New Energy Ecosystem

Ville Erkkilä
General status of battery storages globally

- **2016:**
  - 50 % growth of new storage, mostly batteries
  - Utility-scale energy storage grew to over 500 MW
  - 90 % of installed capacity Li-ion
  - 1 GW of new capacity was announced

- To keep up with the climate targets, 21 GW needed by 2025

- Energy storage Li-ion $20 billion/year market by 2040
  - Small-scale energy storages in homes and offices with PV will account for 57 % of installed capacity by 2040
Battery storage verticals

- Upstream: raw materials
  - Critical materials for Li-ion batteries
    - Cobalt, natural graphite, silicon metal
    - China is dominating global production of natural graphite and silicon metal, increasing control of cobalt production
## Battery storage verticals

<table>
<thead>
<tr>
<th>Raw materials</th>
<th>Main global producers (average 2010-2014)</th>
<th>Main importers to the EU (average 2010-2014)</th>
<th>Sources of EU supply (average 2010-2014)</th>
<th>Import reliance rate</th>
<th>Substitution index</th>
<th>End-of-life recycling input rate</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Cobalt</strong></td>
<td>Democratic Republic of Congo (64 %)</td>
<td>Russia (91 %)</td>
<td>Finland (66 %)</td>
<td>32 %</td>
<td>1.0/1.0</td>
<td>0 %</td>
</tr>
<tr>
<td></td>
<td>China (5 %)</td>
<td>Democratic Republic of Congo (7 %)</td>
<td>Russia (31 %)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Canada (5 %)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Natural graphite</strong></td>
<td>China (69 %)</td>
<td>China (63 %)</td>
<td>China (63 %)</td>
<td>99 %</td>
<td>0.95/0.97</td>
<td>3 %</td>
</tr>
<tr>
<td></td>
<td>India (12 %)</td>
<td>Brazil (13 %)</td>
<td>Brazil (13 %)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Brazil (8 %)</td>
<td>Norway (7 %)</td>
<td>Norway (7 %)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>EU (&lt;1 %)</td>
<td></td>
<td>EU (&lt;1 %)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Silicon metal</strong></td>
<td>China (61 %)</td>
<td>Norway (35 %)</td>
<td>Norway (23 %)</td>
<td>64 %</td>
<td>0.99/0.99</td>
<td>0 %</td>
</tr>
<tr>
<td></td>
<td>Brazil (9 %)</td>
<td>Brazil (18 %)</td>
<td>France (19 %)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Norway (7 %)</td>
<td>China (18 %)</td>
<td>Brazil (12 %)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>United States (6 %)</td>
<td></td>
<td>China (12 %)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>France (5 %)</td>
<td></td>
<td>Spain (9 %)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Battery storage verticals

- Upstream: raw materials
  - Cobalt: market forecast until 2020 indicates a small surplus
  - Natural graphite: large surplus in 2020 (over 10%)
  - Silicon metal: market balance in 2020

- Lithium: 75 000 tonnes 2016; 600 000 tonnes 2025
Battery storage verticals

- Midstream: components
  - 2015: most of Li-ion materials manufactured in Asia
    - 85% of cathode materials
    - 97% of anode materials
    - 84% separators
    - 64% electrolytes
Battery storage verticals

- Midstream: components
  - 2016: 80 GWh of Li-ion cells manufactured
    - 88% of the manufacturing in China, Japan, and Korea
  - Production capacity growth:
    - 2015: 70 GWh
    - 2016: 150 GWh
    - 2020: 260 GWh
    - 2025: 550 GWh
  - Global demand is expected to exceed capacity in 2022-2023
Battery storage verticals

- Midstream: components
  - 26 planned gigafactories totalling 344.5 GWh
    - China 49 %, 169 GWh
    - EU 23 %, 78.5 GWh
    - US 15 %, 53 GWh
    - Thailand, 50 GWh by 2020
    - Australia, 16 GWh
    - India, no specifications
Battery storage verticals

