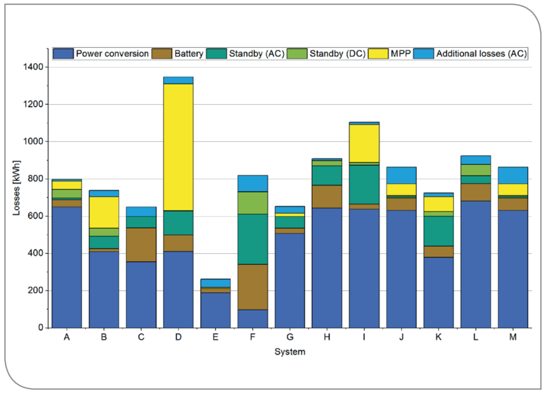
rated size of the power electronics components as well as the size of the PV system. The systems under test showed a measured system efficiency of between 78.5% and 94.1%.

Economic viability

Minimising the energy losses is critical for the economic viability of a storage system. The measurements with



Energy losses for a reference year using the VDI 4655 profiles

reference profiles allow the energy losses to be precisely determined and also be allocated to specific categories. In total the systems showed losses of 262 – 1347 kWh per year (incl. MPP efficiency losses).

Intelligent control strategy

Li-ion batteries that are kept at a high state of charge (SOC) for a long period of time will age faster than batteries whose dwelling time at this high SOC state is minimized. This effect can be avoided by employing an intelligent control algorithm. In addition one can prevent the battery from being fully charged before midday, since this would mean that the entire power surplus must be fed into the grid or in some situations even throttled. In this way the power fed into the grid can be smoothed out, so that the systems contribute to grid stability. Of the systems under test, around 25% possess an intelligent control strategy.

Supported by:

Federal Ministry
for Economic Affairs
and Energy

on the basis of a decision
by the German Bundestag

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Comparison of home storage systems: performance and contribution to grid stability

COMPETENCE E

Home storage on trial – the “SafetyFirst“ project

The quality of lithium-ion home storage systems on the market varies widely, especially in the areas of safety, performance, and the degree to which they support and stabilise the grid. These criteria are used as part of the “SafetyFirst” project, in which more than twenty different commercially available home storage systems are evaluated under real operating conditions. The KIT-coordinated project (the Fraunhofer ISE in Freiburg and the ZSW in Ulm are project partners) is funded by the German Federal Ministry for Economic Affairs and Energy with a budget of nearly 4 million Euros over three years.

The study is carried out by integrating the storage systems into a hardware-in-the-loop test environment, and the measurements are performed on the basis of daily generation and load profiles: measured photovoltaic data from part of the 1 MW solar storage park at KIT as well as load data from VDI 4655 reference profiles and the “ADRES-CONCEPT” project from TU Wien are used. The reference households have an annual electricity demand of 4200 kWh (VDI 4655) as well as 3500 and 4100 kWh (ADRES-CONCEPT) respectively, along with a 3.5 kWp PV system. In addition, measurements of energy conversion path flows (battery charging/discharging and direct PV feed-in), battery round-trip efficiency and control quality are performed, using the “Efficiency Guidelines for Home Storage Systems” published by the Bundesverband Energiespeicher (BVES) and the Bundesverband Solarwirtschaft (BSW-Solar).

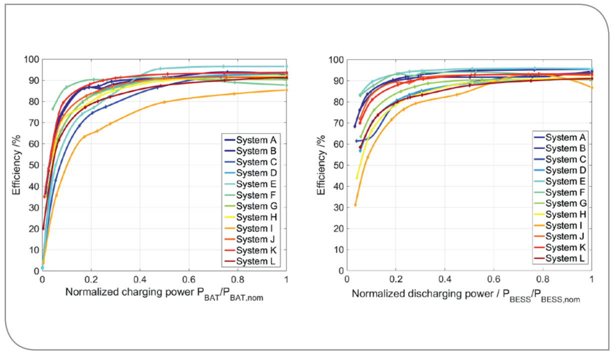
The performance and the achievable self-sufficiency of a home storage system depend on several factors: the efficiency of the individual system components, the standby losses, the response time of the system to changes in load and generation as well as the intelligence of the overall control strategy.

