Stack and MEA manufacturing
11 October 2018, Brussels



Proton Motor at a glance

Proton Motor Fuel Cell GmbH provides CLEANTECH power solutions.

We are a German manufacturer of fuel cell stacks and fuel cell systems for maritime, stationary and mobile applications.



- Headquarter in Puchheim near Munich
- Round 75 employees
- More than 20 years experience in Fuel Cell Technology
- Large in-house and outdoor test capacities
- Hydrogen infrastructure (75 m³ tank)
- Electrical charging station (fed from test field)



Proton Motor is a subsidiary of:



(Holding, listed at LSE since 2006)



Stack Technology

LT-PEM Stacks

- PM200
- PM400

Power ranges:
2 ... 30 kW_{elect}

Fuel Cell Systems

PM Module

- 19" Rack
- S5-Family: 2 ... 8 kW
- S25: 10 ... 25 kW

PM Cube

Cabinet solution for one or more 19" modules
(for both stack formats)

HyRange®

Mobile systems
Power range:
9 ... 30 kW

Energy Solutions

Containerized stationary Solutions

- Indoor & outdoor

Energy supply / Drive trains

- City busses
- LCV
- Boats and ships

Milestones at Proton Motor



Start of first fuel cell development activities at Magnet Motor



Launch of *Proton Power Systems PLC* at the LSE



EPS System in Bachhausen



Energy autarcic multifamily home Brütten (CH)



Bayernbus in Operation



World's first 'Triple Hybrid City Bus'

Cooperation with the
DB
Bahnbau Gruppe



Railway control center Sömmerda

1994 1998 2000 2001 2006 2008 2009 2011 2012 2014 2015 2016 2017 2018

Foundation of



ZEMShip 'Alsterwasser' in Operation (HH)

Merger with



Surf'n'Turf project at the Orkney's



World's first 'Triple Hybrid Fork Lift'



Street approval of Newton with HyRange®



Presentation of the FC REEV van

- 🏠 Rapid change in political environment: governmental restrictions
- 🏠 Still strong demand on eco-friendly and sustainable energy solutions
- 🏠 Growing awareness & interest in the potential of hydrogen and fuel cell based solutions
- 🏠 The Mobile market can be very fast, resulting in high volumes
 - Electromobility will need fuel cells as one part
- 🏠 Stationary market expected to grow as well, but not resulting in as high volumes as mobile
 - House energy market is still promising
 - Major energy supplier suffer from unstable renewable energy production (no energy buffers)
- 🏠 Maritime market: fuel cell based solutions are very attractive
 - Strong requests from (Scandinavian) operators, volumes are also not as high as in mobile
 - Classification agencies: situation of hydrogen as fuel is not clear
- 🏠 Sector coupling will be one relevant topic of the future: first steps have been made
- 🏠 The Chinese market is experiencing rapid growth
- 🏠 European market will follow suit (otherwise we will be disadvantaged...)

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The phrase: „Three years from now to break-through“
has been never so realistic as today!

- 🏠 General understanding in the FC industry: technology-wise we are on a good path
 - most problems seems to be on achieving the market entry / establish markets
- 🏠 Capital costs (invest and partially TCO) are still too high, primarily due to small volumes
- 🏠 The Hydrogen infrastructure is still insufficient (hen and egg dilemma)
 - Focus of funding is more and more on hydrogen generation / electrolyzers
- 🏠 Mobile OEMs and TIER suppliers are very interested and committed:
 - All major OEMs and many TIER suppliers are working on own solutions
 - Synergies between old & new technologies and existing supply chains can be used
- 🏠 Situation of approvals, certification and standardisation is not clear

...beside technical concerns (robustness, endurance, reliability...)





