PUBLIZIERBARER Zwischenbericht

Projektdetails

Titel:	***eMPROVE*** – Innovative solutions for the industrialization of electrified vehicles
Programm:	6. Ausschreibung Leuchttürme der Elektromobilität
Koordinator/ Projekteinreicher:	Institute for advanced Energy Systems & Transport Applications e.V., St.
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Projekt- und Kooperationspartner (inkl. Bundesland):	(P1) AVL AVL List GmbH, St. (P2) SDI Samsung SDI Battery Systems GmbH, St. (P3) ATT advanced thermal technologies GmbH, St. (P4) VIF Kompetenzzentrum Das virtuelle Fahrzeug Forschungsgesellschaft mbH, St. (P5) SDAG Saubermacher Dienstleistungs AG, St. (P6) MUL Montanuniversitaet Leoben, St. (P7) 4a 4a manufacturing GmbH, St. (P8) ZG Zörkler Gears GmbH & Co KG, BG (P9) AIT Austrian Institute of Technology GmbH, Vienna (P10) REDUX REDUX Recycling GmbH, Germany (P11) LKR Leichtmetallkompetenzzentrum Ranshofen GmbH, UA
Projektwebsite:	www.emprove.at
Schlagwörter:	PlugIn-Hybrid-Vehicle, Transmission, Battery, Energy Storage System, BEV, Recycling, EcoDesign, Second Life, Range Anxiety, Virtual OEM
Projektgesamtkosten:	6.669.802 Euro
Fördersumme:	2.771.200 Euro
Klimafonds-Nr.:	KR14EM6F12312

A. Projektbeschreibung

Kurzfassung: Max. 1.500 Zeichen inkl. Leerzeichen Die Kurzfassung sollte umfassen: Inhalte und Zielsetzung des Projekts, methodische Vorgehensweise, welche Probleme werden wie gelöst, Zielgruppen/-märkte. ANMERKUNG: Die Kurzfassung soll keine allgemeine Beschreibung des Beitrags zu den EU2020 und anderen politischen Zielen enthalten.	In order to achieve both a simultaneous increase in energy efficiency and performance as well as a reduction of costs for the electrified full vehicle, the targeted solutions of ***eMPROVE*** take into account the whole life cycle from a technical and economic perspective: • Integration of existing and new solutions in an overall system: Electrified transmission unit and ICE, high performance energy storage systems, improved methods, materials and components, intelligent energy management systems for energy storage as well as for vehicle and functional components • Consideration of possibilities and costs of future mass production already during the development of systems and technologies. • Development of systems, instruction guidelines and business models for secondary use of vehicle’s energy storage components and systems (e.g. for stationary installations). • Improved methods for the recycling of components and second life use. ***eMPROVE*** focusses on the following targets and results, which will be demonstrated via tangible prototypes. <u>Energy- & cost-optimized demonstrator (implemented in WP1)</u> Main Targets & Results: • Build-up of demonstrators: 1) PHEV full demonstration vehicle based on a Golf class vehicle and 2) Modularized battery system demonstrator • Component tests/verification for demonstration • Demonstration of full PHEV vehicle, battery and results of industrial research • Integration of technology elements (e.g. heating device for high efficient warm up of vehicle and transmission) developed in several WPs into the demonstrator <u>Energy & Cost-optimized transmission & ICE (implemented in WP2)</u> Main Targets & Results • Cost reduction of electrified transmission for PHEV powertrain by 10% (w.r.t. VECEPT • Emission reduction: NEDC <31g CO_2/km (as compared to Hybrid VW Golf with 35g CO_2/km) • Reduction of the number of clutch, brake and shifting elements (w.r.t. VECEPT) • Introduction of thermal gearbox housing concept • Cost- and efficiency-optimized ICE (gasoline combustion engine

