# Basic Knowledge
# Electrochemical Storage

## Electrochemical energy storage with accumulators

The usability of electrical power from large-scale renewable sources depends not least on the inclusion of efficient storage systems in order to balance unavoidable fluctuations between supply and demand for electrical power. While electrochemical energy storage in the domain of small storage capacities has been in widespread use for mobile applications (e.g. car batteries), the development and integration of large storage systems is still in its infancy. Low-loss, efficient and economical accumulators with high number of cycles and long-term stability are in demand for typical applications.

## Accumulator types

Extensive research and development activities have to be recognised in the field of electrochemical energy storage systems. New concepts are based, for example, on high-temperature batteries and on the separation of electrochemical converters and storage systems (fuel cell, redox flow battery).

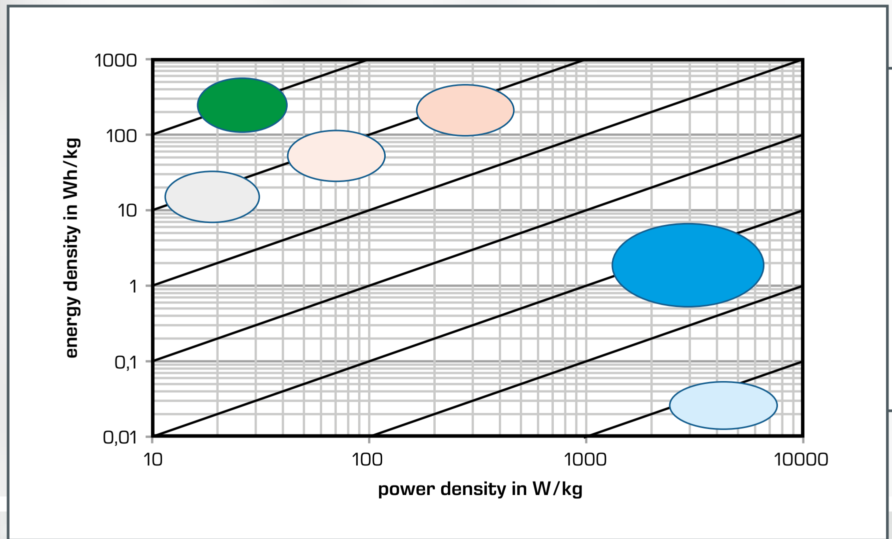
Each intended application results in different requirements for the properties of the accumulators. For example, while the specific weight of an accumulator is crucial in the area of electro-mobility, it is cost-effectiveness and long-term stability which are important when looking at the integration of large electrochemical storage capacities in modern utility grids.

Listed below are the most important industrial electrochemical energy storage systems which are currently commercially significant:

- lead batteries (Pb, as wet or dry cell)
- nickel cadmium (NiCd, as wet or dry cell)
- nickel metal hydride (NiMH, as dry cell)
- lithium ion ($LiMn_2O_4$, $LiCoO_2$ or $LiFePO_4$)

## Energy density and power density

The specific energy density and specific power density are two important criteria for electrochemical storage systems. The Ragone chart, or Ragone plot, gives an overview of these properties for different types of storage. The power density is plotted on the horizontal axis in watts per kilogram. The vertical axis indicates the energy density in watt-hours per kilogram.



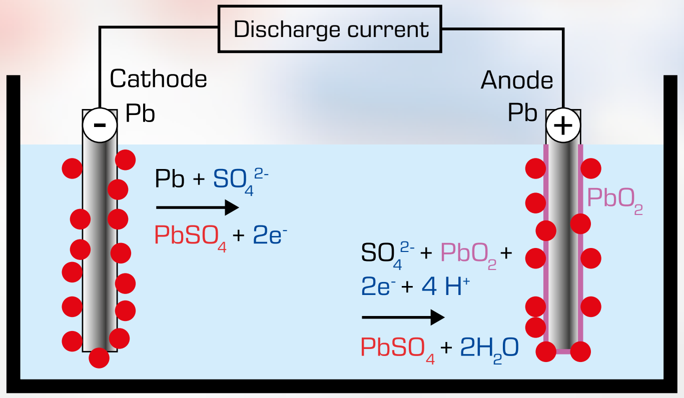

- fuel cell
- lead battery
- NiCd battery
- lithium battery
- Boostcap ultracapacitor
- conventional capacitor

