Final report

1.1 Project details

Project title	Auxilary Hybrid Power
Project identification (program abbrev. and file)	EDUP-2013-I, Auxiliary Hybrid Power, 64013-0117
Name of the programme which has funded the project	Energiteknologisk Udviklings- og Demonstrationsprogram (EUDP)
Project managing company/institution (name and address)	Clayton Power ApS, Pakhusgården 42-48, 5000 Odense C
Project partners	SerEnergy A/S, Falck Schmidt Defence Systems A/S, Per Aarsleff A/S, LEAB Automotive GmbH
CVR (central business register)	29821631
Date for submission	22/07/2016

1.2 Short description of project objective and results

English

With support from the Danish Energy Agency, through their Energy Technology Development and Demonstration Program (EUDP), a scalable Auxiliary Hybrid Power platform has been developed through adaption of existing Lithium Iron Phosphate battery- and High Temperature Polymer Electrolyte Membrane fuel cell technology. During the course of the project, the Auxiliary Hybrid Power platform has been specified, tested and constructed in a wide variety of system builds, aimed for test in different market segments, users and configurations in terms of specifications, physical construction, integration and complementary components. The technical and commercial research and verification carried out through the project has resulted in a tested, proven and unified platform for further market implementation.

Dansk

Med støtte fra Energistyrelsen, gennem deres Energiteknologisk Udviklings- og Demonstrationsprogram (EUDP), er en skalérbar Auxiliary Hybrid Power platform blevet udviklet gennem tilpasning af eksisterende lithium jernfosfat batteri- og højtemperatur polymer brændselscelle teknologi. I løbet af projektet er Auxiliary hybrid Power platformen blevet specificeret, testet og konstrueret i en lang række forskellige systemopbygninger til testformål i forskellige markedssegmenter, konfigurationer og med forskellige slutbrugere i henhold til afprøvning specifikationer, fysisk konstruktion, integration og komplementærer komponenter. Den tekniske og kommercielle research og verifikation, der er udført under projektet har resulteret i en testet, bevist og samlet platform klar til yderligere markeds implantation.

Executive summary

In the period 01/09/2013 to 31/05/2016, a scalable Auxiliary Hybrid Power product platform has been established through adaption of Lithium Iron Phosphate battery- and High Temperature Polymer Electrolyte Membrane fuel cell technology, with support from the Danish Energy Agency through their EUDP program.

Project development, method and participants

The Auxiliary Hybrid Power project team consists of the following companies along with their respective roles; Clayton Power ApS – Technology provider and Project leader, SerEnergy A/S – Technology provider, Per Aarsleff A/S – Testing partner, Falck Schmidt Defense Systems A/S – Testing partner, LEAB Automotive GmbH – Testing partner.

The project logic and progress has been clearly mapped from the beginning through the project plan and the Goals, Milestones and Work packages description. The project methodology and setup enabled clear, measurable targets to be set and tracked.

Project results

In total seven different Auxiliary Hybrid Power systems where made, all based on the joint product platform of lithium batteries and fuel cells. Although all seven systems originated from the same product platform they have all been customized and integrated differently in order to test the adaptability to specifications, needs and compatibility with other required system components. Specifically the three cases of the project testing partners has been the main focus in terms of adaption and test and thereby most insight and learning has been gained in the segments that they represent, being; military, industrial services and automotive emergency vehicles. Additionally safety and functional testing has been carried out to verify and finalize the specifications.

In terms of the commercial setup and potential, an extended business plan, including Market Intelligence report and Product Platform description from a commercial point of view has been described. Furthermore the business setup between the two technology providers and support system around the end-user including the methanol fuel cell setup has been defined and described.

Project financials and timing

Through the EUDP program the project has been granted a total financial support of 6.482.200,00 DKK and with a budgeted contribution of the project participant’s of 6.698.800,00 DKK the total project budget totals at 13.181.000,00 DKK. At the close of the project around 90% of the project budget was spent with all projects objectives realized.

The initial project period was set from 01/09/2013 to 28/02/2016 but was extended with three months in order to include additional field testing and concepts.

1.3 Project objectives

The primary project objectives is the following:

- Specifying and adapting technology to a unified platform
- Developing a complete scalable APU solution
- Adopting the APU solution for specific applications
- Testing the APU platform with three key integrators
- Communicating the project with regard to reaching the relevant customer segments, ensuring commercial relevance and building confidence in the new technology.

With the core deliveries being the following technical and commercial milestones with associated objectives:

Technical

- **Milestone 1 – Specification and design finalized**
  - Design specification
  - Battery pack design
  - Fuel system design
  - BOP design
  - APU overall architecture
- **Milestone 2 – APU system prototype**
  - Working APU prototype
  - Test report
- **Milestone 3 – Internal test concluded**
  - Test results in relation to specifications identified in milestone 1
  - Demonstration of concept
- **Milestone 4 – Methanol fuel setup**
  - Report on methanol Fuel setup
- **Milestone 5 – External test**
  - 3 APU integrations
  - Test reports in relation to specifications identified in milestone 1

Commercial

- **Milestone 1 – Extended business plan**
  - Market intelligence report
  - Extended Business plan
- **Milestone 2 – Product platform**
  - Product platform
  - GoTo market strategy
  - Marketing platform
  - Production and marketing agreement

Project progress

The very first task in the project was to get a key understanding of the starting point that the different project partners had. Therefore we started with a kick-off meeting that had an open dialogue that invited to share expectations to the results already from the beginning. This is also why the final objectives of the project has been in high focus already from the start, along with great respect for the end user and end applications, which all project partners saw big technical and commercial potential in from the beginning. As a result a high number of prototypes where made with the purpose of testing and showcasing as many solutions as possible to generate key learning that would be used for the final integrations.