	200g/kWh) • Flexible design for future PHEV powertrains enabling easier integration in larger classes of vehicle (→ mass producibility) Modularized Storage & Energy Systems (implemented in WP3) Main Targets & Results • Battery system: Cost reduction by min. 15%; increase of energy density by min. 20% • Modularized HV battery system Modular HV battery modules enabling easier integration of battery elements in all vehicle classes (→ mass producibility) • Standardization regarding modularization of batteries (electronics, cell modules, safety circuits, …) • Lightweight concepts for batteries (new housing & cooling, different levels of integration into electric vehicles) Batteries Safety, Recycling and Second Life (implemented in WP4) Main Targets & Results • Recycling process: Increase of energy efficiency of overall recycling process due to pure mechanical recycling step up to 20% + Cost reduction by 5% via re-design and increased output fraction quality (secondary materials) • Development of design rules regarding future recycling concepts to include recycling already during the development process (→ mass producibility) • Extension of battery safety life cycle to logistics, second life, decommissioning and recycling, indicating potential influence factors on early battery design and risk mitigation measures (instructions) • Logistics concept for batteries • Virtual disassembly of existing and new developed systems • Assessment of materials for second life handling and establishment of instructions for design compartments for future batteries suited for second life Research for Improvement (implemented in WP5) Main Targets & Results • Improve component energy efficiency by 4% via thermal active material based on sheet layer composite (test bench for demonstration) and integration of heating technologies, while keeping the same costs • Development, integration and demonstration of surface heating concepts in order to improve the efficiency of the cabin heating system

	• Development, integration and demonstration of thermal active gearbox housing concept in order to intelligently control the oil temperature also while the vehicle is parked • Recycling concepts for new developed materials
Status: Beschreibung des aktuellen Stands des Projektes inkl. Datumsangabe mind. ein Aufzählungspunkt, max. 3 Aufzählungspunkte max. 500 Zeichen pro Aufzählungspunkt	The main goal of the first phase of ***eMPROVE*** (the requirement phase) was to collect requirements (inside the project and outside), coordinate them and lay the base for the next phase (development phase). The main result of this phase is the DELIVERABLE 26: Requirements Architecture, which represents the base for the development phase. It contains all relevant conditions and parameters (overall project goals for energy- and cost efficiency, mass production, external stakeholder input) for the optimization of the vehicle and its components, the energy storage system, the recycling and the research activities. As described in chapter 1.1.3 every work package (WP1 to WP5) developed its requirements. This means for the vehicle the Interim Deliverable 9: Report on transmission concept, which includes also the requirements of the vehicle demonstrator of WP1, for the energy storage system the Interim Deliverable 12: Report on modularization concept: Report summarizing the modularization concept and design, being the basis for development of modular components including the requirements for the battery demonstrator of WP1, for the recycling, Second Life and eco-design the DELIVERABLE 15: Report on virtual disassembly, available theoretical recycling quota and compendium on eco design and second life and for the research work the Interim Deliverable 18: Ready to use models of the single cell for further usage; Feasibility of cabin heating concept and coating concept available; Report detailing the introduced methods and parameters.
Wesentliche (geplante) Erkenntnisse aus dem Projekt: Kurzzusammenfassung der geplanten Erkenntnisse Darstellung der bisherigen Projektergebnisse (sofern vorhanden) mind. ein Aufzählungspunkt, max. 5 Aufzählungspunkte (ggf. auch wesentliche Publikationen) max. 500 Zeichen pro Aufzählungspunkt	**Highlight of WP2** The most important results of the current activities can be summarized as following: • Completion of functional requirement list • Further refinement of DHT transmission development process • Discovery of several novel DHT transmission concepts which meet expectations With the completion of the functional requirements of WP2 all main boundaries are set for the whole vehicle. It reaches from driving functionality, physical component definition, cost optimization, to human machine interface. It can be used as the basis for further steps in transmission development and interaction between work packages.

With the given system boundaries as a starting point a unique way of transmission development was chosen. It combines computer aided automated search for novel structures with experience from previous DHT projects. The search was split in two kinds of transmissions: advanced transmissions (AT) with planetary gear sets and multi plate clutches/brakes and conventional transmissions (MT) with spur gears and dog clutches/synchronizers.

It is very positive that this approach resulted in innovative transmission concepts for both kinds of transmissions above described. They are subject of patent application and represent a step forward in terms of transmission technology. The chosen concept from advanced transmissions (AT) was already successfully applied for. It consists of one extended Ravigneaux Planetary gear set, three clutches and one brake (see Figure 1).

