Final report

1.1 Project details

Project title	Bio fueled Hybrid Vehicle for airport ground handling operations
Project identification (program abbrev. and file)	HV - 64014-0119
Name of the programme which has funded the project	EUDP/Energieffektivitet
Project managing company/institution (name and address)	Lithium Balance A/S (LiB), Hassellunden 13, 2765 Smørum
Project partners	Danish Power Systems (DPS), The Technical University of Denmark (CAS, ECS and MEK), SP Group and Teksis.
CVR (central business register)	29391130
Date for submission	30/4-2019

1.2 Short description of project objective and results

1.3 Executive summary

1.4 Project objectives

1.5 Project results and dissemination of results

1.6 Utilization of project results

1.7 Project conclusion and perspective

Annex

Relevant links

1.2 Short description of project objective and results

The project objective was to develop the technologies for a hybrid power pack for utility vehicles, which both improves fuel efficiency and reduces the emission of ultra-fine particles at the same time. The power pack consists of a fuel cell and a battery and it operates on bio fuel. The vehicle should be used for the demonstration of the technologies developed by the project partners LiB (BMS and charger for automotive) and DPS (fuel cells). A Fiat Scudo was used as a platform for the demonstration at DTU. The project has been an essential driver behind the development of:

- new Automotive BMS products, specifically the n-BMS and the Fast-charge unit. These developments have made LiB attractive to major automotive players and have among other things led to a >10 mio DKK investment from a Chinese automotive company
- significant improvement of the High Temperature PEM fuel cells on all level from manufacturing to price and performance. This has enabled DPS to attract significant investments. DPS continue to pursue the "power pack" concept together with new partner.

Formålet med projektet var et udvikle en hybrid power enhed til arbejdskøretøjer, som dels forbedrede brændstoføkonomien og dels reducerede udledningen af ultra-fine partikler. Power enheden består af en brændselscelle og et batteri, og kører på bio-brændsel. Køretøjet skal bruges til at demonstration af de teknologier som partnerne LiB (batteristyrring og lader) og DPS (brændselsceller) har udviklet. En Fiat Scudo blev brugt som platform for demonstrationen på DTU. Projektet har været essentielt for udviklingen af:

- Nye produkter til batteristyring i biler, specifikt n-BMS'en og en ny fast-charger enhed. Disse produkter har gjort LiB til en attraktiv partner for store spillere inden for automotive, og har bl.a. resulteret i en >10 mio. kr. investering fra en kinesisk bilproducent.
- Markant forbedring af høj temperatur polymer brændselsceller på alle parametre fra pris til ydelse. Dette har muliggjort at DPS har kunne tiltrække betydelige investering. DPS arbejder videre på "hybrid power" konceptet med en ny partner.

1.3 Executive summary

The project has enabled both LiB and DPS to address new markets and partners for their products:

- LiB' Automotive BMS products have made LiB attractive to major automotive players and have among other things led to a >10 mio DKK investment from a Chinese automotive company.
-
- DPS' fuel cells now represent true state of the art for HTPEM, and DPS is collaboration with all HTPEM system manufacturers and developers on implementation of the "power pack" product and scaling of capacity.

In addition, SPG have developed a cost-effective gasket concept that is being further developed together with a stack manufacturer.

The electric car has been delivered to Campus Service (DTU) and is in daily use and serve as a demonstrator for the partners technologies.

The potential market and actual volume for the individual products provided by LiB and DPS far exceed that of the power pack envisioned in the original project. Furthermore, the HTPEM stack developed by the Turkish partner Teksis has not reached a sufficiently high TRL that enables commercialisation of a complete "plug 'n play" power pack. LiB and DPS have therefore naturally chosen to focus on their individual products.

1.4 Project objectives

The project objective was to develop a hybrid power pack (and related components) as range extender for electric vehicles, which both improves fuel efficiency and reduces the emission of ultra-fine particles at the same time (as described in the modified project description). The hybrid power pack is based on a combination of batteries and a fuel cell system (as a battery charger). The market potential for the power pack and related components are much larger than just airport operations (as described in the initial project application). The project was therefore extended to promote the technology to a broader range of end-users by establishing a "stakeholder group". The choice of fuel will be expanded to also include bio-methanol and bio-ethanol. This means that the fueling options is more widespread available. It should be emphasized that the use of a standard van – instead of a specialized airport vehicle – will give access to a much wider market as well as it will make the dissemination and exploitation to customers much easier.

The project successfully addressed all the tasks and deliverables (as described in the "Modified project description"):

- LiB completed the electric part of the demonstration vehicle, including the development of related/required components.
- DPS and DTU completed the fuel cell system, including the development of related/required components.
- DTU and DPS successfully integrated the fuel cell system in the vehicle.

The resulting electric vehicle has the possibility to charge from a standard outlet (onboard charger) or independently through the fuel cell system. The fuel cell system is integrated with a methanol reformer and thus operates on methanol.

The fuel cell stack developed by Teksis and the complete fuel cell system was developed to approx. TRL 5, meaning that marketing the complete hybrid power pack would be premature. Furthermore, both LiB and DPS have established close collaboration with external partners whom are already addressing and present on the automotive market. This provides both a faster path to increased sale for the partners, and a near-term commercialization of a hybrid power pack for automotive applications.

In summary: The project has resulted in increased sales and investments for both LiB and DPS despite lack of success related to the commercialization of the hybrid power pack within the project (CM4).

1.5 Project results and dissemination of results

The project was divided into six work packages (WP):

WP1 – Project Management (LiB)
WP2 – Fuel cell system (DPS)
WP3 – Power management system (LiB)
WP4 – System integration (DTU ECS replaced DTU MEK)
WP5 – Field Test (DPS)
WP6 – Commercial exploitation (LiB)

The main results and findings for the individual WP's are summarized below. The reporting for WP2 and WP4 was merged for practical reasons.

WP1 (LiB):
LiB have been handling the administrative project management of the project (reporting and financial status to EUDP), while DPS have handled the technical project management.

WP2 (DPS) and WP4 (DTU ECS):
The MEA product development has focused specifically on using bio-fuel reformat as fuel. This has resulted in significant improvements and the developed fuel cells (also known as Membrane Electrode Assembly or MEA) represents State of the Art in the world with respect to both performance and durability (see figure 1).

