carpeDIEM

Intelligentes Energie-management für Mikrogrids

FINAL REPORT 2019

carpeDIEM
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Project Partners

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Editorial

"How can we encourage and enable people to consume more energy from local energy resources?". Obviously using the energy where it is produced has the advantage that it does not need to be transported over long distances. This reduces transmission losses and therefore CO_2 emissions. Further, the local power demand, which is supplied by local renewable resources, does not need to be fed by external fossile energy sources. Additionally, people like to reduce their CO_2 footprint by charging their electric vehicles with energy, that is produced by the photovoltaic system on their rooftop.

In our region we have plenty of renewable energy resources with its wind parks and photovoltaic panels on barns, not to forget the silos of biogas plants and the cornfields feeding them. The problem is rather, how can we use all the energy from these local resources to cover our local demand? A major challenge is that the amount of power produced by these renewable energy resources varies with the time of the day, with the weather and the season. Moreover, also the power demand from people living next to these energy resources varies over time.
So the question is: "How can we couple load and supply?" and "How can we raise-people's awareness for local resource utilization and its benefits?".

Seeking answers to these questions we developed and carried out the carpeDIEM project. Thereby, we envision to develop and showcase solutions that find peoples acceptance. Starting with two project initiators the network grew and connected different types of stakeholders ranging from public communities over technology providers to energy suppliers from both sides of the border. We received great attention for the carpeDIEM project that we would not have imagined when we started the project. This culminated in an interview with the German TV station ZDF and a contribution to a TV science show. Further, we are very proud that the carpeDIEM project has been selected as exemplarily project for a film about the Interreg5a program.

We consistently receive requests for case studies, offers for demonstration sites and invitations to present the results of the project. Further, the network is part of several follow-up third-party funded projects. Company consortiums are formed to lift the developed technologies to the next level. A carpeDIEM inspired start-up company was founded, which was inspired by the work done in the carpeDIEM project.
The carpeDIEM technology has been adapted by technology companies and two systems are currently installed to continue to act as demonstration sites. We have applied for third party funding for more installations based on the carpDIEM technology.

The project has drawn additional attention from public as a result of refocusing midway towards complementing the system with electric vehicles. Electric vehicles pose a tangible example for a shiftable load in an energy management system. Prosumers acknowledge their potential to increase the consumption from local energy resources both for mobility and as a shiftable load.

In the following we describe the DIEM technology with respect to its applications and we summarize the results of the case studies. Finally we clarify, whether such energy management systems serve the national supply system.

Sønderborg, 10. September 2019 Robert Brehm

PROJECT FACTS

Duration: Apr. 2016 - Sept. 2019
Total budget: 2.7 million Euro, thereof 1.55 million Euro funding
Partners: 4 project partners, 22 network partners

carpeDIEM s supported by Interreg Deutschland-Danmark with funds from the European Regional Development Fund.

Project partners:
- Mads Clausen Institute, University of Southern Denmark, Sønderborg
- WiE University of Applied Sciences Lübeck
- Centre for Sustainable Energy Systems, Europa Universität Flensburg
- cbb software GmbH, Lübeck

Introduction

One of the major future challenges in energy supply systems will be the energy demand of the exponential increasing world population in the light of decreasing fossil energy resources. The need for a reliable renewable energy supply becomes more urgent due to an additionally increasing energy services electrification.

The increasing electrification is evident in the transportation sector where electric powered vehicles will replace fossil-fuelled vehicles, further in buildings, where heat pumps and electric boilers are future substitutes for oil and gas furnaces. The countries of the European Union have agreed on a 2030 framework, which includes EU-wide targets and policy objectives for the period between 2020 and 2030 to help in achieving the long-term 2050 greenhouse reduction targets, so that the pollutant greenhouse gas emissions can be reduced in order not to exceed the critical carbon budget.

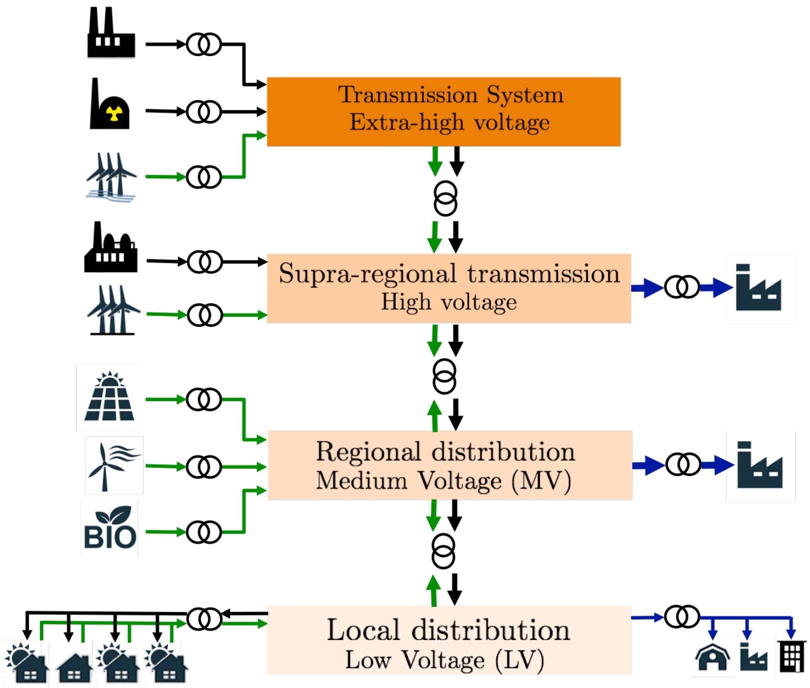


Fig. 1 Transmission system in general.