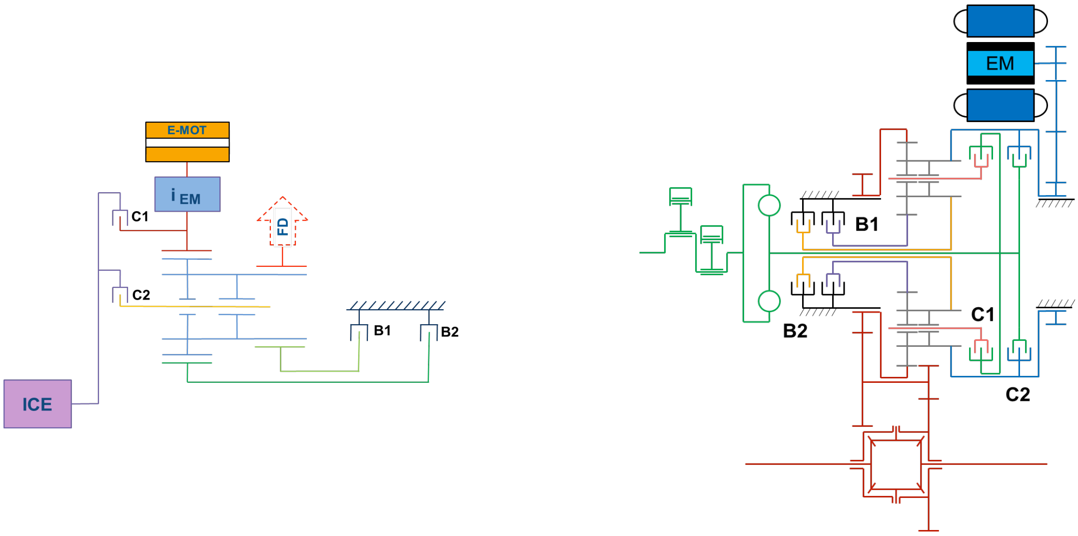

Figure 1: Advanced Transmission concept; left: principal sketch; right: transverse arrangement

The number of moving parts has been reduced with respect to VECEPT and the functionality of the transmission has been increased. This transverse transmission is also very flexible because with small modifications it can be used as longitudinal, 48V or conventional AT transmission.

Some innovative concepts were also found for the conventional transmissions (MT). They are very compact, flexible and cost effective due to the use of standard components. Those concepts don’t need a launch clutch which further reduces costs. A patent application will also be filed for them.

<u>Highlight of WP3</u>

Electric vehicles are still more expensive than comparable conventional vehicles. One of the main cost drivers in an electric car is the battery system. An approach to reduce that costs is standardization of components, so a mass production could leverage the economies of scale. But with mass production the requirement of an ecological friendly product lifecycle rises. Therefore the goal of work-package 3 is to find a modularization potential for automotive battery components in order to reduce costs, including considerations for eco-design and 2nd life usage of the battery.

Starting point for the work in WP3 was the VECEPT battery system. A Samsung SDI expert group analyzed main component per component regarding its standardization potential and developed a ranking system with three categories:

- High standardization potential
- Partly standardize-able
- No standardization potential

As illustrated in Figure 2 the main standardization potential can be identified for the electronic components. Those components have the same purpose in almost every battery system: Collecting temperature and voltage data and then calculating state of charge and health of the system.

One of the main cost drivers for the battery system itself are the battery cells, therefore they are identified as the key to a modularized battery concept. Although there are a lot of different cell formats available (prismatic, round, pouch in different sizes), there is a first approach by the VDA to standardize the prismatic format for automotive usage. The idea is to use those standardized format cells to build up standardized stand-alone modules, so they can be further chained up to a scalable battery system. The next step in ***eMPROVE*** is to determine a battery design using those standardized modules.