- Midstream: components
Battery storage verticals

- Midstream: components
  - Ongoing and announced production plans:
    - LG Chem, 2 GWh by 2018
    - Samsung SDI, 2.5 GWh by 2018
    - Northvolt, 32 GWh by 2024
    - TerraE, 34 GWh by 2028
    - SERI, 200 MWh by 2018
    - SK Innovation
    - Tesla
    - Monbat
<table>
<thead>
<tr>
<th>ZEIT →</th>
<th>HEUTE</th>
<th>KURZFRISTIG</th>
<th>2020</th>
<th>MITTEL- BIS LANGFRISTIG</th>
<th>2030</th>
<th>LANGFRISTIG</th>
<th>2040</th>
<th>PERSPEKTIVISCH</th>
<th>2050</th>
<th>VISION</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>ETABLITET</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hochstrom, langlebig (spezial, micro-hybrid)</td>
<td>LIB</td>
<td>LFP; NMC</td>
<td>LTD</td>
<td>[C1]</td>
<td>180 Wh/kg</td>
<td>150 Wh/l</td>
<td>LiFePO4</td>
<td>[C1]</td>
<td>LFP</td>
<td>180 Wh/kg</td>
</tr>
<tr>
<td>Hochenergie (elektr. Anwendungen, insb. xEV)</td>
<td>LIB</td>
<td>NCA, NMC</td>
<td>LFP</td>
<td>[C2]</td>
<td>NMC, HE-NMC</td>
<td>Si &gt; 5%</td>
<td>LiNiMnCo</td>
<td>[C2]</td>
<td>NMC, HE-NMC</td>
<td>Si &gt; 20%</td>
</tr>
<tr>
<td>Li-basiert</td>
<td>NCA, NMC</td>
<td>[C3]</td>
<td>LiCer</td>
<td>[C3]</td>
<td>NMC</td>
<td>Si &gt; 20%</td>
<td></td>
<td>[C3]</td>
<td>NMC</td>
<td>Si &gt; 20%</td>
</tr>
<tr>
<td><strong>FUENTEIL</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sonstiges</td>
<td>FuE: Materialdesign, Produktionstechnologie</td>
<td>FuE: Feststoffelektrolyt, Na-Me Anode</td>
<td>FuE: Grundlagenforschung, Membranen, Umgang mit Verunreinigungen, Elektroden</td>
<td>FuE: Grundlagenforschung, Materialien</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sonstiges</td>
<td>FuE: Anodenmaterialien</td>
<td>120 Wh/kg, 15%</td>
<td>Kostenmin.</td>
<td>FuE: Feststoffelektrolyt, Na-Me Anode</td>
<td>FuE: Grundlagenforschung, Materialien</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>NEU ENTWICKLUNGEN</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hochenergie (grav.) günstig? (Fluganwendungen)</td>
<td>FuE: Membranen, Elektrolyte, Elektroden</td>
<td>FuE: Grundlagenforschung, Materialien</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hochenergie günstig? [?]</td>
<td>FuE: Grundlagenforschung, Elektrolyte, Elektroden</td>
<td>FuE: Grundlagenforschung, Materialien</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>günstig (ESS, Consumer)</td>
<td>Na-IB</td>
<td>Schichtoxide, hand carbons</td>
<td>70-80%</td>
<td>Energieichte v. LIB</td>
<td>70-80%</td>
<td>Energieichte v. LIB</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>günstig (ESS)</td>
<td>Li-S</td>
<td>400 Wh/kg, 100 Zyklen</td>
<td>600 Wh/kg, 500 Zyklen</td>
<td>&gt;500 Wh/kg, &gt;500 Zyklen</td>
<td>200 Wh/kg, &gt;500 Zyklen</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>günstig (ESS, industriell)</td>
<td>Mg-S</td>
<td>200 Wh/kg, 100 Zyklen</td>
<td>400 Wh/kg, &gt;2000 Zyklen</td>
<td>500 Wh/kg, &gt;500 Zyklen</td>
<td>500 Wh/kg, &gt;500 Zyklen</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sonstiges</td>
<td>FuE: Membranen, Elektrolyte, Elektroden</td>
<td>FuE: Grundlagenforschung, Materialien</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sonstiges</td>
<td>Sonstige elektrochemische Speicher</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Historical development of the global battery demand and future scenarios (1950-2050)