With this mind-set, the starting point for the first system prototypes was the specifications of the end user applications, which where identified very early in the process. Based on these "final" specifications two early prototypes were build to test different concepts and aspects of the expected challenges of the final systems. The first prototype was a basic mobile solution with automotive connectors, tight integration and simple interface with low user interaction required. The second was a stationary telecom solution which allowed for different configurations, easy access to fuel and components and testing of different advanced interfaces and data logging solutions with basis for a high level of interaction with the end user.

Following the two prototype specifications, designs, builds and demonstrations a set of standardised tests was performed. The purpose of the testing was to test the functionality, base specifications of the core technology models, durability and safety of the system. Understanding and application of standards, norms and the legal requirements of lithium battery and fuel cell systems in mobile and automotive applications played a significant part in this process as well.

After a successful testing process, the identification and specification of the methanol fuel setup started along with an extended business plan and market intelligence report, which gave final inputs to a review before the final design of the systems for external testing began.

The construction of the final systems for external field trial went well in terms of configuration of the core system modules, but the different integrations themselves proved to be a challenge in terms of the integration and interaction with the end application, which required extended in house testing to the user application specifications and was the reason for the granted three month extension. With the systems integrated final testing was performed successfully together with the testing partners. The mentioned project period extension even provided LEAB Automotive the opportunity to perform two end-user tests and three integrations in total as opposed to the planned one integration. The largest of the trial systems however proved to be a challenge to the extend that we in the project decided to extend the in field testing to after the closure of the project to further validate the durability, functionality and performance of the system.

As the final process in the project, the product, sales and marketing platform has been specified between SerEnergy and Clayton Power. The commercial agreement and further process through our sales force and joint website was established as a natural extension of the project and we face a promising but also challenging commercial future.

Finally a closure and knowledge-sharing event was conducted internally to close off the project and deliver final inputs to the future process. A process where not only the technology partners have proved their products but also a process where several key stakeholders has been enabled to successfully sell the systems into the market.

Risks associated with the project
Throughout the project the following technical, commercial and collaboration risks has been faced:

Technical risks
Even though an initial investigation was made to investigate the compatibility between the fuel cell and lithium battery modules, additional risks appears in the details such as power regulation, start-up/shut-down profiles and communication protocols. These detailed adaptions have certainly been one of the main challenges throughout the project together with the design and system dimensioning of the individual systems.

Additionally the standards and legal requirements of a hybrid system in automotive applications was clearly a risk from the start that needed to be investigated. However once the requirements where understood the safety features where relatively straightforward to implement in the systems.

Commercial risks
From a commercial point of view several risks where present with some still remaining. The risks are all based on assumptions and expectations that need to be realised in order to fulfil the commercial potential of the solution.

Starting from a financial point of view there are two key factors to be considered when the essential payback and operational saving calculations are made. One is the decreasing module cost over time, which is depending partially on the technical performance of the modules and partially on the production and sourcing setups, as both the fuel cell and the lithium battery module savings are primarily based on increasing volumes and a standardised continuous production. The other key financial factor is the low maintenance cost, which have been proved by the modules separately but not yet as a common system.

Besides the financial aspects the sales process is also to be considered a challenge and thereby also a risk for not hitting the expected sales numbers. Looking at the technologies and the many components the system quickly becomes very complex. However when looking at the core functionality, namely to deliver power, the system becomes simple. The simplicity together with the benefits is what needs to be communicated to the customer together with a basic understanding of what the system is and thereby also realizing the sales.

Finally more generic commercial risks are present such as not identifying the true needs of the customer and getting affected by increasing raw material and/or labour costs. In terms of the customer needs efforts has been taken to compensate for this trough a standardised sales process (Fig. 1). In terms of the raw materials the main risk is focused on the lithium cells, which is always purchased in US Dollars and thereby added additional risk as the final systems are sold in in either Euro or Danish kroner. On the dollar side the exchange rate is secured on a running 12-months basis based on ordered products and partially on forecasts. In terms of the raw material several suppliers are in place and a relatively large increase can be accepted while still generating significant savings for the customer.

Figure 1 - Auxiliary Hybrid Power sales flow chart

Collaboration risks

Besides the technical and commercial risks collaboration risks are also faced in the sense that it is essential that the two technology owners; Clayton Power and SerEnergy, has a good commercial setup and agreement and also natural interest in future collaboration. However with the clear complimentary abilities of the fuel cell and lithium battery modules the path is relatively clear. Additionally the organizations of the companies has matched well, which could also have been a challenge.

Project result implementation

As previously mentioned, a larger part of the project than expected was used on complimentary system components such as communication protocols, display solutions and system regulation. This prolonged the final build and integration of the systems longer than wanted. The integrations them selves did also serve as a challenge and as integration factors such as heat, noise and vibration needed to be considered throughout the integrations.

With the focus on larger systems in mobile industrial applications, additional durability validation is needed before the active sales process is started. Therefore the external project communication has not been as active as it could have but still the results that have been achieved are communicated.

Otherwise all milestones have been met according to the project plan and the expected project development process.

1.4 Project results and dissemination of results

Throughout the project the following systems where designed and constructed.

Mobile APU

Description:

The Mobile APU is basically a minimum viable system based on the product platforms of both companies (SerEnergy and Clayton Power). This means that the system consists of:

- 1 x H3 350 SerEnergy RMFC battery charger
- 1 x 24V – 100Ah Clayton Power Lithium Battery
- 1 x G3 2324-50 Clayton Power Inverter/Charger
- 1 x CDR Battery Separator
- 1 x Clayton Power Display
- 1 x 20L removable fuel container

Although very much a prototype, the concept represents a replacement for traditional gas and diesel generators and is able to handle both high usage peaks of up to 2,5kW for 50 min at a time e.g. for industrial tools and a relatively low continuous consumption of up to 350W for lights and communicational equipment, for up to two days without refuelling. The system comes with a on board battery separator that allows charging from the alternator of a vehicle while driving, a 24VDC output for e.g. extra on-board lighting, a 230VAC input for charging from mains and most importantly a 230VAC 50Hz pure sine wave output, is implemented.