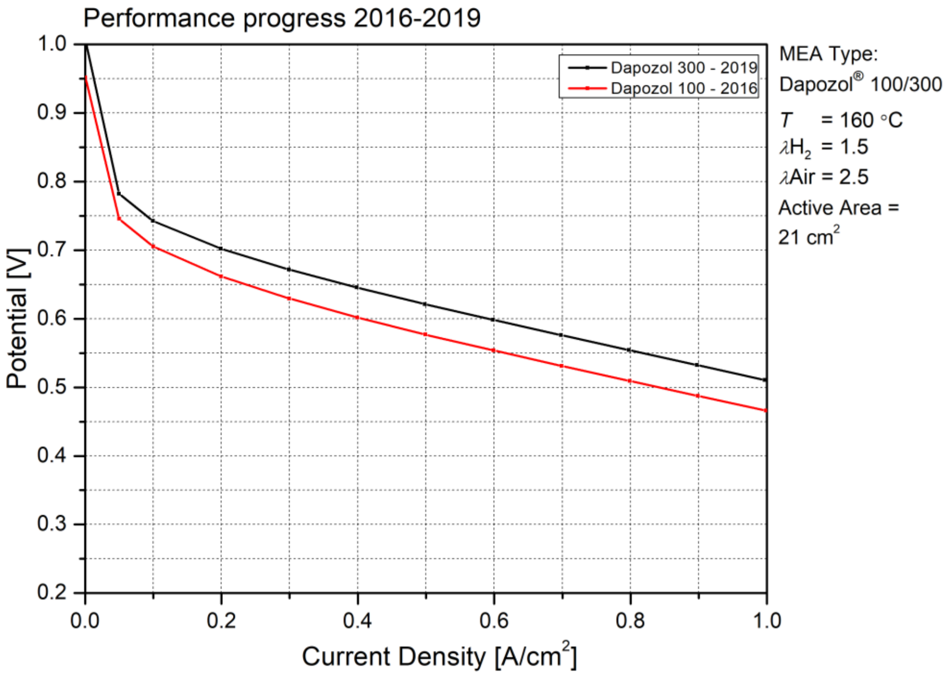

Figure 1: Performance of DPS MEAs in 2019 compared to 2016. The improvement has enabled almost a doubling in current- and power density while reducing the Pt loading with 40%.

More than 5000 h operation with methanol reformate have demonstrated low degradation (<8 μV/h) and high performance (>570 mV@400 mA/cm2, see figure 2).

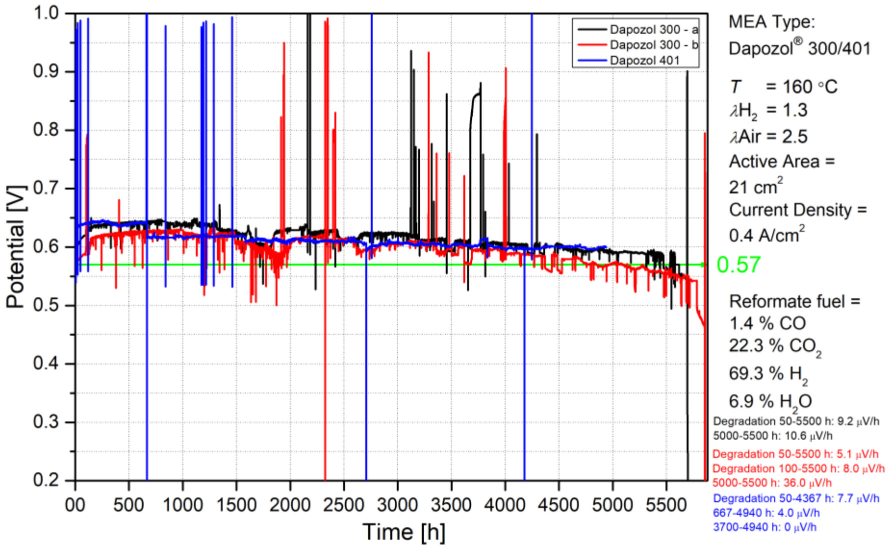

Figure 2: Durability test of DPS MEAs using methanol reformat as fuel.

The scaleup of production has further reduced the cost significantly. Further actions include cost reductions (e.g. better platinum utilization, production setup/processes and scale). DPS has as a result of the project entered into close collaboration with several system manufactures that appears very promising. Their expectation is for fuel cells to be able to compete with diesel engines for backup power and range extenders for electric cars.

SPG has worked on the development of new processes for gaskets and flow plates. The original plan was to manufacture flow plates by injection molding. However, detailed process and material analysis caused SPG to abandon this approach as it did not prove financially viable with the existing materials/compounds. A process for cost effective gaskets has been developed and the test results are very promising. It is expected to result in a significant cost reduction. SPG are discussing with different stack builders regarding scaling of the production.

Teksis developed a modular design for a liquid cooled 5 kW FC stack (see figure 3), including flow plate and gasket design. The stack was optimized for MEAs from DPS.

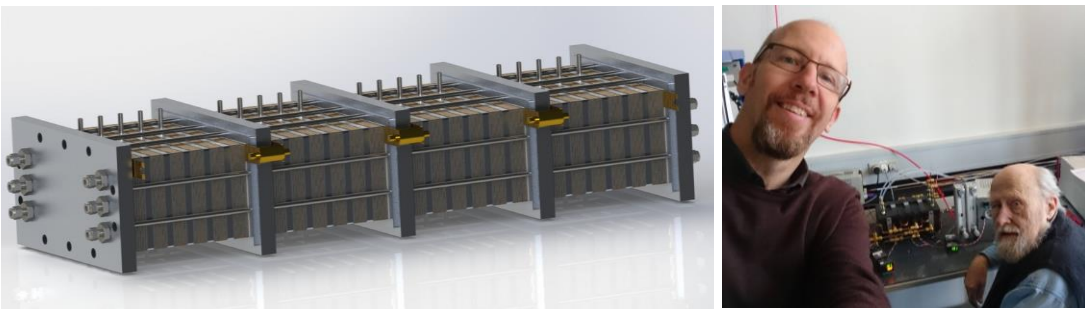

Figure 3: Illustration of the modular stack concept developed by Teksis (left) and first successful test of a module (right).

DPS participated in two project meetings in Ankara (Turkey) regarding the stack development (see figure 4). The planned meeting in Denmark was canceled due to political "turbulence" in Turkey.

Figure 4: Photo of Huseyin Devrim (Teksis) and Hans Aage Hjuler (DPS) during a project meeting in Ankara.

