Energiespeichersysteme und Konzepte für die Umsetzung in der Produktion

Frankfurt (Oder), Dec. 2010

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Scope of Services

Consulting Services, Evaluation, Planning and Design
- Feasibility Studies
- Programming
- Manufacturing Technology
- Site Selection

Planning and Design
- Preliminary Design
- Detail and Final Design
- Permits / Environmental Compliance
- Value Engineering

Construction Management and Build
- Project Management
- General Contracting
- Commissioning
- Hook-up

Facilities Services / Maintenance and Operation
- Maintenance of Technical Building Systems
- Energy Management
- Infrastructure Services
- Commercial Services
- Security Services
Agenda

- Anwendungen und Marktentwicklung
- Anforderungen für Elektromobilität
- Produktionstechnologien
- Modulare Fabrik für Großserienfertigung
- Optimierte Anlagen- und Gebäudetechnik
- Cost-of-Ownership Modell
Lithium Battery Markets

Transportation

- HEV / PHEV / EV
- Heavy-Duty Hybrids

Electric Grid Services

- Grid Stabilization
- Uninterrupted Power Supply

- Fuel Economy
- Reduced Emissions
- Energy Independence

- Increase Plant Efficiency
- Increase Grid Reliability
- Energy Independence
Battery Type Comparison: „Ragone Plot“

Source: SAFT
### Comparison of Weight per Capacity

#### Weight of a 20 kWh Battery System

<table>
<thead>
<tr>
<th>Battery Type</th>
<th>Weight (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lead-Acid</td>
<td>500</td>
</tr>
<tr>
<td>Nickel-Cadmium</td>
<td>500</td>
</tr>
<tr>
<td>Nickel-Metal Hydride</td>
<td>300</td>
</tr>
<tr>
<td>Sodium-Nickel Chloride (High Temp.)</td>
<td>210</td>
</tr>
<tr>
<td>Lithium-Ion:</td>
<td>180</td>
</tr>
</tbody>
</table>

- *Lead-Acid (Gel type) x 20*
- NiMH
- NaNiCl2 (HT)
- Li-Ion

Source: SAFT
Forecast for Li-Ion Battery Market
March 2010, IIT

Worldwide rechargeable battery demand per year

NiCd
Automotive NiMH
Portable NiMH
Automotive LIB
Portable LIB
Forecast - Automotive Battery Production

Forecast Production Area worldwide

Note: Each million m² of production area => approx. 40 large scale Factories (each 1 GWh/a)
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Anforderungen an Batterien für Elektromobilität

- **Energiedichte** in kWh/kg
- **Leistungsichte** in kW/kg
- **Lebensdauer**
  - Kalendarische Lebensdauer
  - Zyklische Lebensdauer
- **Sicherheit**
- **Kosten**
  - 1000 €/kWh >>> 200 €/kWh
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Design of Cells

Cylindrical / Prismatic Cell

Pouch Cell
Battery Factory Modules

Electrode Production

Cell Assembly

Formation

Battery Pack Assembly
Li-Ion-Cell Factory: Plant Layout Concept

- Anode Production
- Cathode Production
- Drying
- Assembly
- Electrolyte Filling
- Final Storage
- Degassing
- Formation
- Aging
- Pre-Formation
- Resting

Air lock
Li-Ion-Cell Factory:
Process Steps

- Material Preparation
  - Slurry Mixing
- Anode Production
  - Coating
  - Pressing
  - Slitting
  - Notching
- Cathode Production
- Electrolyte
- Electrolyte Filling
- Slurry Mixing
  - Coating
  - Pressing
  - Slitting
  - Notching
- Lamination
- Tab welding
- Canning
- Sealing
- QC Steps
- Drying
- Drying
- Final Storage
- Degassing
- Final Storage
- QC Steps
- Formation
- Pre-Formation
- Aging
- Resting
- Pre-Formation
- Resting

air lock
Li-Ion-Cell Factory: Climate Zones

- **Preparation**: Slurry, Cathode Production
  - 15% r.h.

- **Drying**: Slurry, Anode Production
  - <1% r.h.

- **Pre-Forming**: Formation, Heating
  - 0.1% r.h.