Pictures:

Figure 2 - Mobile APU - Front view

Figure 3 - Mobile APU - Side removed

Figure 4 - Mobile APU - Fuel tank

Picture 5 - Mobile APU - View of fuel cell and battery

Schematic:

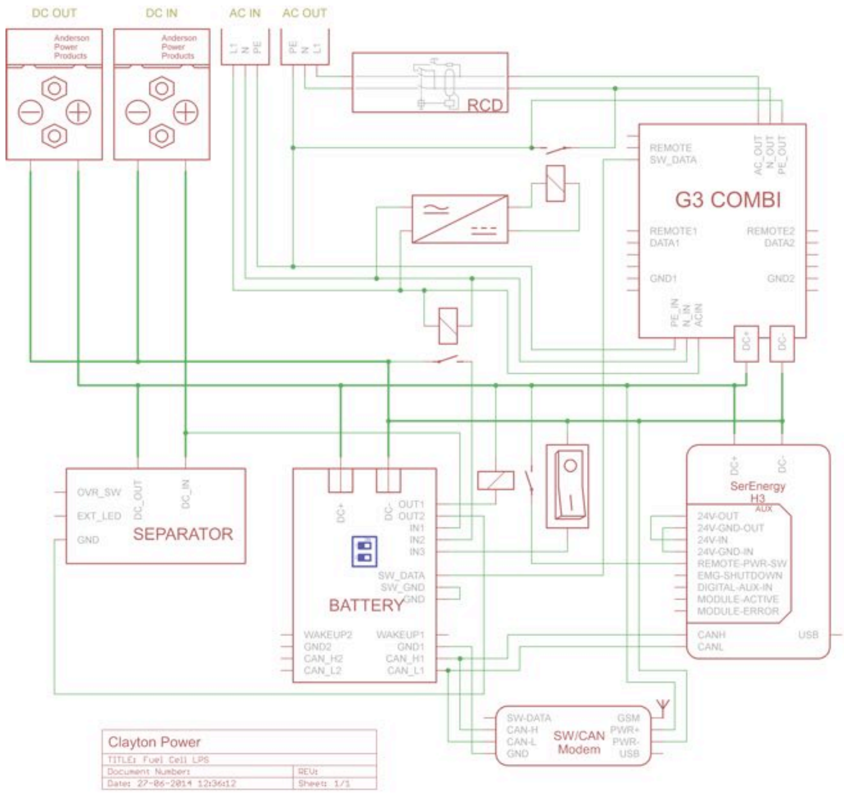


Figure 6 - Mobile APU Schematic

19” Rack APU

Description:

The 19” rack solution has two overall purposes in terms of the project. First of all the 19” rack footprint is widely used within the telecommunications industry, by integrating the APU components and dimensioning the components in relation to that footprint a part telecommunications concept is created and a understanding of what is possible in terms of this type of concept is developed.

Generally in this project, the technical challenge can be divided into two main areas; 1) the communication between the fuel cell and the lithium batteries and 2) the power control when increasing capacity and output.

By installing the components in a 19” rack module, the concept allows for installation of additional interface and communication equipment needed at his point to get access to more detailed information and ensure a smooth running system. The system consists of the following components:

- 1 x H3 350 SerEnergy RMFC battery charger
- 1 x 24V – 100Ah Clayton Power Lithium Battery
- 1 x G3 2324-50 Clayton Power Inverter/Charger
- 2 x Modified Clayton Power CAN modems
- 1 x Intel NUC Single board computer
- 1 x Touch screen
- 4 x 20L removable fuel containers

Upgrading the hardware of the system with two modified CAN modems, a single board computer and a touch screen allows for full data access of both systems (fuel cell and lithium battery). With a custom software application and graphics overlay an overview of charging times, remaining fuel, remaining capacity, power usage and power output from the different components can be precisely generated. Furthermore distinct programs for e.g. automatic power up of the fuel cell at a given battery level, or adjusting the power to partly coming from the fuel cell at a given percentage and from the battery at a given percentage, thereby increasing the lifetime of both subsystems, is eased with this setup.

Additionally the system allows for remote data logging, and can be setup to run various test scenarios, such as full power output, fuel consumption levels at different outputs, charging times at various scenarios and running various types of equipment through a power strip.

Pictures:

Figure 7 - 19" Rack APU - Front view

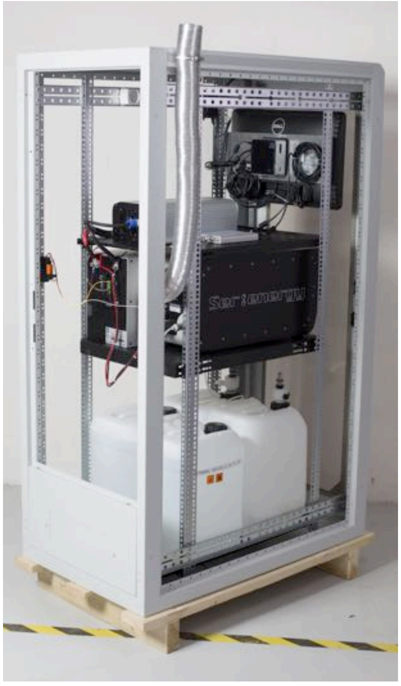


Figure 8 - 19" Rack APU - Back view

Figure 9 - 19" Rack APU - Wiring overview

*Note side and back panels are removed to allow view of the installed components.