The fuel cell is powered by hydrogen from reforming of methanol:

$$CH_3OH + H_2O \rightarrow CO_2 + 3H_2$$

For optimal performance, the fuel cell needs a surplus of hydrogen as compared to the amount corresponding to the current produced. The excess hydrogen is mixed with air and fed to burners heating the reformer. The layout of the reformer – FC circuit is shown in figure 5.

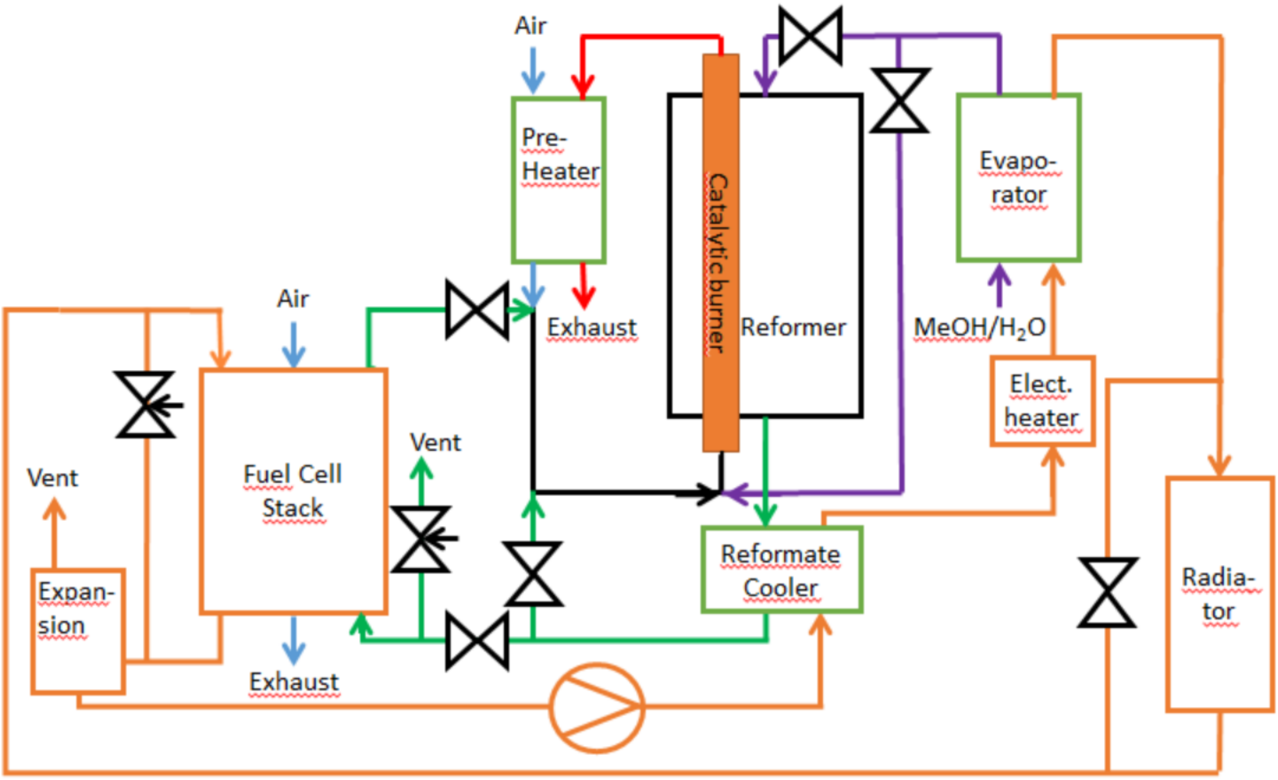

Figure 5: Reformer – fuel cell flow diagram. In normal service the methanol-water mixture is evaporated and fed to reformer. Reformate is fed to fuel cell stack. Excess hydrogen (containing CO_2 and water) is mixed with air and "burned" over a catalyst to provide heat for the reformer. The fuel cell coolant provides heat for the evaporator and stabilizes reformate temperature. The fuel cell stack is protected from over pressure by relief valves on feed lines for fuel and coolant. Overpressure fuel is vented to atmosphere; overpressure coolant is by passed to suction side of circulation pump. The fuel cell stack air feed does not require over pressure protection as the blower stagnation pressure is below the permissible fuel cell stack pressure. During heat up an electric heater provides hot coolant for the evaporator and heating the fuel cell stack. By pass valves allow feeding methanol or reformate to the catalytic burner.

Two reformers was developed: one for methane and one for methanol. For optimal performance, the fuel cell need a surplus of hydrogen as compared to the amount corresponding to the current produced. The excess hydrogen is mixed with air and fed to burners heating the reformer.

The reformer is based on a commercially available catalyst from Haldor Topsøe. In order to assure full conversion and suppress side reactions forming CO an excess of water is feed to the reformer. Since the reformate gas composition and therefore the mixture is a critical parameter for safety and fuel cell performance and service life a premixed reformer feed of methanol and water (1:1.5 by mole) is used (for larger systems reusing condensed water from the fuel cell could save weight both weight and improve efficiency).

The reformer is constructed inside an aluminium block with separate channels for reforming methanol and combustion of excess hydrogen to provide the heat required for heating reactants, covering reaction enthalpy and heat loss.

The fuel cell stack evolves a considerable amount of heat (approximately 50 %). The heat is removed by a cooling loop operating at approx. 160 °C. The reformer requires heat supplied for evaporation of the methanol – water mixture and for heating to reaction temperature as well as for the reformation reaction. In order to reuse heat from fuel cell stack cooling loop (and minimizing the temperature differences inside reformer, the methanol – water feed is evaporated in a heat exchanger against the coolant.

The reformer requires 250 – 300 °C working temperature and hence cannot be heated using the waste heat of the cooling loop. Instead the reformer is heated catalytically by burning excess hydrogen from the fuel cell stack in separate heater channels. The air is preheated using the burner exhaust in order to improve fuel efficiency (i.e. by minimizing the need for excess hydrogen to heat the reformer). Preheating air for the combustion also serves to stabilize the burner temperature when using the CO_2 rich partially spent fuel gas. In the course of optimization the reformer's temperature was fixed at 280 °C as to ensure a stable fuel cell performance. Figure 6 shows a photo of the reformer, cooling loop and related heat exchangers.