The fact that renewable energy generation units will increase their share in the overall energy production, calls for technologies that deal with the two dimensional dynamics and the geographical distribution of renewable energy generation units. During peak feed-in periods when the output power of local renewable generation units exceeds the local demand, power flows from lower grid layers to upper grid layers. During peak load times this flow is reversed recurrently and feeds loads at the lower grid layers again.

This time-dependent circular power flow can be defined as meteorological power flow. These reverse upward power flows drive transformer substations to their limits and result in voltage and frequency instabilities such that the power quality standards defined in the EN50160 are violated and actions have to be taken by the system operator. Part of that has been taken care of by governmental policies where feed-in from distributed generation units is regimented during peak periods.

Our technology addresses the optimal use of renewable energy. During the project time we measured and simulated several cases that pose examples of the challenges we face with a meteorological power flow and the electrification of the transport sector.

Summary

In the past 3.5 years, the carpeDIEM project has focused on rising the public's awareness of available technologies and efficiency of energy management systems, that control energy flow in buildings and building clusters. The aim of such systems is to increase the utilization of locally available energy resources. Solar panels on roof tops for example should feed local load demands and contribute to reduce grid peak loads. The use of these intelligent energy management technologies will increase the use of local available energy resources and decrease the dependence on remote fossil based energy supply.
In the project, emphasis was given to the very specific energy consumption patterns and supply structures, which are typical for the region including companies and many tourist and agricultural areas.

In carpeDIEM we developed and showcased a technology that is capable of reducing grid load at peak times and freeing grid line capacities. We collected data in several places, optimized the system and simulated the effect of autarky for the local environment as well as for the greater perspective from the German energy providers and its neighboring countries. The result was evaluated with respect to the economic benefit and the CO_2 balance. The technology can be viewed at two demonstration sites at the GreenTEC Campus in Enge-Sande (Germany) and at the Alsion building in Sønderborg (Denmark). Both demonstration sites have intelligent energy management units in charge stations that can be integrated in any charge station.

Measurements in Bordelum and on Ærø demonstrated that autarky has to be evaluated in a differentiated way. To reach autarky from an external energy provider it is necessary to establish storages. Our simulations show that they have the greatest effect with respect to economy and CO_2 balance when used centrally. Electrical storage units in the current supply structure of Germany and its electrical neighbors should be made centrally available.

Further the carpeDIEM project aimed to strengthen and pool the complementary cross-border competences in the field of intelligent energy management. With two demonstration sites and a strong network of active collaborations this has been achieved and the technology will be used in the future.

Case studies, data collection and simulations

Biogas plant (CHP)
Image: Colourbox

Our cases

Our goal was to find representative case study sites that could serve to collect energy data for simulations. The requirements expected some degree of renewable energy to be available and establish a data collection. During the course of the carpeDIEM project several case study sites were analysed as reference cases for the DIEM system development.

Fig. 2 GreenTEC Campus, demonstration of controlled charging of e-vehicles and simulation of optimized charging.

Fig. 3 Installation of an intelligent charge controller at GreenTEC Campus.

Case study sites

A first case study site was found in a village located in the North-West of the German federal state-of Schleswig-Holstein, It has wind energy a biogas plant (CHP) and solar panels on private houses. This village seeks on reaching autarky from external power supply and made it therefore suitable for our studies.
The partners installed hardware that allowed data collection of ten different places within the village in intervals of a second. This data served the analysis and the simulation.
Further demonstration sites were found at the GreenTEC Campus where we installed an intelligent charge station that applies the DIEM technology to control charging of e-vehicles. In addition we analysed e-vehicle utilistaion for a company fleet for Kreis-Ostholstein.
On the Danish site we analysed the consumption of Ærø a small Island in the southern Danish Sea. Ærø, produces more power than the island itself consumes. Paradoxically, Ærø is nevertheless forced to export and import power because the consumption pattern of the inhabitants does not match the powerproduction of the six large wind turbines on the island.
As a final demonstration site in Denmark the SDU Sønderborg has established intelligent charge stations for e-vehicles.

Data collection

We received data via diffrent channels. In Bordelum and at GreenTEC Campus we collected data from different Smart Meters for heat and electricity of private households, photovoltaic systems, farms and charging stations for electric vehicles. This data was networked over the data collection system cbb Libra-Smart Metering*. We developed a secure connection for data collection and transfer to the partner cbb and their data collection server. The collected data could be visualized and analyzed in the cbb online management portal: enwiso.
In other locations we used provided data like the one from Ærø complemented with available official statistical data where necessary. The original reports indicate all sources.

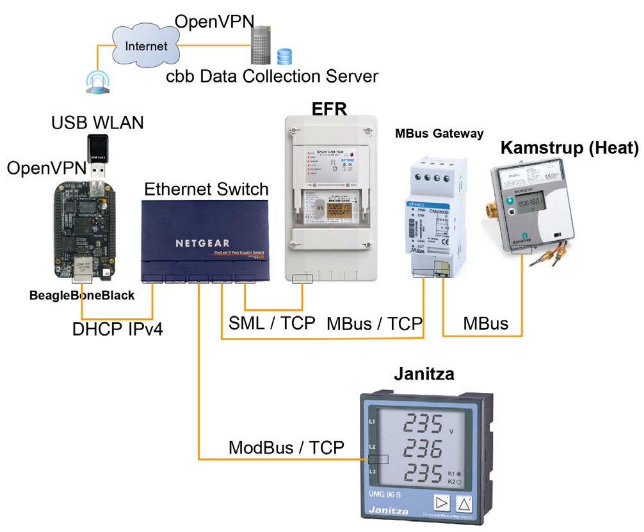


Fig. 4 Data collection and meters as they were used.