Schematic:

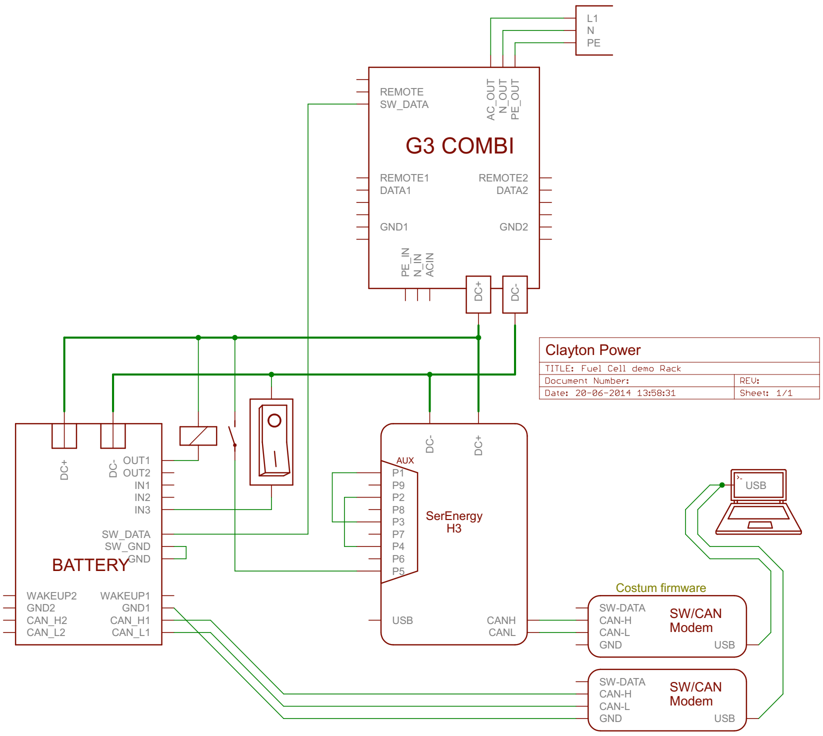


Figure 10 - 19" Rack APU - Schematic

Falck Schmidt Defence Systems

The system for the testing case (powering of an automated elevation mast in a movable tactical operation centre) of Falck Schmidt Defence Systems consists of the following:

- 2 x H3 350 SerEnergy RMFC battery charger
- 1 x 24V – 100Ah Clayton Power Lithium Battery
- 1 x G3 2324-50 Clayton Power Inverter/Charger
- 1 x Modified Clayton Power GSM CAN modem
- 1 x Intel NUC Single board computer
- 1 x Relay controller
- 2 x 20L removable fuel containers
- 2 x 1660 Peli cases
- 1 x Display
- Various accessories

The system configuration can be seen in the following schematic:

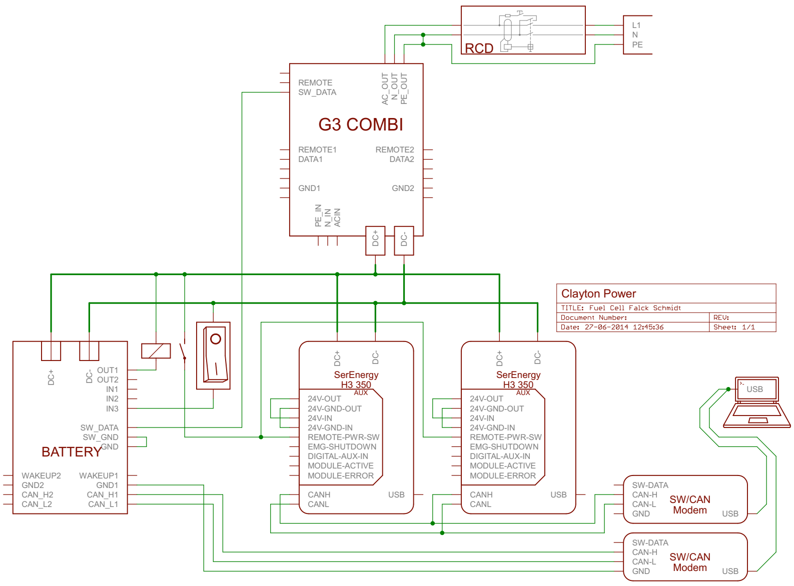


Figure 11 – Falck Schmidt Defence Systems system schematic

As can be seen in the following pictures the system is basically split into two, with the two H350 fuel cells in one Peli case and everything ells, meaning Lithium battery, Inverter/Charger, two control modules, a single board computer and a display in another.

Between the two Peli cases three links exist; one for fuel, one for communication and one for power, all designed for a rough environment.

Figure 12 - FSDS system, picture 1

Figure 13 - FSDS system, picture 2

Figure 14 - FSDS system, picture 3

Figure 15 - FSDS system, picture 4

Per Aarsleff

The system for the testing case (Powering a vehicle based sewer maintenance system) of Per Aarsleff consists of the following:

- 2 x H3 5000 SerEnergy RMFC power systems
- 8 x 24V – 100Ah Clayton Power Lithium Battery
- 3 x Xtender XTH 8000-48 Studer inverter/Chargers
- 1 x Clayton Power GSM CAN modem
- 1 x Industrial touch screen
- 1 x Single board computer
- An integrated 400L tank solution

The system configuration can be seen in the following schematic:

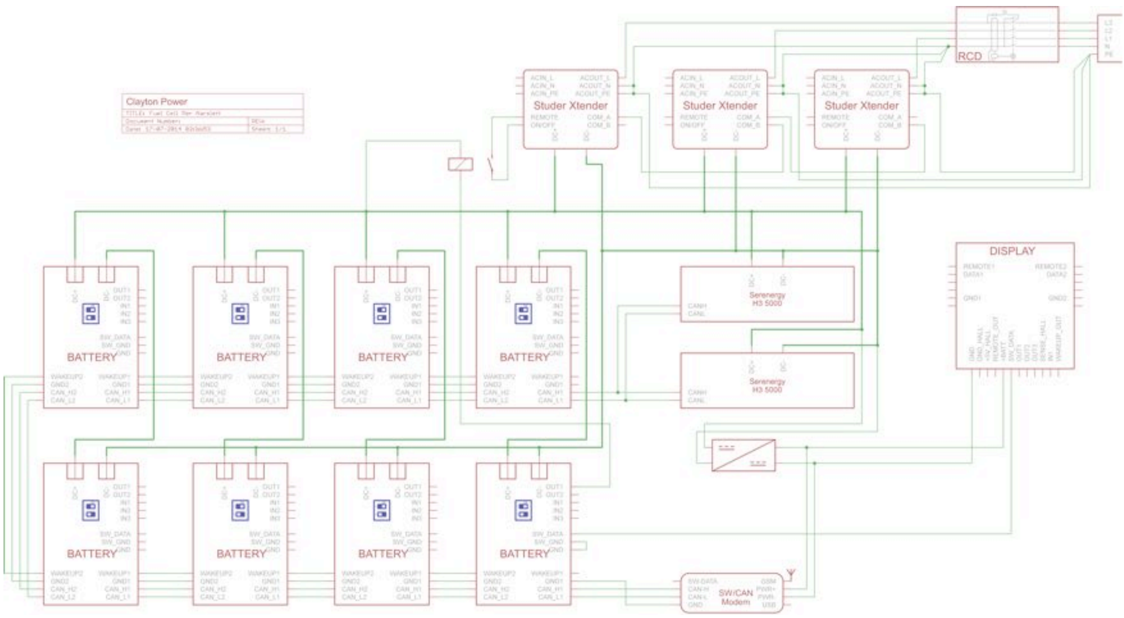


Figure 16 - Schematic of the Per Aarsleff system

The system is integrated in a full sized truck for main sewer line repairs and inspection and replaces a 21 kW generator. Run time is up to 50 hours per week.

Figure 17 – Per Aarsleff truck

Figure 18 – Per Aarsleff truck inside view

Figure 19 – Per Aarsleff system, view 1

Figure 20 – Per Aarsleff system, view 2

LEAB Automotive
LEAB Automotive did three different integrations in the project period. The first one was an integration in a small police surveillance vehicle, the second one; an integration in a small/mid-size Mobile home and the third one; an integration in LEABs own demonstration vehicle.

Police surveillance vehicle
The first integration system of LEAB Automotive (Powering vehicle based police surveillance system) consists of the following:

- 1 x H3 350 SerEnergy RMFC battery charger
- 2 x 24V – 100Ah Clayton Power Lithium Battery
- 1 x Clayton Power Display
- 1 x Clayton Power GSM CAN modem
- 1 x 24V to 12V DC to DC converter
- 2 x 20L removable fuel containers

The system configuration can be seen in the following schematic:

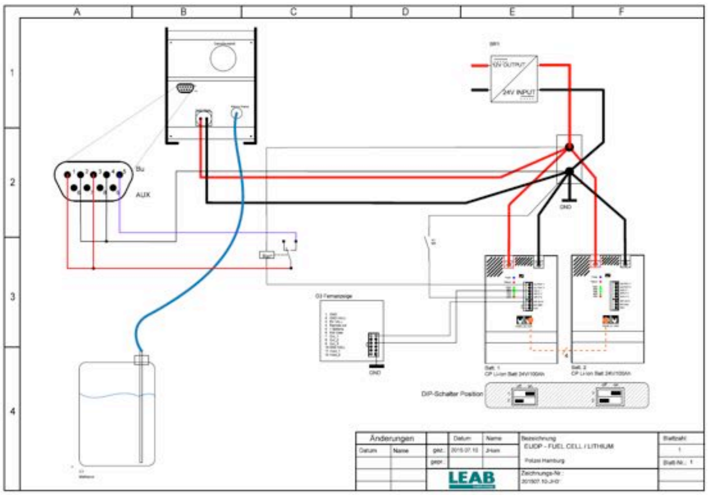


Figure 21 - Schematic for integration in a small police surveillance vehicle

Due to confideinetiallity we where not allowed to take pictures of the actual vehicle and integration.

Mobile home integration
The second integration system of LEAB Automotive (Mobile home integration) consists of the following:

- 1 x H3 350 SerEnergy RMFC battery charger
- 1 x Lithium Power Supply (LPS)
- 1 x 24V to 12V DC to DC converter
- 2 x 20L removable fuel containers

In stead of a conventional battery plus inverter/ charger and safety protections, an integrated unit (the LPS) featuring a 100Ah Lihtum battery, 50A charger, 1500W inverter, display, all required safety functions for a fixed vehicle installation, commincation in/out puts, 12V in/out puts and 230V in/out puts is used.

Because the Mobile home manufacturer clissfies its integrations as commercially sensitive informations, pictures of the actual integration where not allowed.

Demonstration vehicle

Using the same schematic as for the Mobile home integration the system has also been installed in LEAB demonstration vehicle to be showed at fairs and thorugh customer visits.

Figure 22 - Integration of a Auxiliary Hybrid Power system in LEAB Automotive's demonstration vehicle

Figure 23 - Outside view of LEAB Automotive's demonstration vehicle

Objectives

When looking isolated at the core objectives of the project the results where the following based on the single objectives

Specifying and adapting technology to a unified platform

All seven builds had the core basis of the indented core solution, being a lithium battery module together with a fuel cell module coupled with a user interface. In the cases where 230VAC was needed this was coupled with an inverter/charger solution. The main components of connecting the two technologies together were the communication between the modules, the software regulating the power profile, the core power transferring links and the commonly generated user interface. With all these being present in all seven systems and the integration of the system evolving over the builds a truly unified platform has been made.

Developing a complete scalable APU solution

With both technologies developed from a modular mind-set from the beginning, the modularity and scalability was naturally extended into the Auxiliary Hybrid Power platform. Basically the scalability of the system doesn't have a limit as long as the application that needs to be powered can be split into multiple phases, however with the current adaption that also needs to take place from application to application the current focus is applications where maximum a 50 kWh battery pack and 20kW continuous power is needed.