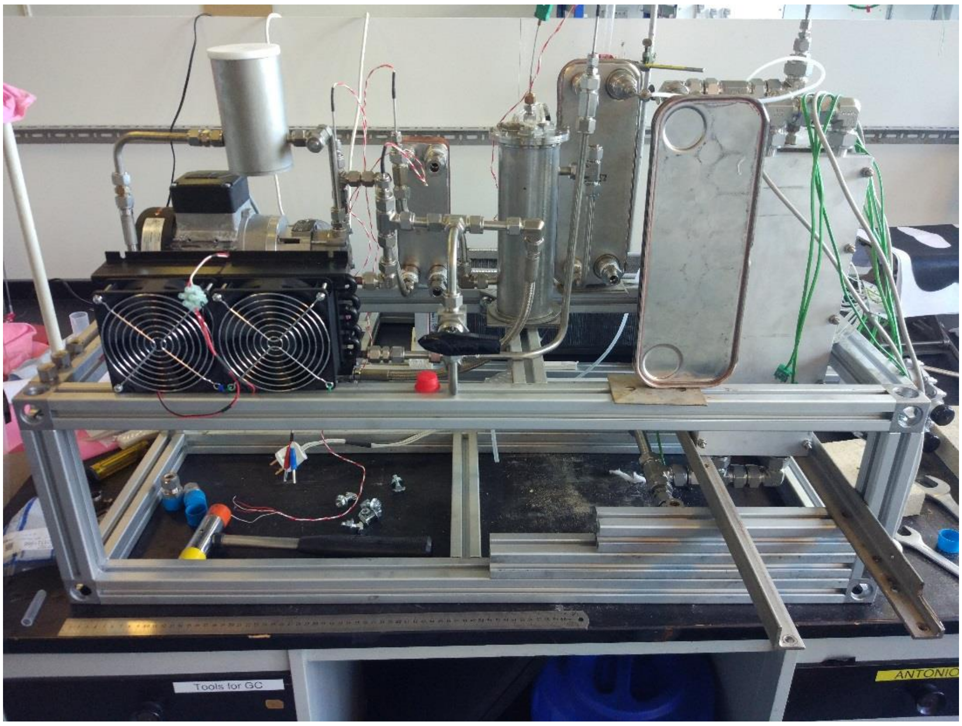

Figure 6: Photo of the reformer and related heating/cooling loops. The reformer is the most right unit and the cooling/heating loop is behind the blowers. The picture was taken during assembly of the setup.

The quality of the reformate was analysed using Gas chromatography. The content of H_2, CO_2 and CO present in the reformate gas decides the quality of reformate and performance of the reformer. The gas composition analysed online in real time as the whole reformer set-up is connected directly to the gas chromatograph instrument. This enabled a detailed study of the process parameters on the resulting reformat quality.

The results show that the reformate gas is free of any methanol vapor peak (or at least below the detection limit of Gas chromatograph, i.e. <0.1 %). The CO level is <1 % during normal operation. Nearly 100% of theoretical conversion of both natural gas and methanol was demonstrated at optimized conditions. The results are presented in Figure 7.

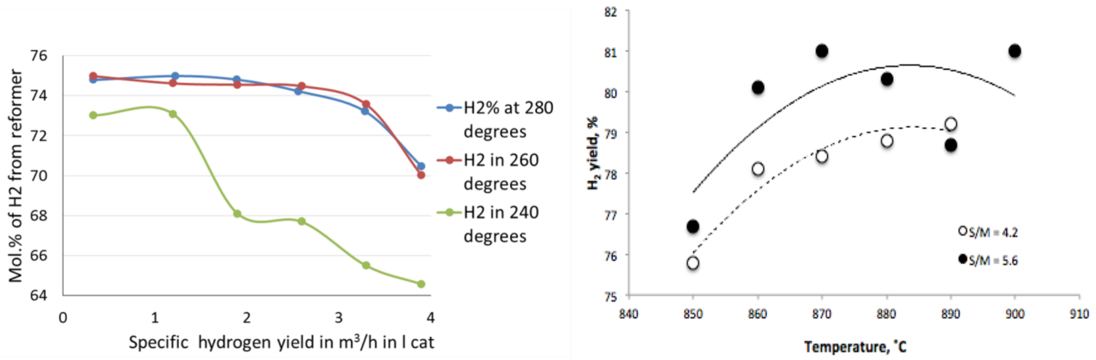

Figure 7: Demonstration of hydrogen yield both in MeOH (on the left) and in NG (on the right) reformers. The practical yields are close to theoretical limits (S/M = steam/methane ratio).

There is a number of important safety considerations related to the reformer – FC system:

- CO from reformer malfunction
- Heating closed volumes
- Leaks
- Back firing of catalytic pre-mix hydrogen burner
- Retaining burner catalyst (displaced catalyst may course local over heating of tubing)

This is addressed by the integrated control system. The main parameter governing the system is the current generated by the fuel cell. This system is greatly simplified by having the FC system operating in only two modes: off/idling (i.e. no current supplied to the car) or nominal load (2 kW nominal, although the system was tested up to 4 kW).

In order to provide heat for reforming, the methanol feed is ~25 % higher than what is required by the FC. This level provides sufficient excess hydrogen for the reformer's burner. The reformer and burner temperatures are secondary parameters for adjusting the additional methanol to maintain a stable reformer temperature. The layout is shown in Figure 8.