OpenVPN Gateway for secure Smart Meter connection

The image in Fig. 4 displays our concept for the data collection from all meters. An ARM based embedded Single Board Computer served as hardware platform. The operating system was a Debian Linux system, as this was already proven as a compatible target platform for the cbb middelware opcsa. We installed an OpenVPN client for secure communication to the cbb data collection server and configured it. We configured the gatewas individually and put them into operation onsite.

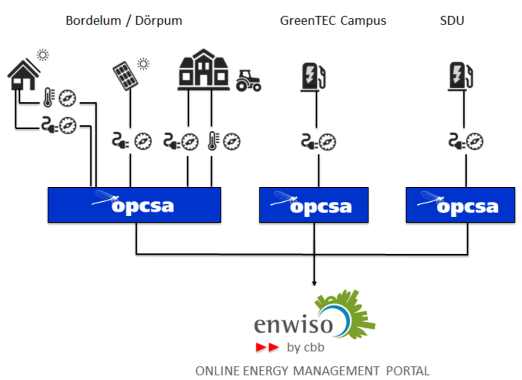


Fig.5 Energy management portal enwiso.

Visualising and analysing the data

The cbb concept for data networking and structuring is called enwiso. It is the energy management portal of the company cbb software GmbH. Through enwiso it is possible for companies to collect, visualize and evaluate their energy consumption or generation (compare Fig. 5). The same counts for the collection of data from the DIEM system that we monitored over a long period.

* Find more on cbb-Smart Metering under the following link:
cbb.de/produkte/cbb-libra-smart-metering

Reaching autarky via integration and intelligent control of energy storage

Rural communities possess a high potential for using renewable energies. Storage technologies can increase their degree of autarky. Therefore we developed a simulation tool to investigate the energy autarky in micro-grids. In this simulation model the electricity or heat sector or both can be considered. Data was collected and investigations were carried out for the township Bordelum (North Frisia, Germany) and the island Ærø in Denmark. Some data had to be complemented by official statistical sources. The case studies indicate that the autarky can be increased.

Electrical autarky of Bordelum*

In some places people would like to become independent of their local power supply. We simulated the degree to which this autarky over time can be reached and under which circumstances. We took into account the electrical consumers, photovoltaic plants, a wind turbine and a biogas plant (CHP) in Bordelum. We simulated the consumers by using the load profile generator from the TU Chemnitz. In seven different scenarios we simulated the efffect of individual storages or a central Redox-Flow battery storage for the village and varied their sizes. Additionally, the workload effect on the grid was monitored. An increasing maximum peak load could lead to expensive grid-upgrades. The diagramm in fig. 7 reveals that full autarky is only possible with the CHP plant as electricity provider. However it is possible to come close to autarky in other cases. If we take into account that the peak load for the external grid should be minimized, then case III is the only case that lowers the maximum peak load (green colour) and is thus beneficial for the system.

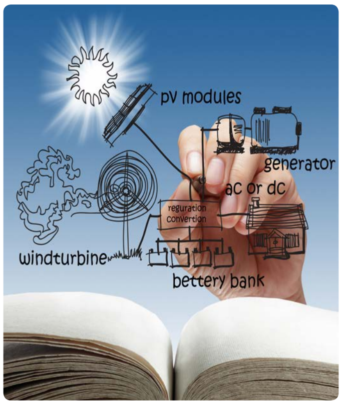


Fig. 6 System components.

Cases	
I	existing PV Plants on buildings get refitted with a battery storage: 8-10 kWh
II-a	all residual buildings should have 9,7 kWp PV-plant and 4,9 kWh battery
II-b	same settings as II-a but 9,7 kWh battery
III	Redox flow battery for local distribution system 2200kWh
IV	Wind power plant for local distribution grid
V	Small redox flow battery (560 kWh) combined with wind power
VI	Using existing CHP (875 kW_{el}) for electrical coverage

Table 1: Cases for the simulation in the graph in fig. 7.

*You will find a poster by Malte Myrau on the webpage publications to the topic.
Image in fig. 5: Colourbox

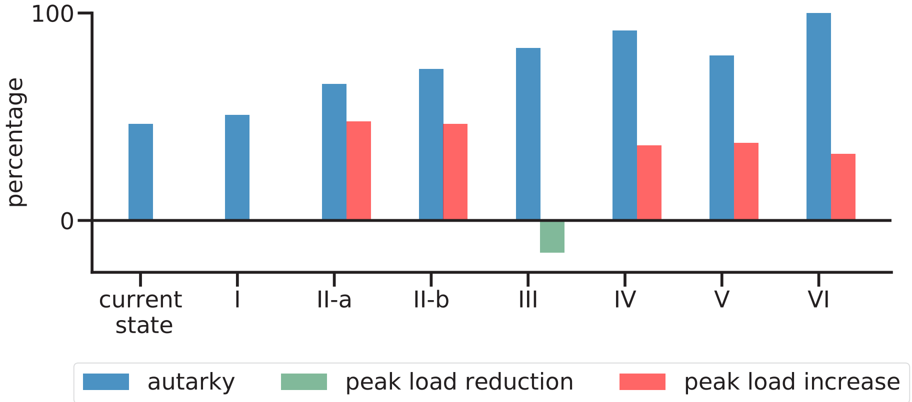


Fig. 7 : Simulation on the degree of autarky and peak load for the different cases in table 1*