- **Formation**: Cooling, Pre-Forming

- **Resting**: Cooling, Shipment

- **Final Storage**: Shipment
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Factory Concept: Buildings and Facilities

- Energy Center
- Electrical Formation, Testing & Shipment
- Central Utility Building
- Electrode Production and Cell Assembly
- Office
- Powder Delivery & Slurry Mixing Area
- Solvent Storage
- Fire Fighting Facilities
- Explosion-proof Wall Elements
- Transport Corridor
Factory Concept: Production Areas

- Powder site
- Slurry Mixing
- Electrode Production
- Cell Assembly
- Electrolyte Filling
- Formation
- Pre-Formation
- Aging
- Final Storage
- Shipment
Factory Concept – Phase I: Capacity 400-600 MWh/a
Factory Concept – Phase II: Capacity 1200-1800 MWh/a
Factory Concept – Phase III: Capacity 1600-2400 MWh/a
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Most Relevant Energy Flows

- **Heat**
  - Coating: Solvents Evaporation (~100°C)
  - Air Drying
  - Assembly: Air Condition

- **Electricity**
  - Formation: Charging, Discharging (~60°C)
  - Rest: Heating
Process Control

- Business Management Level
- Factory Management Level
- Process Control Level
- Field Level
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- Cost-of-Ownership Modell
Total Cost of Ownership Model

- Investment Cost
- Labour Cost
- Utility Cost
- Material Cost
- Maintenance Cost
- Total Cost
- Capacity
- Uptime
- Yield
- Production Capacity Parameters

### Investment Cost

#### 2.1 Investment Cost

| Facility Investment (Building) [M€] | 2.51 | 2.505 | 2.505 | 2.505 | 2.505 | 2.505 |
| Facility Investment (Facilities) [M€] | 2.96 | 2.96 | 2.96 | 2.96 | 2.96 | 2.96 |
| Process Equipment [M€] | 35.04 | 35.04 | 35.04 | 35.04 | 35.04 | 35.04 |
| Licence [M€] | 1.40 | 1.40 | 1.40 | 1.40 | 1.40 | 1.40 |

#### 2.2 Interest Expense [M€]

<table>
<thead>
<tr>
<th>2010</th>
<th>2011</th>
<th>2012</th>
<th>2013</th>
<th>2014</th>
<th>2015</th>
</tr>
</thead>
<tbody>
<tr>
<td>2,68</td>
<td>14,79</td>
<td>15,87</td>
<td>14,11</td>
<td>12,34</td>
<td>10,58</td>
</tr>
</tbody>
</table>

#### Total Investment Cost [M€]

<table>
<thead>
<tr>
<th>2010</th>
<th>2011</th>
<th>2012</th>
<th>2013</th>
<th>2014</th>
<th>2015</th>
</tr>
</thead>
<tbody>
<tr>
<td>5,64</td>
<td>54,19</td>
<td>55,28</td>
<td>53,51</td>
<td>51,75</td>
<td>49,99</td>
</tr>
</tbody>
</table>

### Labour Cost

#### Direct Labour Cost

| Operators/shift [Staff] | 0 | 0 | 66 | 66 | 66 | 66 |
| Technicians/shift [Staff] | 0 | 0 | 7 | 7 | 7 | 7 |

#### Indirect Labour Cost

| Post/Shift Staff | 0 | 0 | 30 | 30 | 30 | 30 |
| Management Staff | 0 | 0 | 16 | 16 | 16 | 16 |
| Engineers & Technicians Staff | 0 | 0 | 35 | 35 | 35 | 35 |
| Maintenance Staff | 0 | 0 | 10 | 10 | 10 | 10 |

#### Summary

| Total Operators [Staff] | 0 | 0 | 198 | 198 | 198 | 198 |
| Total Technicians [Staff] | 0 | 0 | 21 | 21 | 21 | 21 |
| Total Indirect Staff [Staff] | 0 | 0 | 91 | 91 | 91 | 91 |

#### Staff Cost/a [M€/a]

<table>
<thead>
<tr>
<th>2010</th>
<th>2011</th>
<th>2012</th>
<th>2013</th>
<th>2014</th>
<th>2015</th>
</tr>
</thead>
<tbody>
<tr>
<td>13,95</td>
<td>13,95</td>
<td>13,95</td>
<td>13,95</td>
<td>13,95</td>
<td>13,95</td>
</tr>
</tbody>
</table>

#### Staff Cost/Cell [€/Cell]

<table>
<thead>
<tr>
<th>2010</th>
<th>2011</th>
<th>2012</th>
<th>2013</th>
<th>2014</th>
<th>2015</th>
</tr>
</thead>
<tbody>
<tr>
<td>2,79</td>
<td>1,54</td>
<td>1,24</td>
<td>1,17</td>
<td>1,17</td>
<td>1,17</td>
</tr>
</tbody>
</table>

#### Staff Cost/Wh [€/Wh]

<table>
<thead>
<tr>
<th>2010</th>
<th>2011</th>
<th>2012</th>
<th>2013</th>
<th>2014</th>
<th>2015</th>
</tr>
</thead>
<tbody>
<tr>
<td>0,035</td>
<td>0,019</td>
<td>0,015</td>
<td>0,015</td>
<td>0,015</td>
<td>0,015</td>
</tr>
</tbody>
</table>