Commercialisation of battery technology still at its onset

Historical development of the global battery demand and future scenarios (1950-2050)
Global demand vs. production capacities for LIB cells 2010-2030
Li-based high-energy automotive battery roadmap towards HE-NMC based LIB
Development of LIB cells costs by cell format
Development of gravimetric energy density for LIB cells by cell format
Development of volumetric energy density for LIB cells by cell format
Development of gravimetric energy density for LIB modules by cell format
Development of volumetric energy density for LIB modules by cell format
Global LIB demand and future potential demand by applications and segments (GWh)
Global LIB demand and future potential demand by applications and segments (GWh)
Li-ion battery technology R&D landscape

- More patents than scientific publications
Upscaling of ”breakthrough technologies”

- 1 GWh production/year: 1-3 B€ investment
- 2-3 years from decision to turn key (experienced and established producer) / 3-4 years for new players
- New materials for breakthrough technologies: add minimum another year for scale up
- Adoption of automotive OEMs: new technology must prove itself in non-automotive applications - > minimum 4 years to series production
- -> 8+ years from prototype cells into car

Source: Julich AABC
Demand for batteries by commodity

Source: Roskill
Metal needs for batteries will increase

Source: Avicenne Energy
Nickel market supply chain - 2025

Source: Roskill, Wood Mackenzie, UBS, McKinsey, Bank of America, BRN
Nickel market supply chain - 2030

Refinery capacity = 3.45 Mt

Laterite Supply 1.45 Mt
Sulphide Supply 450 kt

Intermediates 350 kt
Matte 500 kt
Ni Powders & Briquettes ~ 350 kt
Ni Metal

Fe Ni 430 kt
NPI 660 kt

Stainless Steel 1.85 Mt
Alloys, plating etc ~ 650 kt
EV Batteries ~ 750 kt
Other 170 kt

Source: Roskill, Wood Mackenzie, UBS, Mckinsey, Bank of America, BRN
Nickel market supply chain - 2030

Most Possible Projects into Production

Total Supply 3.2 M t

- Laterite Supply 2.2 M t
- Sulphide Supply 1 M t

Class 2

- Intermediates 800 kt
- Matte 1.1 Mt

Fe Ni 500 kt
NPI 800 kt

Ni Powders & Briquettes ~ 500 kt

Ni Metal

Stainless Steel 1.85 M t

Alloys, plating etc ~ 650 kt
EV Batteries ~ 750 kt
Other 170 kt

Refinery capacity = 3.45 Mt

Source: Roskill, Wood Mackenzie, UBS, McKinsey, Bank of America, BRN

03/01/2019
Downstream processing adds value

- Spodumene Production: $1
- Lithium Hydroxide Production: $3
- Lithium Titanate Anode Production: $8
- Lithium Battery Production: X

Source: Neometals
Value chains
Li-ion value chain – market demand

**CATHODE**
- > 260,000 T in 2017
- Revenues: 6.8 B$
- CAGR 07/17: +12%

**ANODE**
- 130,000 T
- Revenues: 1.4 B$
- CAGR 07/17: +15%

**ELECTROLYTE**
- 140,000 T
- Revenues: 1.8 B$
- CAGR 07/17: 23%

**SEPARATOR**
- 2,000 M m$^2$
- Revenues: 1.9 B$
- CAGR 07/17: 15%

**ANCILLARY**
- Revenues: 2.6 B$

**CELL MANUFACTURERS**
- Revenues: 27 B$
- Margin: < 0% (!)

**PACK MANUFACTURERS**
- Revenues: 36 B$

**OEMs**

Source: Avicenne Energy
Automotive LIB manufacturing value chain

- **Raw materials**
  - Basic input materials (e.g. lithium, nickel, cobalt, graphite, etc.).

- **Processed materials**
  - Purified input materials ready for transformation into cell components.
  - Processed materials are considered Critical to Quality (CTQ), meaning the materials’ purity greatly influences overall cell performance and production yields.

- **Electrodes**
  - Cathode and anode materials.
  - CTQ, cathode materials quality especially contributes to cell capacity and overall performance.

- **Cells**
  - Fundamental functional, charge-retaining battery unit comprised of cathode, anode, separator, electrolyte, and housing.
  - CTQ.

- **Battery pack**
  - Full battery pack comprised of multiple cells, controls, thermal management, and physical protection.