## Energy storage in the lead accumulator

Chemical material conversions on the two electrodes are a fundamental process in the charging and discharging of an accumulator. While charging, a voltage applied externally causes an increase in chemical energy. This chemical energy is made available again as electrical energy during discharge.

This can be demonstrated in detail using the example of the lead accumulator. In addition to the positive and negative lead electrodes (Pb), an important component is an electrolyte ($H_2SO_4$) wich enables the underlying oxidation and reduction reactions.

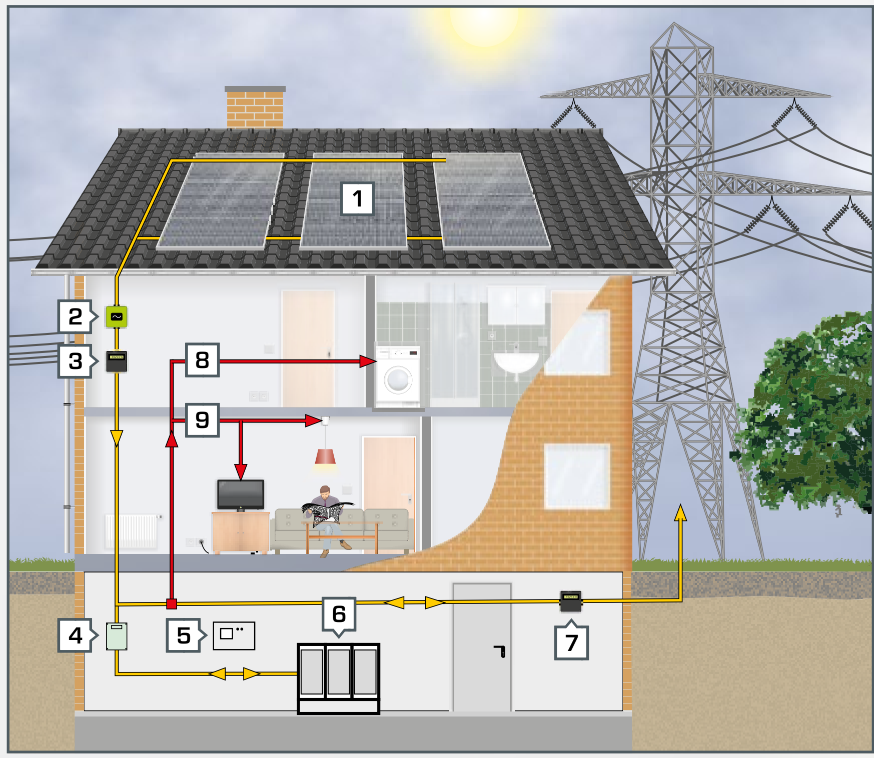
In the discharged state, a layer of lead sulphate ($PbSO_4$) is attached to both electrodes. In the charged state, the positive electrode is coated with lead oxide ($PbO_2$) while the negative electrode consists of pure (porous) lead.




The illustration shows the sub-reactions during discharge of a lead accumulator

The overall reaction is:
$Pb + PbO_2 + 2\,H_2SO_4 \rightarrow 2PbSO_4 + 2H_2O$ + electrical energy

## Example of a grid-connected photovoltaic installation with battery storage




Increasingly larger battery storage systems are also planned as part of grid-connected photovoltaic installations. Consequently it is possible to increase in-house consumption and to reduce the extraction of electricity from the grid.

1 electrical energy
2 inverter
3 yield meter
4 battery charge controller
5 system control
6 battery storage
7 bi-directional energy meter
8 controlled consumer
9 non-controlled consumer