Adopting the APU solution for specific applications

The benefit of the project has been the possibility to do both concepts on trial based on typical use scenarios such as core mobile, telecom or automotive solutions based on the core modules with a variety of supportive components, but also very specific applications based on an actual customer need and as a direct replacement of existing technology. These solutions has very much shown the differences and challenges that arises when you move from concept builds to builds that needs to solve an actual problem, furthermore the replacing technology needs to perform at least as good and also a bit better than the existing technology to even be considered as a replacement. With having the luxury of doing seven different solutions it provided both differentiated valuable lessons and a natural learning curve throughout the project starting with basic functional concepts, moving on to in-depth testing applications and ending up with customer specific applications for external trial and testing.

Testing the APU platform with three key integrators

The three integrators where all very valuable to the project and with all the different positions in terms of value chain, sector and application the result was a good mix and broad variety of requirements and input to the joint technology, allowing it to be tested broadly in terms of technical requirements, durability, standards, usability and commercial relevance. The differentiated inputs to the project are listed in the following overview with the value chain position of each integration and testing partner:

LEAB Automotive

- Sales partner / Distributor / Consultant on auxiliary power solutions
- Situated close to the customer, with maximum one sales link between themselves and the end user.
- Mostly dealing within the automotive segment in Germany.
- Highly focused on commercial / high volume sales and products.
- Experienced in the low to mid range power need. In many cases 230VAC is also required by the customer.

With LEAB Automotive in the project team we have a partner that is very close to the market and highly focused on delivering relatively high volume commercial solutions. With no technology ownership in this field they are also free to supply solutions to the customer that fits his needs best, which makes LEAB Automotive's input highly valuable from a commercial point of view. Together with LEAB Automotive two applications has been tested with the technology, one together with Hamburg's police in a surveillance vehicle and another with a mobile home manufacturer. Finally LEAB Automotive has made an integration in their demonstration vehicle.

Falck Schmidt Defence Systems

- Development company on military Auxiliary Power Units and composite lifting towers.
- Highly experienced in military standards
- High level of development experience
- Supplying directly to the military

With Falck Schmidt Defence Systems as a part of the project we have a unique opportunity to gain first hand information on the requirements from a military point of view, additionally the information comes from a supplier who is an experienced technology provider and thereby understanding the development requirements. Together with Falck Schmidt Defence Systems we tested one of their cutting edge composite lifting mast, which can be used for a variety of military applications.

Per Aarsleff

- Large industrial company solving infrastructure assignments or maintenance tasks for public institutions.
- Highly experienced in industrial development, which has generated several technologies for fast, clean renovation of sewer systems, making the company market leading.
- Good understanding of the needs and wants of the market decision makers.

Per Aarsleff is the heavyweight of the project with high requirements in terms of system robustness and durability. In terms of the applications themselves Per Aarsleff clearly presented the case that would benefit the most from replacing the existing power technology with an Auxiliary Hybrid Power solution. The benefits are widely differentiated and covering lower emissions, better working environment, not conflicting with regulations limited the working hours and financial benefits. The solution itself was implemented in one off Per Aarsleff's demonstration vehicles for testing new technology used to improve the effectiveness of renovating main sever lines.

Communication of the project

As we are still gathering durability and usability data to prove the robustness of the system we have not yet started the active sales process of the solution as such. At the current stage following communicative activities has taken place:

- Marketing – Website and brochure as described in the previous sections.
- The systems has been shown at internal events and meetings at Per Aarsleff, SerEnergy, Clayton Power and a system installed in LEAB Automotive's demonstration vehicle. As a result of these activities quite a number of potential customers has seen the concept over the last years.
- The Per Aarsleff solution was presented in the truck at the opening of the first methanol tank station in Denmark on the 26th of August 2015. Several stakeholders such as public institutions, current and future business partners and press, relevant for the technology segments that we operate within, participated in the event.
- A closure meeting was conducted with the entire project team on the 19th of May 2016. Here all solutions, results and learning generated during the project were presented. Furthermore a knowledge sharing session was conducted together with discussions about future steps.
- An event was planned in the afternoon of the same day as the Closure meeting. However because of a low number of sign-ups, challenges with the event location and as later realised a tight schedule for many of our key stakeholders, the event had to be cancelled.
- Finally a lot of project related communication has taken place in order to reach the current project progress and results.

Key takeaways

The project has specifically enabled both SerEnergy and Clayton Power to develop their platforms further and in a joint direction, building on development platforms of both companies in terms of commercialising the technologies of the two companies even further, which has clearly increased sales for both companies but as actual sales of the Auxiliary Hybrid Power Systems has not started it is hard to quantify the actual numbers.

1.5 Utilization of project results

The utilization of the project results can be divided into two categories:

Further development

For both Clayton Power and SerEnergy, the development activities of the Auxiliary Hybrid Power project has created technical results that allows for continued quality assurance, continued improvement and development of the core technologies. Additionally the shared knowledge gained by both technology companies has created learning that makes future development activities with complimentary technologies easier.

Commercial utilization

All project partners where motivate to participate in the project based on their acknowledgement of the commercial potential of the technology. During the course of the project the relevance of the project results has been greater for some project partners than others and primarily SerEnergy, Clayton Power and Per Aarsleff stand to gain the most from the project. In short the main reasons for the benefits not being so big for LEAB Automotive and Falck Schmidt Defence Systems is respectively focus on pure battery driven products and military applications and mostly a result of strategic decisions.

The commercial utilization for the three companies standing to gain most from the project is as follows:

SerEnergy & Clayton Power

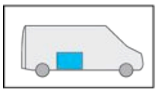
The commercial utilization for both SerEnergy and Clayton Power is based on increased product sales into new markets through the joint collaboration all described in the attached Product platform and commercial agreement: *"Auxiliary Hybrid Power - Product platform and commercial agreement.pdf"*

Per Aarsleff

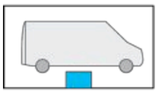
With Per Aarsleff the perspective is slightly different, as their commercial utilization does not focus on product sales but rather supplying a high quality service cheaper, more efficient and less polluting, which is also described in attached extended business plan.