Electrical and heat autarky of Bordelum**

In a second step we considered both, the electrical and thermal energy sector. The heat supply was modeled with heat pumps, heating rods and with heat storage systems and compared to the current state.
It turns out that a very high degree of autarky of 99 % without CO_2 emissions in the electrical and thermal energy sector is possible.
This requires sector coupling of heat and electricity, heat storage and electricity from renewable energy systems.
As in the previous case a central storage for heat in the village is preferrable and each house should have a heat pump. This in addition to the central electrical storage as in case III.
All simulations consider only the village Bordelum and not the effect on an external grid. This was analysed by EUF and is explained on page 12 ff.
Economic aspects were not considered in this study.

*Author: Joscha Höck, Master thesis, can be found under 'Publications' on our webpage.
**Lucas Bergmann, Thesis, can be found under 'Publications' on our webpage.

Images on top of the page: Colourbox

Fig. 8 The electric ferry on Ærø is the first ferry capable to sail 22 seamiles solely on electrical power.*
Illustration: Jens Kristensen Consulting Naval Architects.

Fig. 9 The electrical ferry of Ærø and the power connector on shore.

Ærø's autarky degree, simulation**

In this study we analysed the current state of the electrical and thermal energy supply on Aero in all places with a district heating system. Then the influence of the electric ferry and a redox flow battery on the autarky was investigated. As for Bordelum it is more advantageous for the autarky degree to establish a central storage like a redox flow battery. The size of the battery should be carefully choosen as the autarky increases from 0 kWh up to 500 kWh by approx. 0.48% but from 4500 kWh to 5000 kWh only by 0.24%.

Parameter	Including ferry	Without ferry	Difference
Autarky (%)	66,21	67,15	-0,94
Self consumption part (%)	52,96	50,98	1,98

Conclusions

For the case of Bordelum we conclude that a redox flow battery within the distribution grid leads to a high autarky degree (83%) and also lowers the maximum peak load (-16%).
In all cases it is advisable to use a central storage compared to single prosumer storages.
In the discussed cases the self consumption of the produced energy was not very high due to the fact that both Bordelum and Ærø produce more energy than they actually need.

* More information on the ferry can be found in Danish under : https://www.el-færgeprojekt.dk/om-e-ferry / English: http://e-ferryproject.eu/
** Kilian Menzel, Thesis, con be found under 'Publications' on the webpage.

Local optimized energy management Simulations

The role of a locally optimized power system (e.g. a village grid) within the national and international power system was analyzed. We addressed the questions what effect a local optimization has on the CO_2 balance of the bigger system consisting of the German power system and the connected power systems of the neighboring countries. Further simulations revealed the best economic solution.
Different scenarios were simulated of which four are introduced in this report.

A: Village without storage, Prosumers, PV

B: Village with storage and PV. Isolated approach

Fig. 10
A: Reference with only PV installed
B: Additional decentralized batteries in households

D: Village with storage that is available to the overlaying power system, PV only

F: Village with storage that is available to the overlaying power system, with Wind turbine

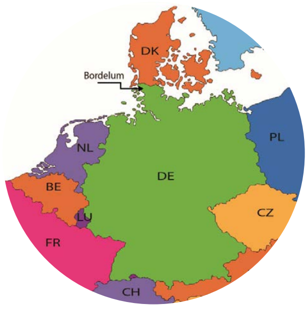
Fig. 11
D: PV and additional centralized battery storage
F: Wind turbine and additional centralized battery storage.

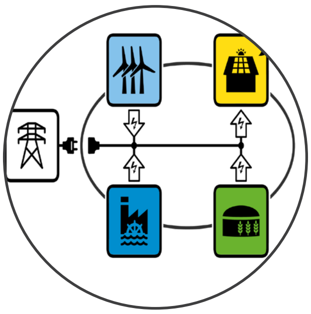
What is important for the overlaying system?

The overlaying power system was considered to be Germany and the connected power systems of neighboring countries.
The data of our model village as well as German and the surrounding neighboring countries was collected and inserted into the model. Load-curves for every hour of the year were stored.
The subsystem can act supportive to the overlaying system or not, depending on the very scenario conditions. The subsystem is supportive to the overlaying system in case it can provide excess power in times when the overlaying system lacks energy, or vice versa.
Here four different scenarios are depicted A,B,D and F comp. fig. 10 and fig. 11.
More settings were simulated (hence the numbering).They can be found in a detailed report (*) as well as the possibility to access all simulations under github.com/znes/carpeDIEM.

*Sönke Bohm and Martin Söthe, Report EUF can be downloaded from our webpage under 'Publications' .

Simulations





Scenario	CO_2 (t/a)
A Base case	0
B Prosumer batteries	9
D PV and centralized battery	45
F Wind and centralized battery	7

Table 2 CO_2 emissions for the isolated case where storage is only locally available.

Scenario	CO_2 (t/a)
A Base case	0
B Prosumer batteries	-7
D PV and centralized battery	-48
F Wind and centralized battery	-5

Table 3 CO_2 emissions for the case where storage is integrated in the overlaying power system.