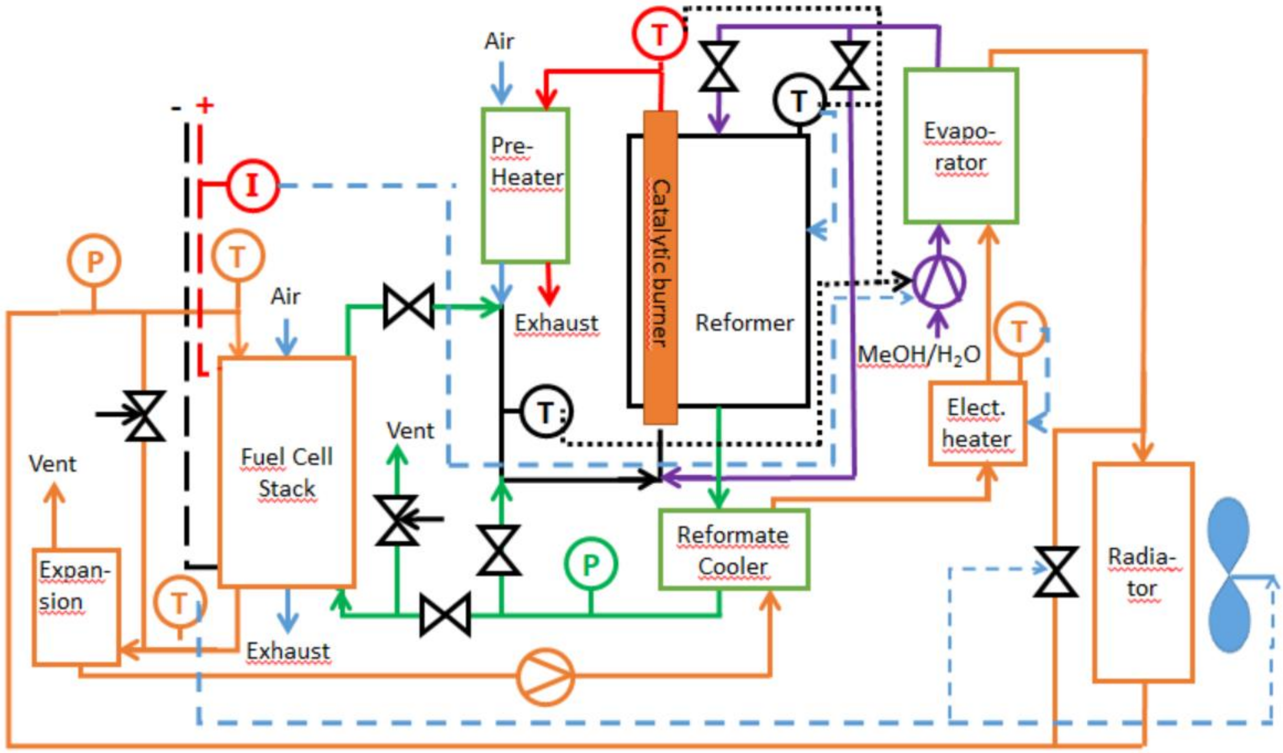

Figure 8: PID diagram of the FC – reformer system. Main control parameter is fuel cell stack current governing the methanol-water mixture feed rate. Fuel cell stack coolant outlet temperature controls radiator by pass and radiator blower. Blowers feeding air to fuel cell stack and catalytic burner as well as coolant pump operate at constant speed. Safety interlocks discontinues methanol-water mixture feed if any of the following temperatures exceeds maximum: reformer, catalytic burner or burner feed line (sign of burner back firiung). During heat up coolant electric heater temperature is maintained at 160 °C and reformer temperature at 300 °C.

The FC system was optimized and tested in the lab using an external load (rather than the car). This work performed at DTU ECS (See figure 9). This integration was optimized thermally in order to utilize the excess heat from the stack for the reforming process.

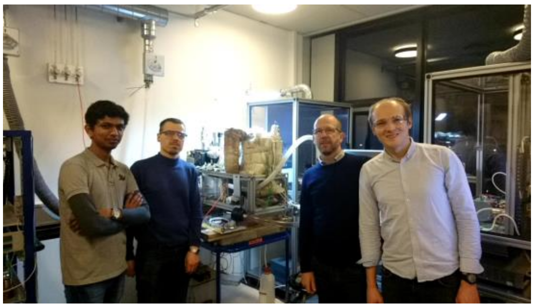

Figure 9: Photo of FC system and FC team.

As expected, the fuel cell stack performs better at higher hydrogen feed rates (higher voltage at fixed current) than required to maintain stable reformer temperature, but at the expense of reduced fuel efficiency (and challenges for the temperature control).
The fuel cell stack – reformer is performing stable at 2 kW electrical power:

- Burners can maintain reformer temperature without overheating sealing materials
- Reformer supplies a stable hydrogen feed of sufficient quality (low carbon monoxide and very low unreacted methanol) to sustain fuel cell performance
- Fuel cell maintains stable temperature while supplying heat for evaporating methanol – water feed for reformer and requiring some cooling power (radiator with intermittent blower action)

WP2 was completed with the delivery of a complete FC system ready for implementation in the car.

The FC system was integrated in the car (WP4) by DPS, DTU ECS and LiB (see figure 10).

Figure 10: FC system as received (left), FC system after integration in the can (top right) and complete car ready for testing.

The integration of the FC system with the car’s electrical system was done via a dc-dc converter, which was connected and controlled by the BMS system. This ensured two autonomous systems, where the car runs on batteries with or without simultaneous charging from the FC system. The FC system can also charge the batteries when the car is not operating.

WP3 (LiB):

	Leader	Effort (MM)	Due
WP3 - Power management system	**LiB**	**26**	
3.1 Components and cost analysis • D3.1 Cost analysis (report)	LiB		 M9
3.2 Dimension of battery and BMS system • D3.2 Power req. for operation (report)	LiB		 M6
3.3 Charge/discharge profile • D3.3 User pattern (report)	LiB		 M6
3.4 On-board charger • D3.4 Development of concept and proto type (component) • D3.5 Validation of charger concept (durability and performance) (report) • D3.6 Construction of final on-board charger (component)	LiB		 M12 M16 M22
3.5 Battery and BMS system • D3.7 Integration of components for electric power (component)	LiB		 M22
Objective: Design of battery management, power management system and the development of an on-board charger.			

In WP3 the power and battery management system for the hybrid vehicle was designed and implemented. The overall system architecture is shown in figure 11 below.