- 🏠 Very low amount of standardized components and interfaces
- 🏠 No or only few standardised test protocols available
- 🏠 Market ramp up has to be matched together with the production capabilities
- 🏠 Quality Assurance is essential: currently there is a strong demand for discussion
- 🏠 Methods for component testing / validation and quality assurance are not harmonised widely (or even not existing)
- 🏠 Other topics affecting FC commercialization (which are not clear today):
 - Governmental restrictions / regulatory issues
 - Fuel quality / fuel mode of payments (hydrogen is not verifiable)
 - Insurance issues

- 🏠 Venture capital: a strong and reliable partner with high commitment and stamina is needed
 - High invest and a long breath is necessary for development, testing and production capabilities
- 🏠 Human Resource Infrastructure: acquire (and pay) well educated personnel
 - Service: qualified service and maintenance personnel is needed
 - Development: qualified technical for development and commercialization
- 🏠 Partially no suitable components available / no access to some key suppliers
- 🏠 Lack of quality in components (especially peripherals): high financial effort for proprietary development of components
- 🏠 Some projects are only possible with a strong general contractor (and/or door opener)
- 🏠 National and European funding instruments require a high amount of resources for:
 - Preparing and writing a good proposal
 - Organisation, coordination, project control and reporting

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Insufficient money!
Insufficient time!
Insufficient resources!

... cost related market barriers:

- ✓ Capital cost reduction:
 -  Increasing power density (without compromising longevity and reliability)
 -  Reduce system complexity while having a higher integration level
 -  Analyse real demands and tailor (hybrid) solutions for the specific application
 -  Scaling up production capabilities (economy of scale) / stream lining processes
- ✓ Establish strategic partnerships with related technologies (batteries, converters, tank systems etc.)
- ✓ Good cooperation, open communication with component suppliers
- ✓ Establish a second source for every key components

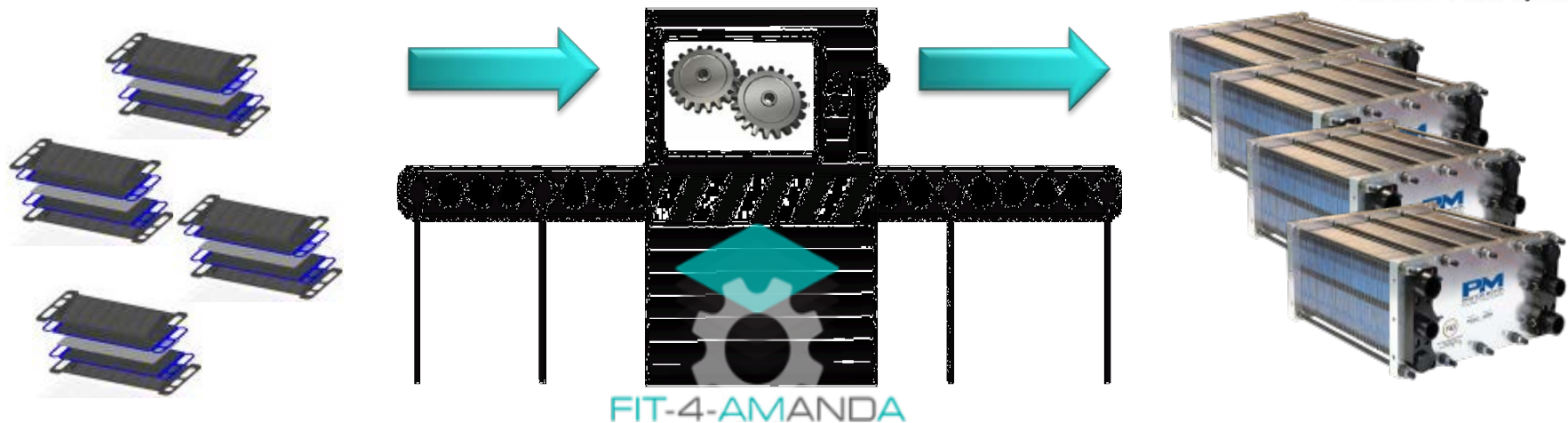
... quality related issues:

- ✓ Ensure high QA/QC in the production line: apply common QC methodology
- ✓ Finding a common base within the FC community:
 - 🔍 Definition: What is a defect? What is a tolerable imperfection?
 - 🔍 How components have to be tested and evaluated → standardised protocols
 - 🔍 Establish certification, standardisation and approval of components, stacks, systems
- ✓ Close and transparent communication within the FC community would be very helpful...
- ✓ A good strategy for ramping up the production and an adequate maintenance & service concepts is necessary

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Funding? Yes gladly!
... but, only when the project is straight forward on our road map ...