Battery efficiency

The measurements based on reference days allow one to determine the battery efficiency over the course of a virtual year, so that conclusions about the real-life operation of the system can be drawn. Besides the effect of the quality of the cells themselves, the efficiency of the battery is influenced by the energy consumption of the battery management system (BMS) and whether it is supplied by energy from the battery itself. General design aspects such as the cell connection technology also play a role. The storage systems under test showed a range of battery efficiencies of between 78.2% and 98.4%.

Power electronics efficiency

The efficiency of the power electronics is determined using the energy conversion pathways (see the “Efficiency Guidelines”). Comparison of the storage systems with the paths “battery charging” and “battery discharging” reveal marked differences in efficiencies, especially under partial load.

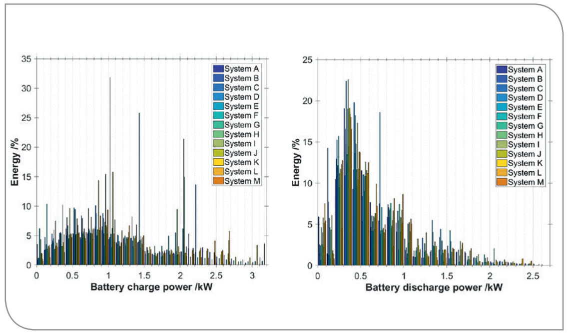


Efficiency of the power conversion paths ”battery charging” (left) and ”battery discharging” (right), as a function of the rated output power

If one further compares the distributions of the energy flows at different battery charge and discharge powers over a synthetic year, it is evident that for all households with an annual consumption of between 3500 kWh and 4500 kWh, a major proportion of the power flows lies below 1 kW. This ratio is also significantly higher for discharging than for charging. In this way the storage systems are very often operated under partial load with lower efficiencies.

Standby power consumption

In order to determine the systems’ standby power consumption, the power flow is measured both at rest (idle mode) as well as in standby mode (system ready for power requests). The load and generation is set to zero and the battery power and grid consumption are averaged over at least three hours. Additionally, the systems have a different standby consumption depending on the state of charge (SOC) of the battery. The consumption in standby mode for the systems were measured to be between < 3 and 72 watt (SOC min). This energy is supplied either from the battery or from the grid.



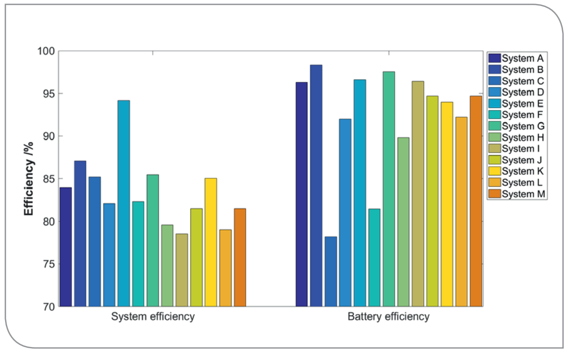
Distribution of energy flows for battery charging (left) and discharging (right) over a synthetic year

Response time upon changes in load and generation

The control quality also influences the overall performance of a storage system. In particular, the length of the dead time and settling time in the control loop can lead to unnecessary energy exchanges with the grid. Current measurements show dead times of between < 0.2 and 21.7 seconds and settling times of between 1.5 and 71.9 seconds.

System efficiency

The term „system efficiency“ refers to the efficiency of the entire system, including the losses due to direct feed-in of PV power (both self-consumption and grid feed-in). Apart from the effect of the battery efficiency, the system efficiency depends on various other factors such as the efficiency of the power electronics, the standby consumption as well as the system sizing. The latter refers to the useable battery capacity, the



System efficiencies and battery efficiencies for a single reference year using the VDI 4655 profiles