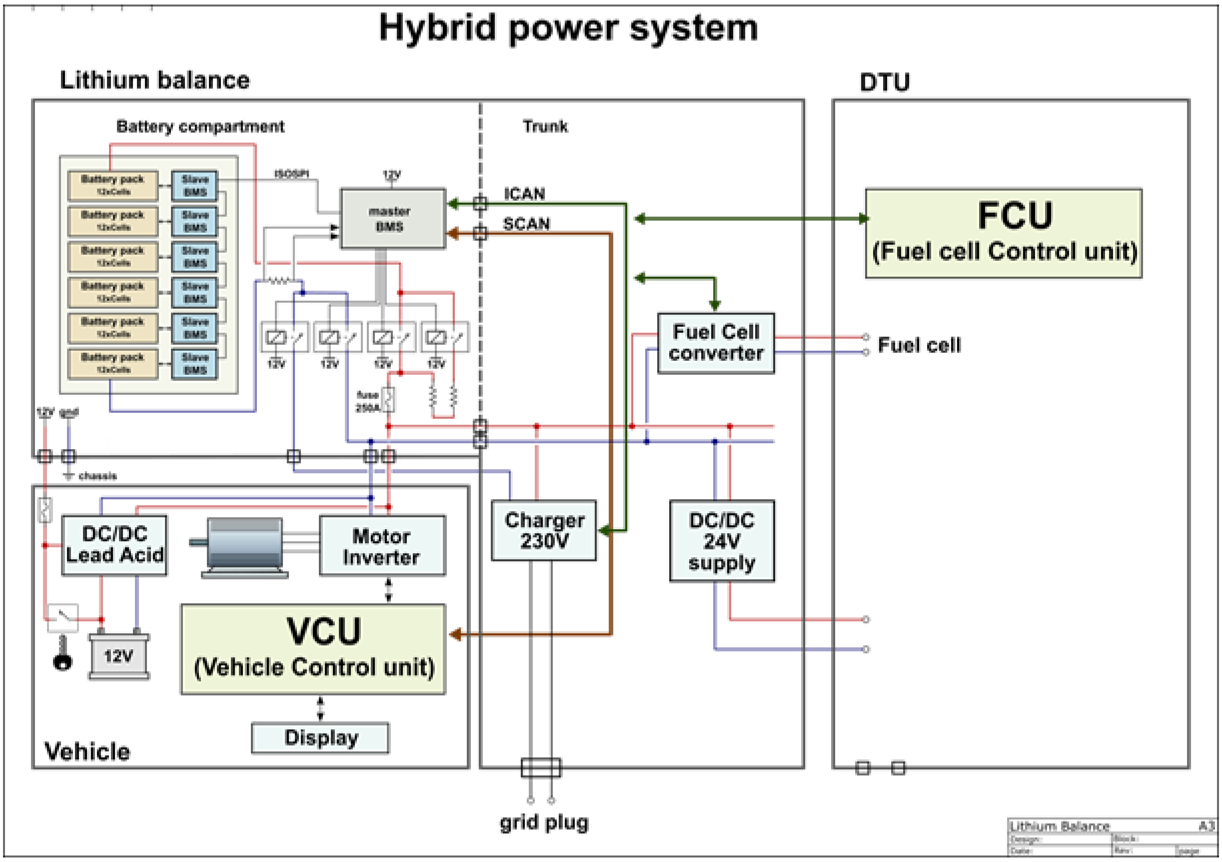

Figure 11: Hybrid power system architecture

The system components used were:

- The BMS is of the type n-BMS supplied by Lithium Balance AS. Please see figure 12
  - The BMS is of the type network BMS build around a patented master – slave architecture. The BMS has one master Battery Master Control Unit (MCU). The MCU is controlling the basic relay and communication functionality and the system safety parameters. The MCU is daisy chained with the Cell Moni-

toring Units (CMUs). The CMU is surveying the individual cells in the pack, by monitoring the cell voltage and the temperature.

  - The BMS connect and disconnect the battery pack, by controlling the main relays for of the battery pack.
  - When the vehicles is turned off or in a state of error, redundant relays galvanically isolate both the positive and negative high voltage from the battery pack to the vehicle.

- Battery cells. The cells are from the Korean manufacturer KOKAM. The cells formfactor is SLPB120255255. The battery chemistry is NMC. The cells are supplied by Korean manufacturer KOKAM. The cells are paced in to modules of 12 cells each. The total number of cells in the system are 72. The cells are power cells, to minimize the heat development during high load or charge current. They are specifically specified to accommodate installation of ChaDeMo, Fast Charge Interface. The cells are each 75Ah or 277.5W at 100% DoD

- DC/DC converter. The system has an implemented DC/DC to convert the battery HV to 24V for operating the FC, this was installed in close cooperation w. DTU. The DC/DC is manufactured by Meanwell, model RSP-1000-24

- The vehicle was equipped with a 3200W charger to charge the HV battery. The charger is of the brand Powerfinn, type: PAP3200. The charger is a CAN based charger. The charger is controlled by the BMS.

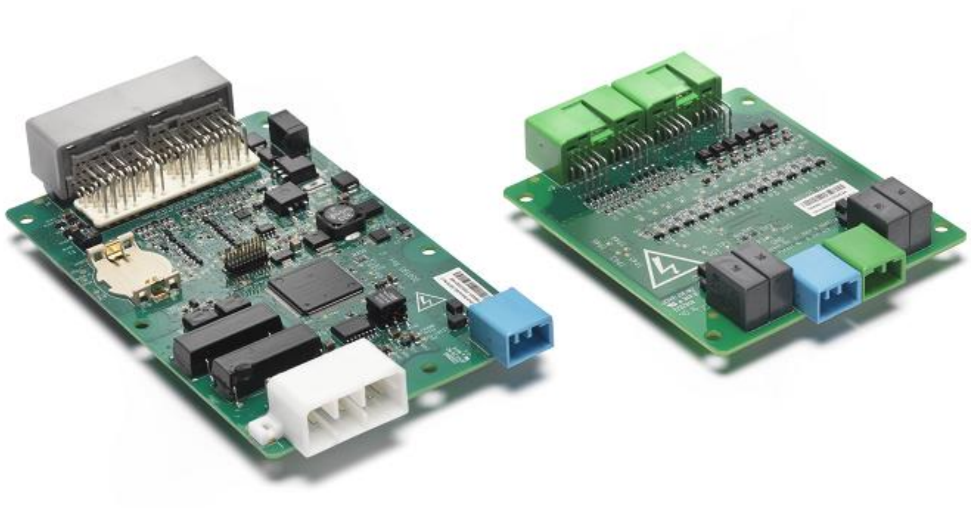

Figure 12: n-BMS used for battery management of the hybrid vehicle

After selecting the relevant components for the hybrid vehicle, these were installed and tested.

The battery pack was placed underneath the car. The pack was placed in line with the vehicle, between the chassis frame structure. This is the original location from the initial conversion of the vehicle. The battery modules were fitted in a single compartment, directly under the center of the care. The battery pack was originally fitted with a split battery pack, of which the smaller pack in the rear is no longer utilized.

Figure 13: Hybrid vehicle battery pack

<u>WP5 (DPS):</u>

The integration of the FC system in the electric car was delayed despite both the car and the FC system being completed. This was due to a long delay in the delivery of the inverter connecting the FC system to the cars electric system. Figure 11 shows the car during the demonstration phase at DTU.

Figure 11: The car during demonstration at DTU.