EU- funding project: “Fit for Automatic Manufacturing and Assembly”

- Project Goals: Cost reduction and achieving mass production capability
 - Improved manufacturability and drastic reduction of manufacturing costs
 - Lower component prices for stacks and prototypes
 - Fast In-line test methods for high quality assurance
 - Automated production line (stacking robot) → Ability for mass production
 - Integration of the "new" stack in UPS delivery vehicles and testing in "daily delivery service operation"

Status:

- ✓ Stack & component improvements are realised and implemented
- ✓ Suitable QA/QC methods (in-line and offline) are determined
- ✓ All major components and units are built up at the machine's manufacturer
- ✓ Functional units were tested
- ✓ Software is to be implemented

Next steps:

- Disassembling of the machine in transportable units
- Transport to PM's facilities in Puchheim
- Re-assembling
- Commissioning and running-in procedures in Puchheim
- First prototype stacks out of the machine in Q1/2019
- Build-up of the fuel cell system and integration into the UPS delivery truck
- Gain information with the real life operation in daily delivery cycles

100%
Energie

Zero
Emission

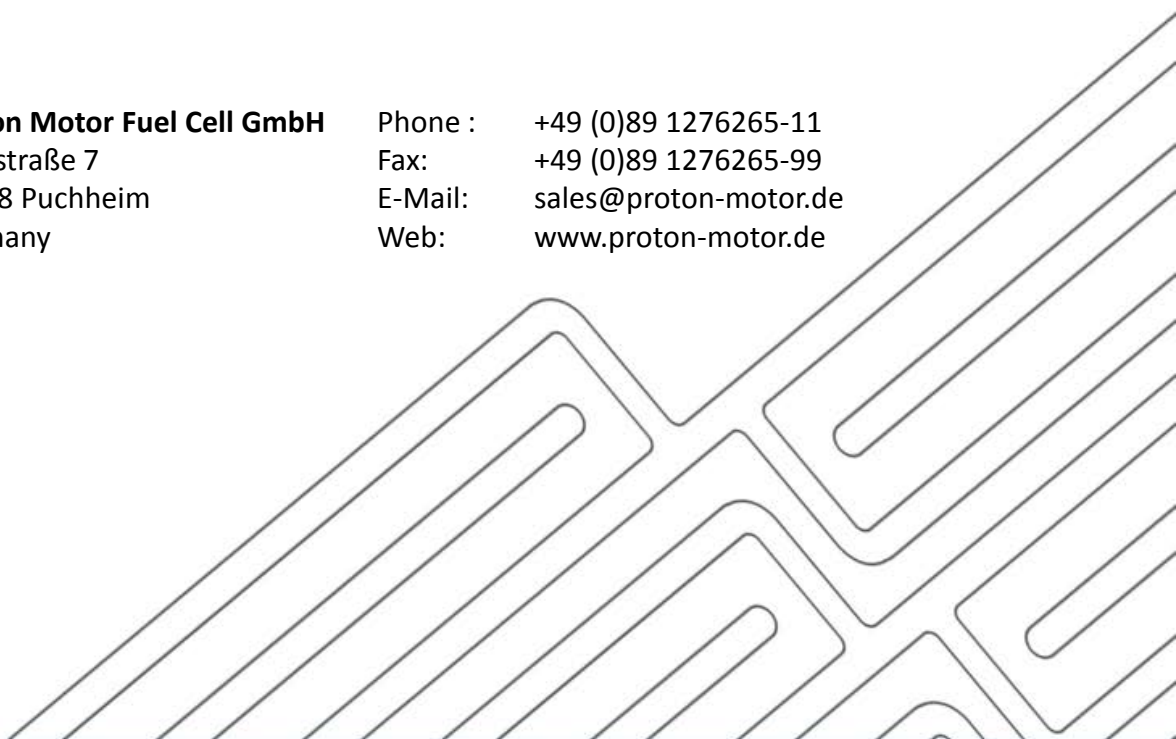
Thank You for Your Attention!