Induced and avoided CO_2 emissions

The simulations allow to determine the CO2 emissions for the described scenarios. We destinguish between an isolated village with storage that is only locally availble and an integrated case where the storages are allowed to be integrated in the overlaying power system.
Table 2 lists the results for an isolated case.
The positive values show that for all scenarios we have additional CO2 emissions, the reference case is set to zero.
The results for the integrated approach, as in table 3, show, that in this case for all scenarios CO2 emissions can be avoided, hence negative values for CO2 emissions.

Costs

The economic data can be categorized into central and decentral batteries. For decentral batteries it was assumed that the technology of Vanadium Redox Flow (VRF) batteries is utilized whereas for the centralized approach Li-ion batteries were assumed. This takes into account that a VRF battery would be the most cost effective village solution according to the evaluation of our partners from THL. In the calculations, a mean value of the technology-specific cost range was applied, i.e. 985 and 855 Euros per kWh, respectively. Moreover, financial parameters such as an interest rate and a depreciation duration were inputs to the calculations.

Image top right: Colourbox

Simulations

Scenario Period	Costs €/a 20 a	Costs €/a 30 a
B Prosumer batteries	2729,73	1819,82
D PV and centralized battery	2370,18	1580,12
F Wind and centralized battery	5416,66	3611,10

Table 4 Abatement costs for CO_2 emissions were calculated.

The scenario setting D appears to be the one in which an integrated approach reduces CO_2 emissions most compared to the isolated approach (compare table 4). A centralized battery storage seeems therefore more beneficial than multiple distributed battery storages.

Fig. 12 Battery storage of Li-Ion batteries.

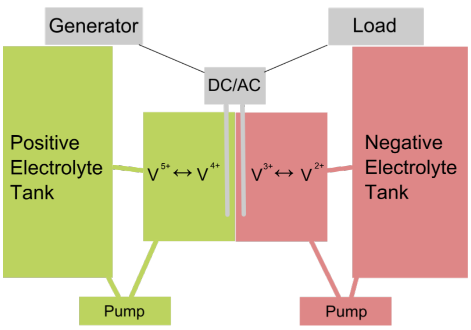


Fig. 13 Vanadium redox flow battery principle. The system requires tanks for the electrolyte.

Economy of local battery systems

The residual load curves of the sub-system were further analyzed with reference to potential financial yields from sales and purchases of electricity to the overlaying power system.

The theoretical cost and benefit of a reference case was calculated and so was the theoretical cost and benefit of the cases with battery storages. It was found that the battery storage indeed would reduce the amount of money to be spent for electricity purchases in times of low production. On the other hand it was detected that in most cases the return of sold electricity would also be reduced, even further than the increase of cost savings. As shown in table 5, the balance of both cost and benefit resulted in negative values in scenarios B and D whereas in scenario F a positive value was found. However the cost for the battery needs to be set against any savings.

Scenario	Income	Expenses	Balnace	Relation to reference case
A	75500	18183	57317	
B	73552	16821	56731	-586
D	60475	5079	55396	-1921
F	123639	4812	118829	643

Table 5 Income from power sales and expenses for power purchases (all figures in Euro).

Fig 13 by Paj.meister - Newscientist, Public Domain, https://commons.wikimedia.org/w/index.php?curid=1559479

Simulations Key findings

1. In the cases of an isolated approach, additional CO_2 emissions would be induced in the overlaying power system. It can be concluded that the integrated approach reaches the lowest CO_2 emissions in the simulated scenarios and any isolated approach leads to a sub-optimal solution.

This indicates that battery storages should be made centrally dispatchable, if possible, in order to minimize CO_2 emissions. In comparison with other storage options, however, battery storage constitutes an expensive way to store energy.
To sum up, batteries might make sense from a system perspective if other flexibility options are not available or not reasonable – but the batteries' ability to charge and discharge should be made available to the entire power system.

2. Does it make sense to attach a local battery storage to a micro-grid? From a user's point of view, it might make sense to buy a battery and include it in a micro-system. This could save money if it allows to avoid cost-intense peak power purchases or if the link with the overlaying power system – e.g. an inverter or a power line – is too weak to transport all the power that is either surpluses in the sub-system or that needs to be obtained from the overlaying power system. A fair comparison of options, however, should include grid reinforcement then, too.
From a macro-perspective, local batteries can help reduce CO_2 emissions if the batteries are made available to the entire power system, i.e. if their charging and discharging is conducted along the system's needs. If they are not, their behavior in the entire power system will always be suboptimal.

Conclusions

- An "optimization" of a local sub-system can induce additional CO_2 emissions in the overlaying power system.
- The integration of storages in the overlaying system will reduce CO_2 emissions.
- In any case battery storage is an expensive option to reduce CO_2 emissions.
- Recommendation: if battery storage is desired, it should be made centrally dispatched.

The simulations are based on the current net infrastructure.
Including storage in a local environment might make sense:

- if the local infrastructure is limited to an extent that further use of renewables could not be integrated.
- for remote systems, basically also because for them the net infrastructure is limited.
- if the net stability could profit from storage solutions, especially when renewable sources increase their share on the electric market.

Reference: Sönke Bohm and Martin Söthe, Report EUF can be downloaded from our webpage under 'Publications'.