The demonstration is ongoing/continuing as the car is now part of DTU CAS' fleet of utility vehicles operating at DTU.

The key feature of the car is the independence of charging infrastructure. The continuous charging during the day means that the car can be left to charge at any point at DTU without having to search for a charging station. At night it is recharged using a standard 16 A outlet.

WP6 (DPS):
The project has resulted in significant external investments (< 2 M€ during the project duration) in development and manufacturing processes at DPS. This has created the foundation for the next step for HTPEM fuel cells: An investment and collaboration agreement with an external partner. This will scale HTPEM for automotive use (the hybrid power concept) with more than an order of magnitude within 1-2 years.

The hybrid vehicle project has been a major element in the transition of Lithium Balance to become a supplier of BMS'es to the growing automotive market. Integrating our BMS and fast charger into a vehicle has provided extremely valuable feedback to the product development and the vehicle project has been an important show-case towards customers.

1.6 Utilization of project results

The hybrid vehicle project has been a major element in the transition of Lithium Balance to become a supplier of BMS'es to the growing automotive market. Integrating our BMS and fast charger into a vehicle has provided extremely valuable feedback to the product development and the vehicle project has been an important show-case towards customers.

As a first step towards the automotive market the n-BMS developed partly through this project has led to additional investments into the company and into a second generation of automotive BMS'es, the so-called z-BMS. The z-BMS is targeting the Chinese and worldwide high volume passenger car market. This investment has created at least 8 new jobs in R&D and more jobs in sales and production are expected when the new product reaches the market

The results of the present project are very important for the future collaboration between DPS and Blue World Technology (BWT) in Ålborg. BWT focuses entirely on the automotive sector using the same technology as here. The business plans for the involved companies will be updated accordingly, presumably already in 2019.

The project partners do not expect to take out patents.

Operation of vehicles on green methanol is a very important step to pave the way for a fossil free Denmark in the future.

The collaboration with the Turkish company Teksis is expected to open the market for Danish fuel cell technology in the Middle east.

1.7 Project conclusion and perspective

The project has been highly successful both in terms of technical progress and commercial progress:

- The new products developed by LiB have both created new jobs and attracted investments from collaboration partners.
- The significant advances in HTPEM fuel cells have enabled DPS to attract both investments and a collaboration partner for the next step towards commercialization of the hybrid power pack concept.

The project has enabled the industrial partner to make significant advancements within their respective fields, thus made an essential contribution to the transition towards fossil fuel free transportation. The developed products and technologies are being applied to electric vehicles today.

The actual hybrid power pack (as developed within the project) is not ready for commercialization (too low TRL). However, DPS is continuing to develop the concept together with BWT and the first small series production are expected to begin already in 2019.

The commercialization of the products and concepts developed by SPG awaits feedback for a partner before any further activity.

Annex – dissemination

The HV project have contributed to the following publications:

Merit Bodner, Hector R. García, Thomas Steenberg, Silvia Martinez, Anton Vassiliev, Hans Aage Hjuler and Carina Terkelsen, Enabling Industrial Production of Electrodes by use of Slot Die Coating for HT-PEM fuel cells, European Hydrogen Energy Conference 2018, abstract, EHEC 2018: Proceedings, ISBN: 978-84-09-01620-4, Málaga, 14-16 marts 2018.

Jens Oluf Jensen, Tonny Søndergaard, Arvind Kannan, David Aili, Lars N. Cleemann, Hans Becker, Thomas Steenberg, Hans Aage Hjuler, Qingfeng Li, Durability of High-Temperature PEM Fuel Cells, 22nd World Hydrogen Energy Conference 2018, abstract, Rio de Janeiro, 17-22 June 2018.

Nikoline Skytte Aaskov, Danish Power Systems Sets New Record with Low Degradation Rate in Fuel Cells, https://fuelcellsworks.com/news/danish-power-systems-sets-new-record-with-low-degradation-rate-in-fuel-cells/, FuelCellsWorks, 13. February 2018.

Merit Bodner, Thomas Steenberg, Hans Aage Hjuler, Upscaling the production of high temperature polymer electrolyte fuel cells – an assessment of reproducibility, performance and durability, lecture, International Hydrogen and Fuel Cell Conference, Trondheim, Norge, 14-15. May 2018.

M. Bodner, H. R. García, T. Steenberg, A. Vassiliev, S. M. Alfaro, G. Avcıoğlu, and H. A. Hjuler, Upscaling the Production of High Temperature Polymer Electrolyte Fuel Cells – an Assessment of Reproducibility, Performance and Durability, AiMES 2018 Meeting, ECS abstract, 30. September – 4. October 2018, ECS Trans. 2018 86(13): 281-285.

Nikoline Skytte Aaskov, High Energy Efficiency – methanol fuel cells, Nordic Clean Energy Week 2018, poster, Industriens Hus, København, 11. April – 25. Maj 2018.

Hans Aage Hjuler, Merit Bodner, Thomas Steenberg, Upscaling the production of high temperature polymer electrolyte fuel cells –an assessment of reproducibility, performance and durability, abstract, Book of abstracts, H2fc2018, Trondheim, May 2018.

Merit Bodner, Héctor R. García, Thomas Steenberg, Carina Terkelsen, Silvia M. Alfaro, Gokce S. Avcioglu, Anton Vassilies and Hans Aage Hjuler, Enabling Industrial Production of Electrodes by use of Slot Die Coating for HT-PEM fuel cells, International Journal of Hydrogen Energy, EHEC special issue, xxxxx

Danske brændselsceller er endnu engang blevet både bedre og billigere, Forskning i Bioenergi, Brint & Brændselsceller, biopress, 14. årgang, Nummer 75, juli-august 2018.

Vinh Nguyen, Jason Ziolo, Yuan Yang, David Diercks, Silvia Alfaro, Hans Aage Hjuler, Thomas Steenberg, Andrew M. Herring, Imbibed Polybenzimidazole for Enhanced Protonic Conductivity for High Temperature Fuel Cell Applications, J.Electrochem. Soc, doi: 10.1149/2.0331706jes, J. Electrochem. Soc. 2017 volume 164, issue 6, F504-F513.

Jens Oluf Jensen, Tonny Søndergaard, Lars N. Cleemann, Thomas Steenberg, Hans Aage Hjuler and Qingfeng Li, Durability Studies of High Temperature PEM Fuel Cells. Operational Parameters, Accelerated Testing and Acid Retention, abstract A1205, proceedings, Chapter 03 – Sessions A07, A11, A05, A12 – 28/32, EFCF, Luzern, July 2017.