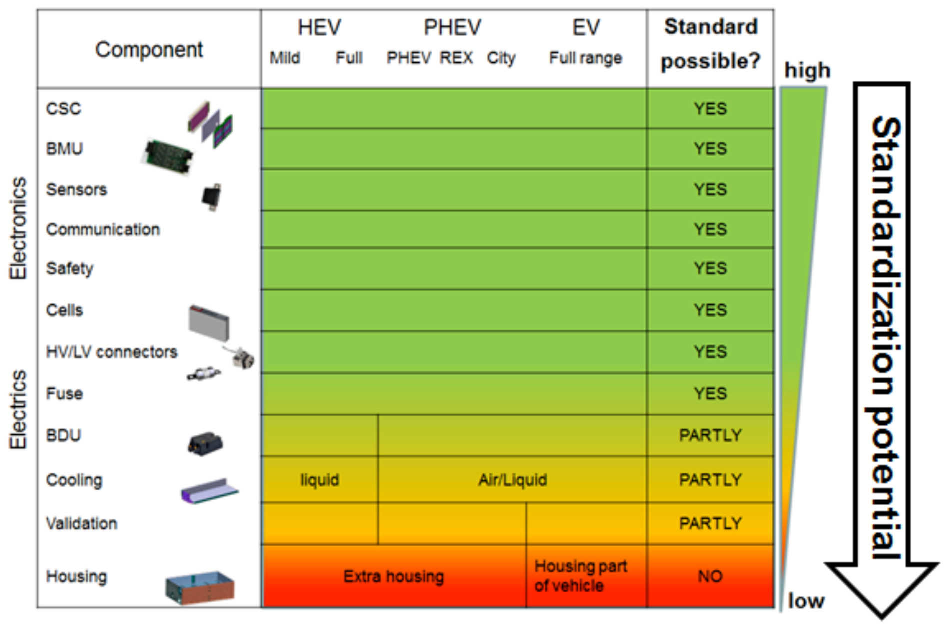

Figure 2: Standardization potential of an automotive battery system

Besides the easy to standardize parts there were also components identified that are partly usable for standardization, like the cooling system.

At last one component was identified that has almost no standardization potential: The battery housing. It is an integrated part of the vehicle and therefore always tailored to the available design space and requirements of the manufacturer.

After determining the standardization potential requirements for the demonstrator were developed. As already mentioned also eco-design and 2nd life will be considered in the battery design. The main resulting requirement is that the design has to use technologies that enable an easy disassembling.

Another approach to raise efficiency of a battery system could be to implement a thermal active housing, which could have a positive effect especially on EVs in cold conditions. Therefore in cooperation with work-package 5 different design options were evaluated and requirements for the ***eMPROVE*** system were derived.

Summarized Samsung SDI was able to identify with their partners several design specifications that will make future batteries more efficient with a lower price per kWh, covering life-cycle considerations. The next step of the project is now to implement those requirements in an EV battery design.

Highlight of WP4

WP 4 takes a look at the whole battery life cycling and focuses four main topics:

- 1. Eco-Design,
- 2. Functional Safety and Second Life,
- 3. Recycling.

1.) **Eco Design:**

The design of a battery pack was observed from a life cycle perspective. Different technical workshops helped understanding the system structure and change major functionalities as well as materials. The main results of the workshops are an optimized structure to reduce the HV while disassembly and repair, screws are the main joining technology (instead of glue and other technologies, which force destructive disassembly), the module format is chosen to ease recycling and re-use. Two other points are highlighted: the same material characteristics are used to separate the different parts easily as well as the marking of materials (cell chemistry etc.) on system, and module level is identified as necessary.

2.) **Functional Safety and Second Life:**

Based on the HARA (hazard assessment and risk analysis) the requirements of a first life battery are identified. Therefore the ISO 26262 and other normative and legal requirements were collected and examined if they influence the functional safety. To assure a holistic safety concept the safety issues for automotive and stationary use as well as transport, storage and charging are demonstrated and validated. The results of the HARA of a first life battery are shown in the 6 requirements shown in the following table and will be compared to the results of a second life battery (IEC norm).

ID	Safety Goal	ASIL
SG01	Prevent overheating of battery cells	C
SG02	Prevent overcharging of battery cells	C
SG03	Prevent deep discharging of battery cells	C
SG04	Prevent no monitoring	C
SG05	Prevent wrong balancing	C
SG06	Prevent wrong charging	C

Figure 3: Main requirements of a first life battery identified by HARA according to ISO 26262

3.) **Recycling**:

Based on the planed recycling concept, different experiments on laboratory and pilot scale were performed. The results help to dimension the aggregates for an industrial plant and optimize the process steps as well as the output fractions. A discharging station was established that will feed in the discharging energy in the internal energy net. Compared to the previous activities (discharging with a light bulb), the new approach will save energy and tries to reduce the discharging time. Concerning the output fractions the active materials fraction is optimized for industrial use by separation. Different cells were opened and chemically analyzed; these cells will be the basis for pilot scale tests in the second year. Due to the different pre-recycling steps, a comparison of LIBRES material and ***eMPROVE*** material is done. Different separation possibilities were evaluated and two of them were chosen for further experiments. The experiments with active materials show a potential to optimize the output on laboratory scale. An investigation on aggregates for a pilot/industrial plant was done to identify the important parameters. The activities will now lead to the build-up of a new recycling plant at our project partner REDUX as base for the development of an more energy- and cost efficient recycling process.