DIEM system Architecture

The DIEM system is a versatile software and hardware framework, which consist of a hardware-, communication- and DIEM application layers. The framework is generic. This means that it can host a platform with miscellaneous distributed energy applications, e.g. to manage electric vehicle charging infrastructures or battery co-located photovoltaic panels. The system was validated in a laboratory setup with varying energy consumers and producers*. Here the time response was determined and communication protocols have been optimised.

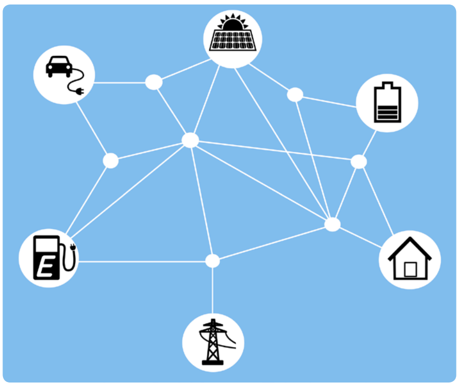


Fig. 14 Sketch of decentralized communication of components.

DIEM system

We designed the DIEM system as a decentralized distributed system. This means there is no central control instance, rather all individual system components share information among each other and coordinate energy flow to follow specific pre-determined objectives. These objectives can be to charge electric vehicles, so that primarily local energy resources are used, or the load to the supply grid is reduced at specific times of the day.
The advantage of a decentralized architecture is, that there exists no single point of failure and the system is easily scalable, so components can be added or removed.

Interaction with the hardware

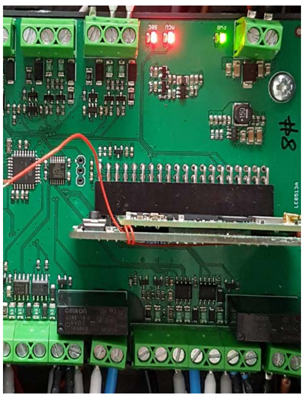


Fig. 15 Part of the hardware for charge control unit

The hardware layer provides the device level interface to control, e.g. the power flow from and to a storage device, control the maximum charge power for an EV or provide information from local PV panels. On top of the hardware layer, a middleware layer serves the communication and data handling for the distributed system. This means it abstracts the distributed system, so that it occurs as a single coherent system to the user. The middleware layer for the system has been developed as part of the project and is available under the name: opcsa (Open Process Communication – Simplified Architecture)**.
In the DIEM application layer software can be implemented as if it would be operated on a central system.

** Timo Helsper and Christian Ziegelmann, thesis, can be found on our homepage under 'Publications.
* For more information on opcsa visit https://opcsa.de/

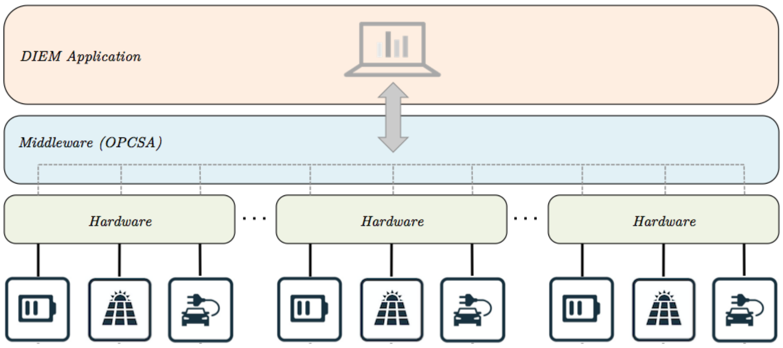


Fig. 16 : Hardware and software interaction layers.

Fig. 17 Carport with electric vehicles and PV on top.

Application example

In this application a photovoltaic (PV) system should be used as energy source for the charging of an electric vehicle (EV) fleet (fig.17). The time mismatch between the demand for charging the EVs and the energy generation from the PV system results in non-optimal self-consumption. A large share of the produced electricity is send to the overlaying grid. Using the DIEM system to control the EV fleet charging and a co-located Vanadium redox flow battery (VRFB), the self-consumption from the PV system can be maximized. Consequently, the need for additional power is minimised.

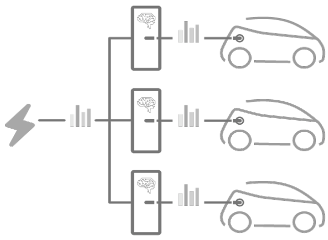


Fig. 18 Steering of charge stations.

Role of the DIEM system

Crucial for the efficient use of a battery is an energy management system based on the DIEM technology, which combines the operational constraints of the battery, such as maximum charge and discharge power, with the EV fleet charge management constraints. The key is an efficient utilization of the battery, which is tailored to the EV charge management constraints. It is seeked for a maximal use of local energy resources.

Charging station with DIEM technology.

DIEM
Intelligent charging infrastructures

An increasing electric vehicle share calls for suitable, affordable and reliable support infrastructures, such as EV recharging. A major challenge in the integration of this support infrastructure into the existing grid is the increasing load demand, especially peak load demands are problematic. If many EVs are charged simultaneously, the utility grid has to serve great peak power demands. These can cause overload conditions for the grid's infrastructural components, such as transmission lines and transformer substations. Grid peak loads occur, e.g. in the evenings as people plug in their EVs when returning home from work, or after plugging in commercial EV fleets, which have been used over the day.
Charging vehicles at times when there is a surplus of renewables in the energy mix increases utilization of renewable energy resources. In order to reduce the amount of energy that is transported, local energy resources should be preferred. This will prevent grid reinforcements.