Elisabeth Therese Ulrikkeholm, Hector Rodrigo García, Hans Aage Hjuler, Thomas Steenberg, Advanced Materials for High-Temperature PEM Fuel Cells, abstract A1203, proceedings, Chapter 02 – Sessions A07, A11, A05, A12 – 26/32 , EFCF, Luzern, July 2017.

Elisabeth Therese Ulrikkeholm, Hector Rodrigo García, Hans Aage Hjuler, Thomas Steenberg, Understanding the degradation of High-Temperature PEM Fuel Cells, abstract A0802, proceedings, chapter 02 – Sessions A08, A10, B02, B04 – 6/47, EFCF, Luzern, July 2017.

H.A.Hjuler, Latest results on high temperature PEM fuel cells, lecture,
TKK, Hiratsuka, Japan, 23. May 2017.

H.A.Hjuler and T. Steenberg, Newest developments in High Temperature PEM Fuel Cells, 24th FCDIC Fuel Cell Symposium Proceedings, pp. 161-164, FCDIC, Tokyo. H.A.Hjuler, invited speaker, same place.

H.A.Hjuler and T. Steenberg, Recent Developments in High Temperature PEM Fuel Cells, Solid State Ionics, SSI21, Program Guide and Abstracts, pp. 58, 271-272, Padova, 18-23. June 2017. H.A.Hjuler, invited speaker, same place.

Thomas Steenberg, Hans Aage Hjuler, Lars Nilausen Cleemann, Qingfeng Li and Jens Oluf Jensen, Performance improvements in High-Temperature PEM Fuel Cells, abstract, 232nd ECS meeting, Meeting program, p. 204, 1-5. October 2017, National Harbor, MD.

Silvia Martínez Alfaro, Héctor Rodrigo García, Anton Vassiliev, Thomas Steenberg and Hans Aage Hjuler, HTPEM CHARACTERIZATION – ANALYTICAL TECHNIQUES, Electrochemical science and technology conference 2017, abstract book, p. 47, Lyngby, 2-3. november 2017.

Thomas Steenberg, Hans Aage Hjuler and Søren Primdahl, 20 years with High Temperature PEM Fuel Cells, Electrochemical science and technology conference 2017, abstract book, p. 30, Lyngby, 2-3. november 2017.

Hans Aage Hjuler, Performance improvements in High-Temperature PEM Fuel Cells, Qualifix Workshop, Oldenburg, 5. December 2017.
T. Steenberg and H. A. Hjuler, Progress in High-Temperature PEM Fuel Cells, presentation, EnerjiSA, Teknokent, Ankara, 19. Jan. 2016.
T. Steenberg and H. A. Hjuler, Progress in High-Temperature PEM Fuel Cells, presentation, Ford Otosan, Sancaktepe-Istanbul, 21. Jan. 2016.
T. Steenberg and H. A. Hjuler, Progress in High-Temperature PEM Fuel Cells, presentation, Kocaeli University, Kocaeli, 19. Jan. 2016.
T. Steenberg, New method for upgrading biogas to natural gas, poster, energinet.dk, Fredericia, 10. Feb. 2016.

Hüseyin Devrim, Kübra Pehlivanoğlu, Ömer Erdemir, Thomas Steenberg, Hans Aage Hjuler, Hector Rodrigo Garcia, Yılser Devrim, İnci Eroğlu, Development and Integration of 5kW HT-PEM Fuel Cell Powered Hybrid Power Station for Airport Service Vehicles, National Hydrogen Technologies Congress, 20-23 December 2015, İstanbul.

Thomas Steenberg and Hans Aage Hjuler, Recent Developments in High-Temperature PEM Fuel Cells, poster, Advanced Automotive Battery Conference, Detroit, MI, June 14-17, 2016.

Hans Aage Hjuler, Carina Terkelsen and Thomas Steenberg, C. Terkelsen, H. A. Hjuler and T. Steenberg: High Temperature Polymer Electrolyte Membrane Fuel Cells, poster, Advanced Automotive Battery Conference, Detroit, MI, June 14-17, 2016.

T. Steenberg and H. A. Hjuler, Progress in High-Temperature PEM Fuel Cells, Lecture, Kettering University, Flint, MI, 13. June 2016.

V. Nguyen (Colorado School of Mines), H. A. Hjuler, T. Steenberg (Danish Power Systems), and A. M. Herring (Colorado School of Mines), The Effects of Adding Heteropolyacids to Phosphoric Acid Doped Polybenzimidazole for Enhanced Conductivity in High Temperature Fuel Cell Applications, Abstract #93375, ECS230/PRiME 2016, Honolulu, 2-7. Oct. 2016. Poster presentation.

T. Steenberg, H. A. Hjuler (Danish Power Systems), J. O. Jensen, and Q. Li (Technical University of Denmark), Optimization of Catalyst Layer Properties for High Temperature Polymer Fuel Cells, Abstract #89392, Op ECS230/PRiME 2016, Honolulu, 2-7. Oct. 2016.

Elisabeth Ulrikkeholm1, Hans Aage Hjuler1*, Robert Kerr1, Thomas Steenberg1, Carina Terkelsen1, Jens Oluf Jensen2 , Lars N. Cleemann2 and Qingfeng Li2, ADVANCED MATERIALS FOR HIGH-TEMPERATURE PEM FUEL CELLS, ELECTROCHEMICAL SCIENCE AND TECHNOLOGY CONFERENCE 2016, Abstracts, p 32, Dansk Elektrokemisk Forening, Nyborg, 13-14. Oct. 2016. http://www.electrochemistry.dk/images/Programfolder_2016.pdf

T. Steenberg, Hybride Vehicle, lecture, DANSKE BRINT- OG BRÆNDSELSCELLEDAG 2016 I ODENSE, 10. Nov. 2016.

C. Terkelsen, H. A. Hjuler and T. Steenberg: High Temperature Polymer Electrolyte Membrane Fuel Cells, Poster, poster, DANSKE BRINT- OG BRÆNDSELSCELLEDAG 2016 I ODENSE, 10. Nov. 2016.

E. Ulrikkeholm, T. Steenberg and H. A. Hjuler: Membrane Electrode Assemblies for High-Temperature PEM Fuel Cells, poster, DANSKE BRINT- OG BRÆNDSELSCELLEDAG 2016 I ODENSE, 10. Nov. 2016.