Future market potential

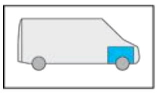
When looking at the market potential in general the following three segments are interesting:



The **Auxiliary Power Unit** (APU) will be an integrated part of a vehicle and will provide energy for functions other than propulsion. The APU's are typically used to provide power when the car stopped and are off grid, to prevent it from using idle mode.



The **Transportable Power Supply** (TPS) can be used to supply electrical equipment off grid. The TPS can easily be disconnected from its charging station in a vehicle and can be used everywhere in road maintenance, forestry, construction, etc.



As a **Power unit for Propulsion** (PPU), the MHPU is applied to provide the power to run a vehicle, where there is a need for low CO2 emission and a low noise level, e.g. in airports, indoor warehouses, hospitals and municipalities. The PPU can be implemented in e.g. forklifts, airport service vehicles, municipal service vehicles, service and maintenance vehicles in various industrial applications, as well as for recreational purposes, e.g. campers and yachts.

Decreased global fuel consumption, less CO_2 emission and a higher utilization of work assets is expected to impact industries ranging from huge global transport sectors to various niche transport markets. The potential benefits of the Auxiliary Hybrid Power technology are promising. According to our customer value proposition we expect to enter those niche industrial markets in which we identify the strongest user need for the benefits of the technology, such as environmental, cost savings and noise issues.

Economical / Performance		Environmental / User friendliness	
1	Very high efficiency and very low fuel costs	5	Low CO_2 emission
2	Very long operational time	6	No harmful emission / improved working environment
3	Low maintenance	7	Very low noise
4	Low downtime.	8	Easy to integrate

Markets

Auxiliary Power Unit (APU)

Total available market	Expected market	Est. Market value	Growth	Early adopter example
2.894.000 € (2020)	5.000 units (2020)	€ 66.000.000 (2020)	<1%	IBAK GmbH

Sources: Research and markets[1], Pike Research[2].

Main segments of the APU market are Marine, Trucking, Aviation, Recreational vehicles and Special vehicles. The market is described as a slow but steady growing market[7] and the total market expected to reach € 2.89 Billion in 2020[6]. The APU market has high barriers of entry, especially the military part of aviation and marine. Market drivers for change towards fuel cell solutions are primarily fuel efficiency and lower emissions. Subsequently legislation is also an important driver for change. The US market for heavy-duty trucks for example was legislated with new state laws against trucks running in idle mode[3].

While the legislation may be an important factor for long-term success we estimate that short-term success is more likely with Special vehicles market. e.g. ambulances, police surveillance vehicles, sewer inspection vehicles, command vehicles, etc.

Proof of market

(APU) IBAK GmbH delivers sewer inspection equipment for utility companies. For IBAK GmbH the Auxiliary Hybrid Power technology is able to impact their product performance; in the sense of improved efficiency, less downtime, longer operational time and reduced system weight. With reduced weight IBAK GmbH will be able to keep their vehicle weight below 3500kg, decreasing vehicle cost and avoiding truck driver licenses for the inspection equipment operators. Furthermore the decreased emission allows them to operate in environmental areas any time of the day as opposed to now, with the diesel generators. For IBAK GmbH adoption of the technology would mean better competitiveness and significant cost savings compared to other technologies like AGM gel lead-acid or diesel combustion generators.

Power units for Propulsion (PPU)

Total available market	Expected market	Market value	Growth	Early adopter example
€ 18-366 billion (2025)	25.000 units (2025)	€ 72 million (2025)	2%	MAFI Transport-Systeme GmbH

Sources: MGI Disruptive Technologies Report May 2013 (Hybrid/Electric vehicles)

The PPU market consist of 3 major segments, industrial-, airport- and municipal vehicles. Industrial vehicles are often battery driven while municipal and airport vehicles are often fuelled by fossil fuels. Internal market research has revealed a tendency in municipal and other PPU markets that customers are focusing on win-win scenarios where they can have both cost-savings and improvement to their environmental profile. This mind-set combined with the maturing technology in lithium batteries and fuel cells is what makes PPU a promising market. Furthermore the operational environment of the airport service vehicles is ideal

[1] http://www.reuters.com/article/2013/08/26/research-and-markets-

[2] http://www.navigantresearch.com/newsroom/investment-in-fuel-cells-for-auxiliary-power-unit-applications-to-reach-400-million-by-2020

[3] www.arb.ca.gov/msprog/cabcomfort/cabcomfort.htm

for implementing an Auxiliary Hybrid Power system since they a operating under a well defined physical area with a relatively well-defined consumption profile maximizing the circumstances for a perfectly dimensioned power system and lowering the investments in charging and refuelling facilities.

Proof of market (PPU)

MAFI Transport-Systeme GmbH (MAFI) is specialized in designing, engineering and producing state of the art heavy-duty vehicles, including a range of Terminal and RoRo tractors and trailers. Besides the obvious benefits of reduced fuel expenses and low CO_2 emission the Auxiliary Hybrid Power technology will enable MAFI to transition from a diesel, transmission and hydraulic based system to an integrated electrical setup. With an integrated hybrid setup in their products, MAFI would see significant cost reductions in operation expenses and decreased CO_2 emission, while still having the operating time to satisfy their customers need.

Transportable power supply (TPS)

Total available market	Expected market (2020)	Est. Market value	Growth	Early adopter example
162200 companies*	16220 units	€ 22 million	-3,30%	Per Aarsleff A/S

*Source: Eurostat

Technologically the transportable power supply is very similar to the Auxiliary Power unit but due to its mobility the markets are somewhat different, the main segment being craftsmen or contractors. The primary added value is the extension of the application area for current equipment. In this market we directly compete with idle running vehicles or diesel generators, both of which the Auxiliary Hybrid Power system is vastly superior to in regards of efficiency and CO_2 emission.

