Decentralized Energy Storage – Challenges for Batteries
VARTA Microbattery GmbH – Company Figures

Headquarter: Ellwangen, Germany

Management: Herbert Schein (CEO)
             Jens Stahmann (CFO)

Employees: Germany: 530
           worldwide: 1700

Turnover: 150 Mio. €
Company history and world history go hand in hand

1893  First electromobile
       The electric car Baker „Runabout“ captures the German market. VARTA supplied the battery.

1896  First North Pole expedition
       Fridtjof Nansen explores the utmost north of our planet. VARTA supplied the expedition with light.

1969  First moon landing
       Neil Armstrong entered as first human being the moon. VARTA enabled the historic pictures of the expedition.

2003  Smallest rechargeable hearing aid cell
       Small devices with huge help. VARTA develops new microbatteries.

2009  Research company
       The car of the future drives with electric current. VARTA is pumping energy into the heart of the electromobile.

2010  Energy turnround
       Germany starts with the energy turnround. VARTA makes energy storage possible.

STYRIAN ACADEMY for Sustainable Energies
VARTA Strategy

VARTA Microbattery

Core Business Microbatteries
- Retail
- PPS
- OEM

E-Mobility
- Research & Development together with Volkswagen

BESS
- Battery Energy Storage System
- Competence Center

VARTA Micro Innovation

STYRIAN ACADEMY for Sustainable Energies
Energy Problem of the World

Fossil Fuels
- Peak Oil

Fossil Fuel Power Station
- CO₂ Production
- Global Warming

Atomic Power Station
- Technical Risk
Solution of the Energy Problem: Renewable Energy

- Wind Energy
- Hydro Power
- Bio Gas
- Solar Energy

Installed Renewable Energy Resources in Germany [MW]

Quelle: AGEE-Stat
Problem of Renewable Energy

The balance between power production and consumption must be ensured every second.....

....but the production of renewable energies is decoupled from the consumption.
How to integrate Renewable energy

Expansion of the Power Grid

Demand Side Management

Centralized Energy Storage

Decentralized Energy Storage

Transmission line, Distribution line

Sufficient up to 35% renewable energy*

Smart Home, Smart Metering

Pump storage hydro power plant, Compressed air power plant, Hydrogen, Methan storage

Batteries
- Lead-Acid
- Li-Ion
- NaS
- Redox Flow

*Source: Dena II Study
# Battery Storage: Chemistry

<table>
<thead>
<tr>
<th>Chemistry</th>
<th>Lithium Ion Battery</th>
<th>Lead-Acid Battery</th>
<th>NaS High Temperature Battery</th>
<th>Redox Flow Battery</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy density</td>
<td>200–400 Wh/l</td>
<td>50–120 Wh/l</td>
<td>170 Wh/l</td>
<td>20–30 Wh/l</td>
</tr>
<tr>
<td>Power density</td>
<td>700 – 1300 W/l</td>
<td>10 – 400 W/l</td>
<td>20 – 40 W/l</td>
<td>5 W/l</td>
</tr>
<tr>
<td>Efficiency</td>
<td>90 – 95 %</td>
<td>75 – 85 %</td>
<td>75 %</td>
<td>75 %</td>
</tr>
<tr>
<td>Lifetime</td>
<td>~8 Years</td>
<td>~3 Jahre</td>
<td>~7 Jahre</td>
<td>~35 Years</td>
</tr>
<tr>
<td>Cost (Cell)</td>
<td>500 – 1000 €/kWh</td>
<td>150 – 350 €/kWh</td>
<td>200 – 300 €/kWh</td>
<td>300 – 800 €/kWh</td>
</tr>
<tr>
<td>System costs</td>
<td>1800 €/kWh</td>
<td>300 €/kWh</td>
<td>1000 – 2000 €/kWh</td>
<td>1500 – 4000 €/kWh</td>
</tr>
<tr>
<td>Market maturity</td>
<td>Development</td>
<td>Mature</td>
<td>Development</td>
<td>Research</td>
</tr>
</tbody>
</table>

Source: FhG Energietechnologien 2050
Applications for Battery Storage

EXHIBIT 1 | Financial Attractiveness of Electricity Storage Applications and Related Technologies

<table>
<thead>
<tr>
<th>Application</th>
<th>Pumped hydro</th>
<th>CAES</th>
<th>A-CAES</th>
<th>Hydrogen</th>
<th>Sodium-sulfur batteries</th>
<th>Redox-flow batteries (VRBs)</th>
<th>Lithium-ion batteries</th>
</tr>
</thead>
<tbody>
<tr>
<td>Price arbitrage</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Balancing energy</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Provision of black-start</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>services</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stabilizing conventional</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>generation</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Island and off-grid storage</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>T&amp;D deferral</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Industrial peak shaving</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Residential storage</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Source: BCG analysis.  
NA-CAES is the second generation of CAES technology; it includes a thermal storage unit to avoid thermal energy losses during compression and decompression, thereby potentially increasing round-trip efficiency to approximately 70 percent. The technology is not yet mature and faces several challenges.  
Expected WIR of 3 percent or more.

Source: BCG Study Revisiting Energy Storage  
STYRIAN ACADEMY for Sustainable Energies  
Source: DU Sauer
Components of a Storage Battery

- Energy Management
- Inverter, power electronic
- Battery Module
Challenges for Batteries

- Capacity
- Costs
- Safety
- Lifetime
## Challenges for Batteries

### Capacity

- Energy of laptop cell \(~11\text{Wh}\)
- Energy of a large format cell \(~150\text{Wh}\)
- Assembly of a huge number of cells necessary to reach reasonable capacity of a battery system
  - 4500 respectively 300 cells for \(50\text{kWh}\)

- Battery storage system’s suited for decentralized energy storage
  - The energy will be stored where it was produced before e.g. energy from photovoltaic system's

- Vision: virtual storage plant
  - Connection of a huge number of battery storage system
  - Needed:
    - Centralized intelligence
    - Communication system
Challenges for Batteries

- Operation of lithium ion cells only in a small operating window safe
- Research of cell chemistry to extend operating window
  - New electrode material
  - Improved electrolyte
- Every cell has to be controlled with respect to voltage, current and temperature → protection circuit
- Battery management system for series connected battery cells
  - Passive BMS: bypass with a resistor (loss of heat)
  - Active BMS: charge transfer from weak cell to strong cell
Challenges for Batteries

- 2 modes of aging
  - Calendric aging
  - Cycle aging
- Target Lifetime
  - >20 years
  - >7000 cycles
- Short lifetime increases life cycle costs
- Ways to increase lifetime
  - Research of cell chemistry
    - E.g. new electrode material
  - Reduced depth of discharge (DoD)
    - Example cell was cycled till 94% of its original capacity is remaining
    - 100% DoD: 500 cycles, 80% DoD: 2500
Challenges for Batteries

- Costs for battery storage system’s are still too high
  - Costs Today (Cell Level): 500-1000€/kWh
  - Target Costs (Cell Level): 150€/kWh
- Action needed
  - Incentive program by government to stimulate the market, (e.g. like at the PV market)
  - Research for cost reduction
  - Using synergies with EV batteries (economy of scale)
VARTA Battery Energy Storage System

Engion by VARTY Microbattery
Residential energy storage in combination with PV system
6kWh usable Capacity.
THANK YOU.