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ZEMSHIPS Project, Hamburg

- Zero Emission Fuel Cell Ship
- Capacity for approx. 100 passengers
- ZEMSHIPS project partner: ATG, Linde, German Lloyd, Stadt Hamburg, Proton Motor
- Proton Motor was responsible for the complete propulsion system of the ship
- In use since summer 2008 → in approx. 4'000 operating hours more than 50'000 passengers were transported (01/2014)
- 1.7 kg hydrogen consumption per operation hour

TriHyBus®



- Fuel cell power: 45 kW
- Li-Ion Battery: 27,4 kWh
- Ultracaps: 1 kWh, 200 kW
- Propulsion: 120 kW
- H₂-Tank : 20 kg @ 350bar
- H₂-Consumption: 8 kg /100 km

- 12m Bus for 45 passengers
- Triple Hybrid propulsion system
- Patented TRIple Hybrid concept with fuel cell, battery and ultra capacitors
- Configuration and testing since 2008/2009
- Future Award for Alternative Propulsion Technology 2010 of the „Innovationsvereinigung der deutschen Wirtschaft IDWI“
- Nominated for the Hermes Award 2010
- Project partners:



5 kW BZ DC-EPS System



- 5 kW-DC-RPP (220V)
- 1 PM Module S5
- DC/DC converter
- Bridging time: > 10 h
- H₂ Consumption: 0,4 kg/h

Emergency power supply substation (UW) Bachhausen

- Pilot project of E.ON Bayern AG and Modl GmbH on the functioning of the fuel cell replacing power plants
- Proton Motor is subcontractor of Modl GmbH
- Scope of delivery of Proton Motor for this project:
- PM module S5 DC / DC converter
- Concept for visualization, data acquisition and remote monitoring
- Engineering support during the concept phase, setup and commissioning of the system
- In operation since 05. November 2012

bayernwerk **modl** ✓
Intelligente System-Lösungen

Newton mit HyRange®



- Fuel cell power 8,4 kW
- Li-Ion Battery: 80 kWh
- Charging current: 400 VAC / 32 A
- Propulsion: 120 kW
- H₂-Tank : 5 kg @ 350bar
- H₂-Consumption: ~ 0,5 kg/h

Proton Motor Project

- Plat form: 7.5 t LKW von Smith Electric Vehicles
- Electric vehicle (EV) plus fuel cell (FC) Range Extender
- In test operation since 2011/2012
- Approval of FC system and Vehicle according 79/2009
- Nominated for the Clean Tech Media Award 2012

- Funded by:



Gefördert durch:



Repowering of LOHC* Hydrogen



PM Cube S5 for a Smart Grid Solar Project

- Subcontract of AREVA GmbH
- Proton Motor will supply a PM Cube S5 BZ system with a PM Module S5 and a DC / DC - DC / AC combination from Fraunhofer IISB and SMA
- Technical specifications:
 - PM Module S5 - 5.6 kW
 - DC / DC converter by Fraunhofer IISB
 - DC / AC converter by SMA
 - Minimum H2 inlet pressure
- In operation since February 2016
- Project partners:

* LOHC = Liquid Organic Hydrogen Carrier





Energy autarkic multi family home in Brütten (CH)

- PM Cube cabinet solution with 5 kW net power (one PM200 stack)
- Energy supply in bad weather / little sunshine (seasonal energy storage)
- Use of fuel cell exhaust heat for hot water and heating → high efficiency
- Partners: W. Schmidt Architects, Proton Motor



FC REEV (Fuel Cell Range Extended Vehicle)

- Range: > 300 km
- Maximum speed: 130 km/h
- Project aims: Zero emission (tank to wheel), short refueling, 4x4 for high dynamics
- Proton Motor fuel cell system (HyRange®25 with nominal power of 25 kW)
- H₂ Consumption: 1.5 kg / h @ Nominal power / H₂ Tank 3 kg @ 70 MPa
- Project partners: Magna, Proton Motor, TU-Wien, HyCentA, FFG, bmvit



Surf'n'Turf project at the Orkney's (UK)

- Clean Energy solution with wind and tidal power combined with FC and electrolyser
- Electrical energy supply on demand for ships and load at Kirkwall Harbour facilities
- Additionally designated as training center for maritime fuel cell applications
- PM Container with 75 kW net FC power output (powered by three HyRange®25 systems)
- Utilisation of FC exhaust heat for building heating.
- Partners: OIC, EMEC, EDAY RE, ITM Power, Arcola Energy, Proton Motor

- R & D in the field of fuel cell technology and energy solutions
- Consulting, market and feasibility studies
- Partner in national and European (funding) projects
- Simulation, design and hybridization strategies for powertrains and power supply
- Design and engineering of complete fuel cell-based energy solutions
- Test and validation of system components and components
- Prototyping and mass production of fuel cell systems
- Project management for energy solutions
- Training for customers and users, 24/7 service

Customers, Partners and Network