Source: CEMAC
Automotive LIB manufacturing value chain

2014 Best-in-Class PHEV LIB Value Chain ($US/kWh)

<table>
<thead>
<tr>
<th>Stage</th>
<th>Global Value</th>
<th>Regional Contribution</th>
<th>Locally Contributed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Raw Materials</td>
<td>$168</td>
<td>29%</td>
<td></td>
</tr>
<tr>
<td>Processed Materials</td>
<td>$28</td>
<td>5%</td>
<td></td>
</tr>
<tr>
<td>Electrodes</td>
<td>$146* (cum. $342*)</td>
<td>26%</td>
<td></td>
</tr>
<tr>
<td>Cells</td>
<td>$229</td>
<td>40%</td>
<td></td>
</tr>
<tr>
<td>Battery Pack</td>
<td>$571</td>
<td>100%</td>
<td></td>
</tr>
</tbody>
</table>

* Ex-factory gate – shipping from Asia to the west coast of the United States adds approximately $7/kWh

Source: CEMAC
Automotive LIB manufacturing value chain

Source: Roskill
1. The largest share of the value (40%) comes from cell components.

2. Cell manufacturers & OEM alliance may be the winning model but comes with high risk if the wrong cell manufacturer is selected.

3. Tiers 1- cell manufacturers alliance: most of them disappear (e.g. Saft-Johnson Controls, Bosch-Samsung, Enerdel-Delphi...)

4. Tiers 1- OEM alliance on Battery are not successful.

5. Panasonic and LG Chem, cell manufacturers develop raw-material in-house and make the pack integration for OEM.

6. On a different scale, Toyota, BYD or BOLLORE are fully integrate.
<table>
<thead>
<tr>
<th>Production of components</th>
<th>Production of cells</th>
<th>Production of modules</th>
<th>Production of packs</th>
<th>Vehicle integration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Samsung SDI</td>
<td>BMW</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BYD</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A123 Systems*</td>
<td></td>
<td></td>
<td></td>
<td>Chevrolet Spark**</td>
</tr>
<tr>
<td>LG Chem</td>
<td></td>
<td></td>
<td></td>
<td>Chevrolet Volt</td>
</tr>
<tr>
<td>Li-Tec - Smart (Tochter: Daimler)</td>
<td>Accumotive - Smart (Tochter: Daimler)</td>
<td>Daimler</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Panasonic – B-Klasse</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LG Chem</td>
<td></td>
<td></td>
<td></td>
<td>Daimler</td>
</tr>
<tr>
<td>Lithium Energy Japan (Joint Venture: MMC, Mitsubishi, GS Yuasa)</td>
<td></td>
<td></td>
<td></td>
<td>Daimler</td>
</tr>
<tr>
<td>AESC (Joint Venture: Nissan, NEC)</td>
<td></td>
<td></td>
<td></td>
<td>Mitsubishi</td>
</tr>
<tr>
<td>LG Chem - ZOE, Twizy</td>
<td></td>
<td></td>
<td></td>
<td>Nissan</td>
</tr>
<tr>
<td>AESC - Fluence, Kangoo</td>
<td></td>
<td></td>
<td></td>
<td>Renault</td>
</tr>
<tr>
<td>Primearth EV Energy (Joint Venture: Toyota &amp; Panasonic)</td>
<td></td>
<td></td>
<td></td>
<td>Toyota</td>
</tr>
<tr>
<td>Sanyo</td>
<td></td>
<td></td>
<td></td>
<td>VW Group</td>
</tr>
</tbody>
</table>

Source: MFiVE
A graph showing the actors of LIB (Lithium-ion Battery) value chain in Germany. The value chain is divided into R&D, battery materials and components, cell production, battery production, and OEM. Companies involved in each stage are listed, with a focus on raw material recycling, anode, cathode, separator, electrolyte, components, production technology, automation, cell production, and battery production. The source of the information is KLIB.
Actors of LIB value chain in Finland

R&D
- VTT
- Aalto-ylfiopisto
- LUT University of Technology
- University of Oulu
- University of Eastern Finland

Mining
- FINOCOBALT
- BOLIDEN
- NICKEL
- KELIBER
- Terrafame
- Freeport Cobalt

Metal refining
- Outotec
- beneq
- Picodeon
- broadbit

Battery materials
- European Batteries
- VISEDO
- Valmet Automotive
- KALMAR
- Rocla
- SANDVIK
- normet