What makes it intelligent ?

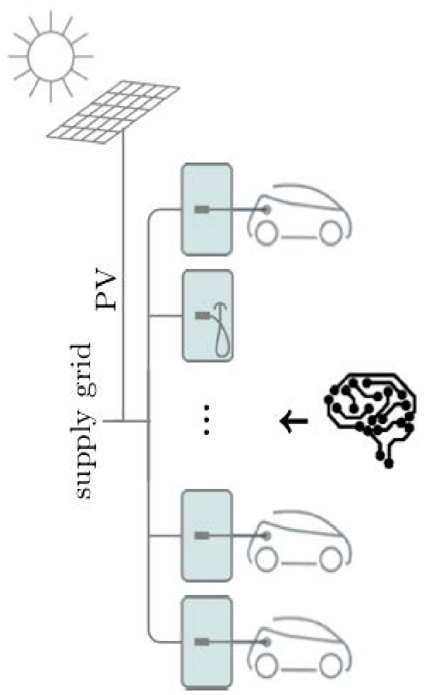


Fig. 19 Charging infrastructure needs intelligence to match demand and available green energy supply.

Simultaneously charging EVs can lead to undesirable and unmanageable peak loads. Peak loads can be avoided by sophisticated load management algorithms, based on mathematical optimization. A necessary prerequisite, though, is the availability of arrival and departure time information. Fortunately, our preliminary EV fleet load data analysis indicates that the peak load problem can be tackled by machine learning (ML) With the knowledge of recurring time patterns, it is possible to predict future (time versus load) states, as well as typical EV arrival and departure times. Note that, applying ML yields other beneficial byproducts: in principle, the EV types, their optimal demand profiles and the available renewable energy percentage time pattern can be learned. Machine learning algorithms have two phases in common: first the collected data is fed to the ML algorithm in the training phase. After that, the system enters a so-called test or prediction phase, where, based on the previously "learned" training data, decisions or predictions can automatically be made (see fig 20). The test data validates the prediction performance.

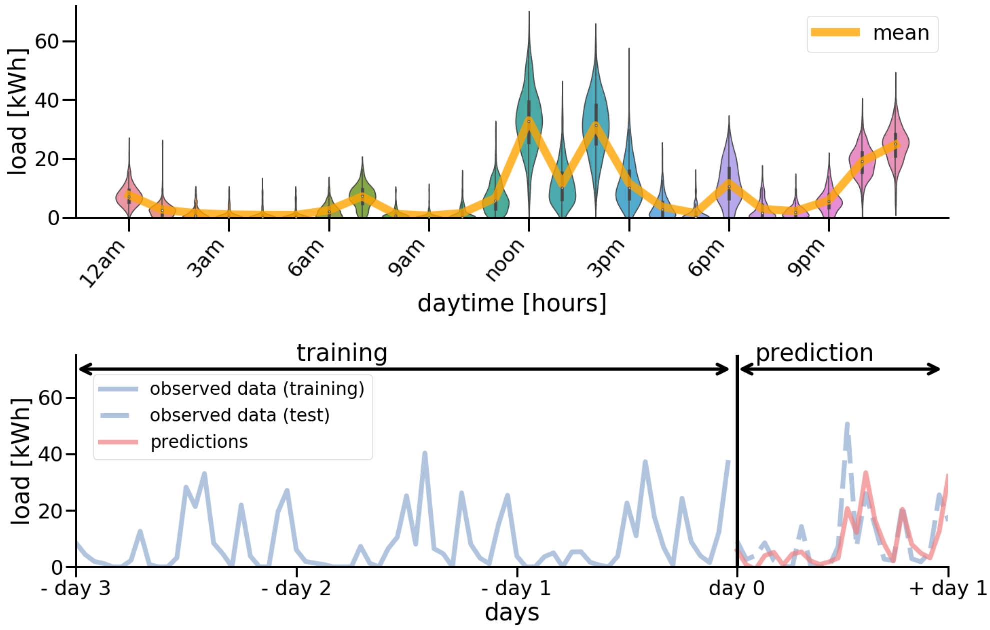


Fig. 20 Top: Preliminary data analysis: "Typical" mean daily energy consumption (orange line) based on hourly measurements over the year 2018 ("violin" plots showing the statistical energy consumption distribution for every hour of the day – typical peak load times recur at 12 noon, 1pm and at 11pm). Bottom: Tentative results showing that recurring energy consumption time pattern prediction can be predicted via Kalman filter. The data is based on EV charging data measured at Samsø.

Apart from an adequate choice of ML algorithms to serve the task, the reliability of such predictions depends critically on the available training data. To foster a precise arrival and departure prediction, we plan on collecting a vast amount of densely sampled data from our charging stations connected to the grid. Different recurrent neural networks can be trained to take seasonal as well as daily time patterns into account.

Two installations at GreenTEC Campus and Alsion will remain to serve the public as demonstration sites. Further projects are in the process to be developed, so that the work on intelligent charging algorithms based on Machine Learning Algorithms can continue.