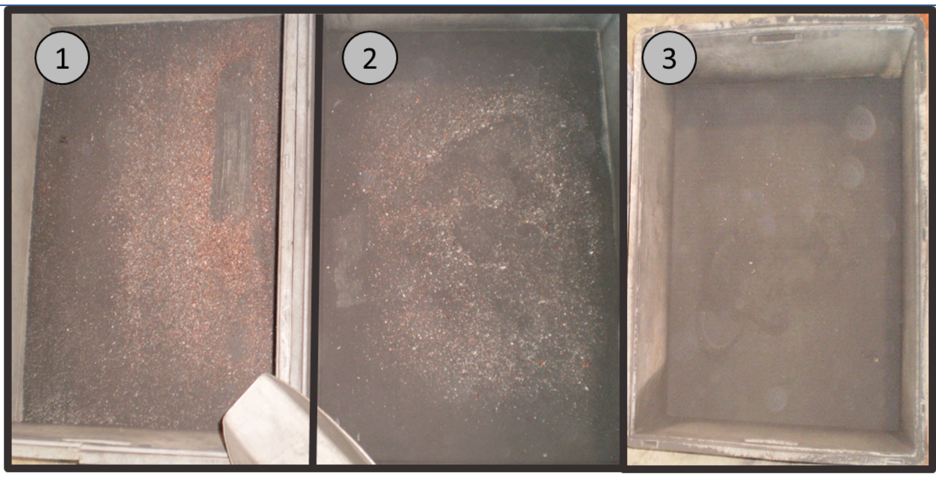

Figure 4: Active material separation in the first experiments

<u>Highlight of WP5</u>

Research focus 1 deals with establishing thermal comfort while using infrared radiation. The main idea behind this topic is to change the main heat transfer mechanism inside the vehicle from convection to radiation, which has several positive impacts. To do so, different areas inside the vehicle have been declared to be radiation areas at a temperature of about 60°C. The energy needed for powering these areas was taken from the air, resulting in the air being less warm than before. But even while using less warm than before it could have been shown, that thermal comfort inside the vehicle can be reached faster and consumes less energy than doing it in a classical way. During these investigations different numerical methods have been coupled together in order to get the entire picture represented by the thermal comfort a human would feel in certain environments. Figure 5 shows the difference between classical heating (left side) and radiation heating (right side) in the same car.

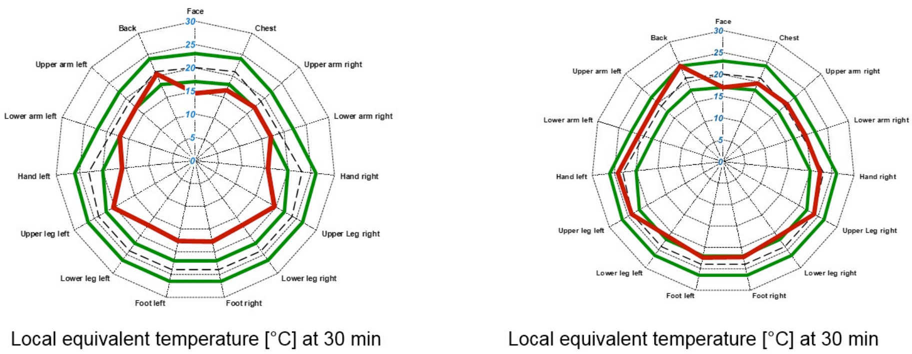

Figure 5: Standardization potential of an automotive battery system

Research focus 2 tries to answer a very interesting question: will it be possible to save energy if the automatic transmission fluid (ATF) will be heated up prior to vehicle operation? Cold ATF is doughy compared to warm. This results in high friction losses produced by the gears itself but also by the bearings of the axels. Normal ATF needs about 15 minutes to heat up to normal temperature. During this time, high friction losses are produced resulting in a higher energy consumption compared to the same situation with warm ATF. Using electric cars in an all-day scenario will result in driving short distances like going to work or to shopping places or to similar destinations. This means, that using an electric car this way during cold seasons will produce energy losses due to cold ATF. Furthermore, driving such distances will never heat up the ATF properly, as no heating unit is available for problems like this. So, during the first period of the project, it was investigated, how big the impact of a preconditioning system for the ATF will be. To do so, the efficiency of a standard gear system was compared with the same gear system featuring a heating concept for the ATF. With these analysis it could have been shown, that there is a huge energy saving potential when a heating system heats up the ATF once the vehicle starts moving. Figure 6 shows, that the efficiency of the gear system is at its maximum already 3 minutes after the vehicle was taken in operation. Normally it takes about 15 minutes to reach the same level of efficiency.