Cell manufacturing
- AVANT
- ABB
- Wärtsilä
- KONE
- KONECRANES

Module/pack manufacturing
- Linkker Future Moves
- Suomi Recycle

OEM
- AKKUSER
- Kuusakoski Recycling
- Akkukierrätys Pb Oy

2nd life/recycling
CRM value chain analysis

Value-Chain Structure

Production
- Cobalt
- REE
- Graphite

Adv. mat. manufacturing

Components
- Cathode
- Anode

Battery cells & stacks
- NiMH
- Li-ion

Battery system

Recycling

Europe
- umicore
- Arkema

Entry in Europe of REEs in alloys form

North America
- Covalent
- Sullender

47% Cobalt supply

Asia
- Umicore
- BTR
- NICHIHA
- KUREHA

Chinese domination

75% market share

Umicore Korea: N°1 worldwide

New unit (2013)

BASF

80% market share

SONY
- LG
- Panasonic
- SANYO
- SAMSUNG SDI
- MITSUBISHI

85% market share

Source: CRM_InnoNet
European Battery Alliance

<table>
<thead>
<tr>
<th>Raw materials</th>
<th>Active Materials</th>
<th>Battery Cells and Battery Packs</th>
<th>Applications</th>
<th>Recycling/2nd life</th>
</tr>
</thead>
<tbody>
<tr>
<td>EIT Raw Materials</td>
<td>Nanomakers</td>
<td>Litarion GmbH</td>
<td>Akasol</td>
<td>VOLKSWAGEN</td>
</tr>
<tr>
<td>Leading Edge Materials</td>
<td>Blue Solutions (Bolloré)</td>
<td>Saft</td>
<td>E4V</td>
<td>FIAT</td>
</tr>
<tr>
<td>Outotec</td>
<td>BASF</td>
<td>Varta</td>
<td>Continental</td>
<td>RENAULT</td>
</tr>
<tr>
<td>EUROMINES</td>
<td>Arkema</td>
<td>Ledionché</td>
<td>LION E-Mobility</td>
<td>Jaguar-Landrover</td>
</tr>
<tr>
<td>Eramet</td>
<td>NXP Semiconductors</td>
<td>EAS Batteries</td>
<td>BMW</td>
<td>PSA Groupe</td>
</tr>
<tr>
<td>Bolden</td>
<td>SGL Carbon SE</td>
<td>Terra E</td>
<td>BMZ - Batterykompetenzzentrum</td>
<td>Atlas Copco</td>
</tr>
<tr>
<td>Terrafame</td>
<td>BELENOS</td>
<td>Liacon</td>
<td>Sonnen GmbH</td>
<td>cyberGRID GmbH</td>
</tr>
<tr>
<td>Rio Tinto</td>
<td>CEFIC</td>
<td>Northvolt</td>
<td>EnCell Inc</td>
<td>EDF</td>
</tr>
<tr>
<td>Magnis/ Allocate</td>
<td>Heraeus</td>
<td>CustomCells</td>
<td>HEIDA</td>
<td>Total</td>
</tr>
<tr>
<td>Nanomakers</td>
<td>Klub</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Research and associations active in all parts of the value chain:
- Fraunhofer
- CEA
- ENEA
- T&E
- EASE
- EURORAT
- EMIRI
- ANIE
- Ångström Advanced Battery Centre

03/01/2019
Regional comparison of cell manufacturing costs

- Materials and labor constitute the key cost differences across countries
- Labor costs are driven by location, whereas materials costs are driven by country and company characteristics

Source: CEMAC
LIB cell manufacturing

Szenario I “Copy-paste” factory

Start for maximal period

Start for minimal period (best case)

About 20-30 months

Prior project and business planning
Specifications and call for bids for plant
Allocation of plants and suppliers for production ionsmaterial
material until acceptance of delivery of plant
Planning and approval of plant
Construction period
Installation of plant, production and validation of sample C
Installation sample D / PPAP of suppliers
Evaluation sample D

2017  2018  2019  2020  2021

Plant planning ~ 4-6 months
Plant construction and launch ~16-24 months
# LIB cell manufacturing

## Scenario 2: Establishment of new player

**About 48 months**

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Prior project and business planning</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Design until free of sample B</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Validation of sample B</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Specification and call for bids for production plant</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Allocation of plants and suppliers for production</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Material until acceptance of delivery of plant</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Planning and approval of plant</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Construction period</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Installation of plant, production and validation of sample C</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Installation of sample D / PPAP of suppliers</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Evaluation of sample D</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Development of sample B ~ 6 months**