Proof of market (TPS)

As explained throughout the project Per Aarsleff A/S is a leading Danish contracting company. Amongst multiple relevant business areas, Per Aarsleff's sewer maintenance division appear most promising. Per Aarsleff uses state of the art technology to rebuild and repair sewers and the operations require multiple vehicles and a number of heavy power consuming equipment. By implementing Transportable Power Supplies instead of large conventional diesel generators Per Aarsleff is able to operate in environmental zones, beyond conventional operation hours and will realize a 70% reduction in operational costs. Furthermore a requirement for winning public tenders today is consideration and actions to overcoming social challenges such as improved working environment, reduced CO_2 emissions etc. all improved by using the MHPU instead of fossil fuelled technologies

Competitors

The main global and European competitors for the Auxiliary Hybrid power technologies are also known competitors to SerEnergy and Clayton Power. These competitors are expected to be able to directly compete with the Auxilairy Hybrid Power technology by setting up similar alliances like Clayton Power and SerEnergy and undergoing similar projects. .

Lithium Battery Module Suppliers

victron energy BLUE POWER	MASTERVOLT	SUPER B
Specialised in auxiliary automotive power equipment.	Specialised in auxiliary marine power equipment and solar applications.	Specialised in low cost lithium battery modules.
Main focus: Inverter/chargers in configuration with Lead-acid batteries.	Main Focus: Inverter/Chargers.	Main Focus: Lithium Batteries
Knowledge about solar systems.	Lithium batteries in their portfolio.	Limited system experience, No inverter/charger development.

Fuel Cell Suppliers

SFC ENERGY	ENERFUEL™	TOPSOE FUEL CELL
Pioneers of the fuel cell industry Strenght: Commercialization.	American fuel cell company Strenght: Battery/fuel cell technology	Promosing fuel cell company Strenght: Production expertise
Distribution of system have mostly been focused to low capacity systems.	Part of the Ener1 Group, developing energy storage technology.	Part of the Haldor Topsoe Group, producer of catalysts and chemical production equipment.
Expensive technology in terms of the medium to large systems. (DMFC)	Using HTPEM technology, with a limited target application of 0,1 – 3kW.	Immature technology with fuel handling barriers before commercial-istion. (SOFC)

Strategy and growth potential

By combining the two technologies (fuel cells and lithium batteries) SerEnergy and Clayton Power are able to compete in the combustion operated market. This market is much larger than the markets for fuel cells and lithium batteries - €8 billion global market yearly for diesel generators. Entering this market will significantly increase company size by only gaining a fraction of the market, potentially 50-500 extra employees per technology company would be realistic.

Other interesting applications and markets for later focus would be Uninterruptable Power Supply application for various markets such as the telecom industry or infrastructure applications that needs continuous power.

Contribution to realize energy policy objectives

With all these applications the Auxiliary Hybrid Power project has the potential to contribute significantly to meet the following energy policy targets set out by the Danish government:

- A minimum share of 30% of the total domestic energy consumption must be provided by sustainable energy sources by 2020
- A minimum share of 10% of the total domestic energy consumption in the transport sector must be provided by sustainable energy sources by 2020.
- Danish independency of fossil fuels in 2015.

Exactly how much the technology will contribute to meet these targets are very hard to quantify currently.

1.7 Project conclusion and perspective

During the course of the Auxiliary Hybrid Power project, a successful demonstration of a joint HT-PEM fuel cell and LiFePO4 lithium battery platform has been performed. The platform is highly scalable and adaptable in terms of capacity, voltage, output, interface and physical integration. Throughout the project; lifetime, safety and functional aspects of the platform has been tested and verified with positive results, proving the hybrid technology technically ready for market introduction. Furthermore the market potential of the Auxiliary Hybrid Power technology has been investigated and verified, resulting in identification and definition of initial customer target segments.

To define and describe the joint product platform the key interface parameters between the two technologies has been identified and matched together with the testing partners of the project, with the most important being voltage, power and communication protocols. Through verification and test of seven different demonstration systems in various configurations and applications the joint product platform has been verified and finally specified.

Through four end-user test periods, clear user specific performance indicators for the systems has been identified and used in the updated business plan and will be applied in the upcoming marketing and sales process. Additionally the system specific benefits being; significant CO_2 savings, clear operational cost savings, improved working environment, reduced pollution and improved abilities to win public tenders, has been verified for the core segments.

The cases that the three testing partners have presented has been very important throughout the project and served as key references to measure the success of the Auxiliary Hybrid Power systems, as the goal and challenge throughout has been to match the technology to the application and not the other way around thereby truly evaluating the technical and commercial opportunities of the product platform.

Furthermore the successful technical, commercial and organizational match between the two technology providers of the project has created a solid base for further product developments and demonstration projects, either in the sense of more integrated products into e.g. electrical vehicle applications or even larger scale systems.

Finally a Product platform and Commercial agreement between SerEnergy and Clayton Power has been established. The agreement not only describes the how the single systems should be sold to the customers but also how the complimentary products such as the methanol fuel is made available to and integrated in the customers individual setup.

All in all the project results meet the initially set objectives with only an additional limited period of system robustness testing extended beyond the project.

Annex

Following project specific general documents and information is attached separately:

- Auxiliary Hybrid Power Homepage: www.mobile-hybrid-power.dk
- Extended business plan: *"Auxiliary Hybrid Power - Extended Business plan V1. .pdf"*
- Market intelligence report: *"Market intelligence report 1.0.pdf"*
- Fuel setup report: *"Methanol Fuel Supply Report V1.1.pdf"*
- Product platform and commercial agreement: *"Auxiliary Hybrid Power - Product platform and commercial agreement .pdf"*
- Yearly report 2014: *"Auxiliary Hybrid Power - 2014 yearly report V1.0.pdf"*
- Yearly report 2015: *"Årsrapport 2015 - AHP - ref 64013-0117.pdf"*
- Yearly report 2016: *"Åsrapport 2016 - AHP - ref 64013-0117.pdf"*
- Presentation from project closing meeting: *"AHP - Project closure meeting.pdf"*