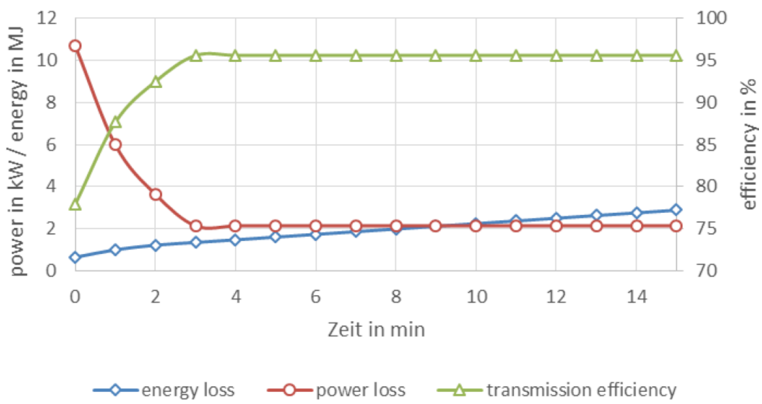

Figure 6: Energy-Efficiency increase by pre-conditioning of transmission oil

Research focus 3 deals with innovative technology to be integrated into housings of battery systems. Normally, battery housings are made of non-active materials like steel, aluminum or plastic. As the battery produces waste heat while being operated, battery systems need a cooling system. Normally, a water based cooling system is being used. During operation, the water picks up the energy produced by the battery and exchanges the heat in a special heat exchanger. Vice versa, during cold nights, the warm batteries are cooled down, as the batteries are losing heat over the battery housing. So, the idea behind the innovative battery housing is, that the heat conductivity of the entire housing can be controlled from outside. So, if well heat conduction is needed in order to support the cooling system, the heat conductivity will be switches to maximum. If the heat should be stored in order to keep the batteries warm during a longer period (overnight), the housing should be a good insulator in order to minimize the heat losses. To be sure, that such a system can really help to save energy and to improve the efficiency it is necessary to run several investigations including different seasons and driving cycles. During the first year of the project, a virtual model of a single cell was developed and also validated, which means that a virtual model was generated which behaves precisely like the real battery. With this model, an entire battery system can be built up. With this virtual battery system, all the necessary investigations will be performed during the next year of the project. An important parameter is the aging of the battery represented by single cells. Figure 5 shows the correlation of the aging by means of simulation with the virtual model compared to physical tests of the same cell in reality.

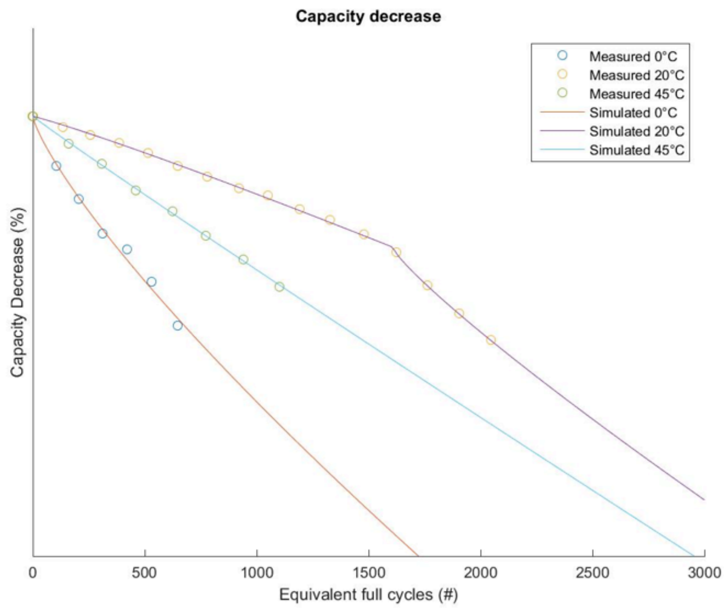

Figure 7: Optimization potential of pre-conditioned energy storage system

To sum up the activities of the first project year all work packages have worked together to define the central requirements architecture laying a stable and reliable base for the development activities in the second year of ***eMPROVE***.

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