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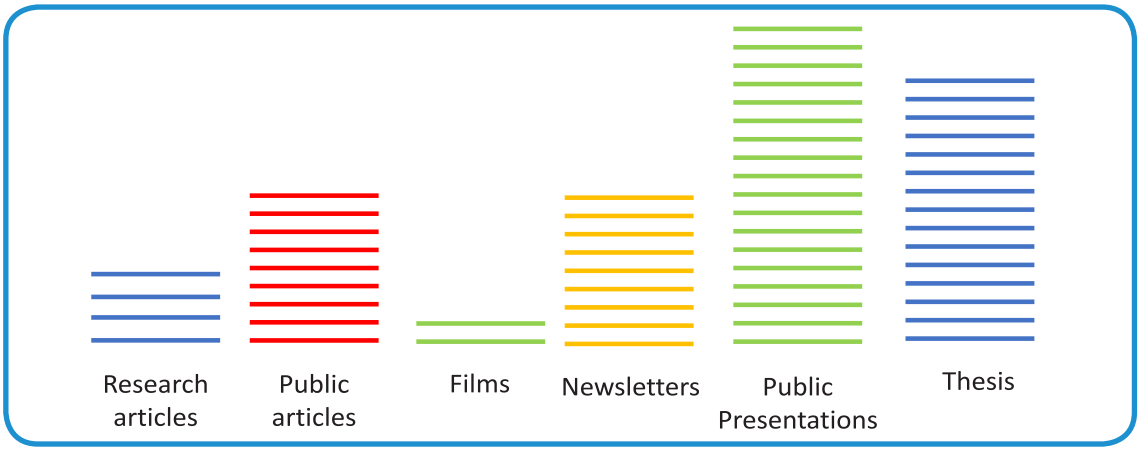

Fig. 20 Publications of carpeDIEM in different media.

Scientific Publications

Brehm, R., Mt-Tempi, R., and Top, S. (2017). Consensus based scheduling of storage capacities in a virtual microgrid. Advances in Smart Systems Research, Advances in Smart Systems Research ISSN 2050-8662 Vol. 6. No. 1 : pp.13-22 : ams17-04

Brehm, R., Redder, M., & Kazakov, D. Bruce-Boye, C. (2018). 6. Agentenbasierte Regelung von Energieflüssen in Verteilnetzen durch ein Softwarebussystem. In Agentensysteme in Der Industrie 4.0. In Birgit Vogel-Heuser (Editor), Softwareagenten in der Industrie 4.0 (pp. 109–124). Berlin, Boston: De Gruyter. https://doi.org/10.1515/9783110527056-006

Robert W. Brehm ; Hossein Ramezani ; Jerome Jouffroy, Distributed coordination of energy-storage capacities in virtual microgrids, 2018 European Control Conference (ECC18), Limassol, Cyprus, DOI: 10.23919/ECC.2018.8550574

Brehm, R., Redder, M., Flaegel, G., Menz, J., Bruce-Boye, C. (2018, June). A framework for a dynamic inter-connection of collaborating agents with multi-layered application abstraction based on a software-bus system. In International Conference on Intelligent Decision Technologies (pp. 150-157). Springer, Cham.DOI: 10.1007/978-3-319-92028-3_15

Qian, K.; Brehm, R. and Duggen, L. (2019). Experimental Evaluation of a Method for Simulation based Learning for a Multi-Agent System Acting in a Physical Environment.In Proceedings of the 11th International Conference on Agents and Artificial Intelligence - Volume 1: ICAART, ISBN 978-989-758-350-6, pages 103-109. DOI: 10.5220/0007250301030109

Films

ZDF 'Nano' contribution in Dec. 2018
DIEM Technolgy explained https://youtu.be/XfGgjlBSjgI
Intelligent charging https://youtu.be/BRUzcZiwopU

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Master Thesis

Hendrik Sass, Machine Learning Based Identification of Electrical Appliances

Joscha Höck, Analyse von Szenarien für die Nutzung von erneuerbaren Energien und Batteriespeichertechnologien in subautarken Ortsnetzen

Jendrik Menz, Dynamic Reconfiguration of Multi Agent System Topologies

Christian Mørk-Pedersen, Architecture for distributed energy management

Jegvan Jon Hansen, Methods for decentralized scheduling of load and storage capacities

Forvaldur Reynir Ásgeirsson, Investigation and implementation of multi-agent based decentralized charge management system for electric vehicles

Bence Magyar, Investigation and implementation of methods to predict charge behaviours of electric vehicles when connecting to mode 3 charging stations

Bachelor Thesis

Entwicklung einer Schnittstelle zur Anbindung von dezentralen Steuerungssystemen an simulierte sub-autarke Mikronetze

Bestandsaufnahme und Kategorisiserung des Energiesystems Schleswig Holsteins

Analysis of Reinforcement Learning Methods in Multi-Agent-System Topologies

Janina Leptien, Charakterisieren des transienten Verhaltens von Photovoltaikmodulen mittels eines Versuchsstands auf Basis eines Sonnensimulators

Lukas Bergmann, Analysen von Ausbauszenarien von erneuerbaren Energien und Wärmespeicher-technologien in subautarken Mikronetzen ländlicher Räume

Kilian Menzel, Analysen von Ausbauszenarien von erneuerbaren Energien und Speichern der Insel Aero in Dänemark

Timo Helsper, Entwicklung einer Simulationsumgebung für den Test von Steuerungsalgorithmen für Energieflüsse in Mikronetzen

Christian Ziegelmann, Entwicklung einer Simulationsumgebung für den Test von Steuerungsalgorithmen für Energieflüsse in Mikronetzen

Projectwork

Hendrik Sass Programmierbare Mehrfachsteckdose

Find out more on our webpage: www.project-carpediem.eu/publications

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