### Maintenance Cost

#### Investment Percentage

<table>
<thead>
<tr>
<th>Site</th>
<th>2010</th>
<th>2011</th>
<th>2012</th>
<th>2013</th>
<th>2014</th>
<th>2015</th>
</tr>
</thead>
<tbody>
<tr>
<td>Site</td>
<td>1%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td>Fab</td>
<td>2%</td>
<td>1%</td>
<td>1%</td>
<td>1%</td>
<td>1%</td>
<td>1%</td>
</tr>
<tr>
<td>Process Equipment</td>
<td>3%</td>
<td>1%</td>
<td>1%</td>
<td>1%</td>
<td>1%</td>
<td>1%</td>
</tr>
</tbody>
</table>

#### Maintenance Cost [M€]

<table>
<thead>
<tr>
<th>2010</th>
<th>2011</th>
<th>2012</th>
<th>2013</th>
<th>2014</th>
<th>2015</th>
</tr>
</thead>
<tbody>
<tr>
<td>0,00</td>
<td>1,58</td>
<td>7,43</td>
<td>7,43</td>
<td>7,43</td>
<td>7,43</td>
</tr>
</tbody>
</table>

#### Cost per Utility Unit

<table>
<thead>
<tr>
<th>2010</th>
<th>2011</th>
<th>2012</th>
<th>2013</th>
<th>2014</th>
<th>2015</th>
</tr>
</thead>
<tbody>
<tr>
<td>0,00</td>
<td>1,00</td>
<td>1,00</td>
<td>1,00</td>
<td>1,00</td>
<td>1,00</td>
</tr>
</tbody>
</table>

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**Production Capacity Parameters**

#### Investment Cost

- Total Cost of Ownership Model
- Total Cost
- Capacity
- Uptime
- Yield
- Production Capacity Parameters

**Labour Cost**

- Total Cost of Ownership Model
- Total Cost
- Capacity
- Uptime
- Yield
- Production Capacity Parameters

**Utility Cost**

- Total Cost of Ownership Model
- Total Cost
- Capacity
- Uptime
- Yield
- Production Capacity Parameters

**Material Cost**

- Total Cost of Ownership Model
- Total Cost
- Capacity
- Uptime
- Yield
- Production Capacity Parameters

**Maintenance Cost**

- Total Cost of Ownership Model
- Total Cost
- Capacity
- Uptime
- Yield
- Production Capacity Parameters

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Battery Factories – Dec. 2010

© M+W Group
Li-Ion Cell Factory: Production Parameters (20 Ah Cell)

Production Capacity

- Production Capacity in MWh/a
- Production Capacity in Cells/a

Graph showing the projected production capacity from 2010 to 2024, with an increase in both MWh/a and Cells/a over the years.
Li-ion Cell Factory: Total Net Investment

- Process Equipment: 55%
- Factory Automation: 8%
- Facility Investment: 22%
- Net Working Capital: 6%
- Real Estate Investment: 1%
- Process Integration Support: 6%
- Investment Licence Fee: 2%
Li-Ion Cell Factory: Cost Development

TCO per kWh

[€/kWh]

Other Cost
Maintenance Cost
Utility Cost
Material Cost
Labour Cost
Investment Cost

Li-Ion Cell Factory: Cost Development

TCO per kWh

Expected Market Price

- Other Cost
- Maintenance Cost
- Utility Cost
- Material Cost
- Labour Cost
- Investment Cost

Year:
- 2010
- 2012
- 2014
- 2016
- 2018
- 2020
- 2022
- 2024

Cost [€/kWh]
Lithium-Ion Batteries: Cost Forecast

Lithium-ion battery cost assumptions, $ per kilowatt hour (kWh), pack level

Projected breakthrough for materials and/or productivity, in addition to improvements in battery’s state-of-charge window

Scenario:
- High cost
- Medium cost
- Low cost

Learning curves not predictable in long term

Source: McKinsey Quarterly 2009, 3

1 State-of-charge window, is the available capacity in a battery relative to its capacity when full. Conservative applications work within a 65% window, whereas more aggressive applications use 80%; over the next 5 to 10 years, most applications will likely migrate to the higher value.
Thank You…..

- General Contractor for High-Tech Facilities
- Advanced Factory Design
- Integration of Manufacturing, Facilities & Automation
- Cleanrooms and Dry Rooms for Cell Manufacturing
- Chemical Supply Systems and Solvents Recovery
- Environmental Systems and Air-Lock Separation
- Energy Optimization and Material Recovery

➤ Consulting ➤ Design ➤ Construction ➤ Operation