**Plant planning, construction & allocation of orders ~ 18 months**

**Launch of production of samples C and D ~ 24 months**

Source: NPE UAG 2.2 M. Weiss, members, 2015
LIB value creation

- Three major value creation steps:
  - Cell manufacturing
  - Module manufacturing
  - Pack manufacturing and vehicle integration

- Further important steps:
  - Production of processed materials
  - Manufacturing of electrodes
  - Manufacturing of machineries for LIB production plants

- Two additional steps:
  - Second life of LIB as part of the renewable energy system
  - Recycling of raw materials of LIB at their end-of-life
Criteria for selection of LIB cell manufacturing site

- Access to raw materials (graphite, lithium, cobalt, nickel, manganese).
- Proximity to machinery suppliers.
- Existing clusters of battery and materials manufacturers.
- Protection of intellectual property, including process innovations.
- Energy cost and environmental legislation.
- Logistical risks and proximity to end-markets.
- Supply chain optimization e.g. degree of vertical integration.
- Access to talented workforce, especially in RD&D.
- Labor cost of RD&D staff and of skilled factory staff.
- Competitive edge of incumbents that can not be caught up anymore.
- Sunk cost of factories that would produce old technologies if new cell technologies were produced by the new factory.
- Discounts provided to regional customers or members of the regional cluster but not to foreign customers.
- Opportunity to generate lead markets or at least export markets.
- Policy and regulatory context.
- Ease-of-doing-business-considerations.
- Brand and reputation.
Key players
## Lithium suppliers

### Mined product
- Talison 31 % (AU)
- SQM 22 % (Chile)
- Albemarle 17 % (USA)
- FMC 9 % (USA)
- Orocobre 5 % (AU)
- Galaxy 3 % (AU)
- Neometals 1 % (AU)
- China mineral 5 %
- China brine 2 %
- Other mineral 5 %

### Converted minerals
- Tianqi 43 % (China)
- Ganfeng 17 % (China)
- Zhonge 13 % (China)
- Ruifu 11 % (China)
- General Li 9 % (China)
- Sichuan Ni&Co 7 % (China)
- China 100 %

### Refined products
- SQM 23 % (Chile)
- Albemarle 17 % (USA)
- Tianqi 13 % (China)
- FMC 10 % (USA)
- Technical minerals 8 %
- Orocobre 6 % (AU)
- Ganfeng Li 5 % (China)
- Sichuan Ni&Co 5 % (China)
- Sichuan Ni&Co 5 % (China)
- Ruifu 4 % (China)
- Zhonge 4 % (China)
- General Li 3 % (China)
- China brine 2 %
Nickel sulphate suppliers

- Sumitomo 18 % (Japan)
- Jilin Jien 13 % (China)
- Jinchuan 11 % (China)
- Norilsk Nickel 8 % (Russia)
- Umicore 6 % (Belgium)
- Others 23 %
- Others China 21 %
Cobalt suppliers

Share of cobalt supply by stage (%)

From Congo to China
Congo produces more than half of the global supply of cobalt.

Percentage of raw cobalt production, by country

For batteries:
- China 80%
- Finland (Freeport) 20%

Source: Roskill
Cobalt suppliers

- 77% of refined cobalt produced in China (67% in 2012)
- CRU: soon 90%
Cobalt mine in Congo
Cobalt miners in Congo produce 14 % of the output
Cathode materials – LCO suppliers

- L&F 16 % (Korea)
- Umicore 15 % (Belgium)
- Pulead 12 % (China)
- B&M 12 % (China)
- ShanShan 10 % (China)
- Easpring 9 % (China)
- Reshine 9 % (China)
- Nichia 8 % (Japan)
- Xianmen Tungsten 7 % (China)
- Others 2 % (China)

- China 61 %
Cathode materials – NMC suppliers

- Umicore 18 % (Belgium)
- Internal 12 % (LG Chem, Samsung SDI, etc.)
- ShanShan 12 % (China)
- Xianmen Tungsten 10 % (China)
- L&F 9 % (Korea)
- Nichia 9 % (Japan)
- Easpring 8 % (China)
- Jinhe 7 % (China)
- Tianjiao 6 % (China)
- Kelong 2 % (China)
- Dahua 2 % (China)
- Pulead 1 % (China)
- Others 4 % (China)

China 52 %
Cathode materials – NCA suppliers

- Sumitomo 73 % (Japan)
- Toda Kogyo 10 % (Japan)
- Ecopro 5 % (Korea)
- Nihon Kagaku Sangyo 5 % (Japan)
- Kelong 5 % (China)
- Others 2 % (China)

- Japan 88 %
Cathode materials – LFP suppliers

- Internal 27 % (BYD, Hefei, Huanyu, LG, A123, Hi Power)
- Pulead 13 % (China)
- BYD 8 % (China)
- Zhuoneng 6 % (China)
- STL 5 % (China)
- Johnson Matthey 4 % (UK)
- Alees 3 % (Taiwan)
- Kelong 2 % (China)
- Tatung 1 % (Taiwan)
- Others 28 % (China)

- China 92 %
Anode materials – natural graphite suppliers

- Shenzhen BTR 40 % (China)
- Mitsubishi 15 % (Japan)
- Hitachi 10 % (Japan)
- Shinzoom 9 % (China)
- Posco Chemtech 4 % (Korea)
- Nippon Carbon 4 % (Japan)
- Sinuo 3 % (China)
- Others 10 %

- China 70 %
Anode materials – artificial graphite suppliers

- ShanShan 21 % (China)
- Sinuo 20 % (China)
- BTR 16 % (China)
- Zichen 15 % (China)
- Hitachi 7 % (Japan)
- JFE 5 % (Japan)
- Mitsubishi 4 % (Japan)
- Shinzoom 4 % (China)
- Showa Denko 2 % (Japan)
- Others 6 % (China)

- China 82 %
LIB separator suppliers

- Asahi 17% (Japan)
- Toray 15% (Korea)
- SK Innovation 9% (Korea)
- Celgard 8% (Asahi subsidiary)
- Sumitomo 6% (Japan)
- Ube 6% (Japan)
- W-Scope 6% (Japan)
- Jinhui 4% (China)
- Entek 4% (USA)
- Senior 3% (China)
- Green 3%
- Others 19%
LIB electrolyte suppliers

- Zhangjiagang Guotai-Huarong 15 % (China)
- Capchem 14 % (China)
- Mitsubishi 12 % (Japan)
- In-house 9 %
- Panax-Etec 8 % (Korea)
- ShanShan 8 % (China)
- Jinniu 8 % (China)
- Tinci 6 % (China)
- Soulbrain 5 % (Korea)
- Ube 4 % (Japan)
- Mitsui 3 % (Japan)
- Tomiyama 3 % (Japan)
- Others 5 %
Li-ion cell production

Source: Avicenne Energy

* Others: Malaysia mainly
  (1) Government subsidies only
  (2) Avicenne estimation
Gigafactory projects in the European Union (as of 20 February 2018)

**NORTHVOLT**
- Announced in spring 2017, construction to start in S2 2018
- Demo line ready mid-2019 with 8GWh/yr capacity
- 32GWh/yr production target for 2023/2024
- Investors: InnoEnergy, Stena, Vattenfall, Vinnova
- Grant from the Swedish Energy Agency: €15 million
- EIB loan: €52.2 million

**LG Chem Wroclaw factory**
- Announced in 2016
- Start of operation in Q4 2018
- 100,000 EV batteries (4GWh/yr) production target
- €310 million to be invested up to 2020

**TERRA-E**
- Announced in spring 2017
- Start of operation in Q4 2019 with 6-8GWh/yr capacity
- 34GWh/yr production target by 2028
- Consortium of 17 industrial stakeholders and research institutes, with BMW as the main shareholder
- Benefiting from a €5.2 million grant from the German Ministry of Education

**Samsung SDI Göd factory**
- Announced in 2016
- Start of operation in Q2 2018
- 50,000 EV batteries (2GWh/yr) production target
- €300 million investment

**SK Innovation Komárom factory**
- Plans to break ground in February 2018
- Start of production in early 2020
- 7.5 GWh/yr production target
- €620 million to be invested

Source: Carole Mathieu, "The EU Battery Alliance: Can Europe Avoid Technological Dependence?", Études Énergie, Ifri, February 2018.