German-Japanese Energy Symposium 2011

Lithium-Ion-Technology in mobile und stationary applications

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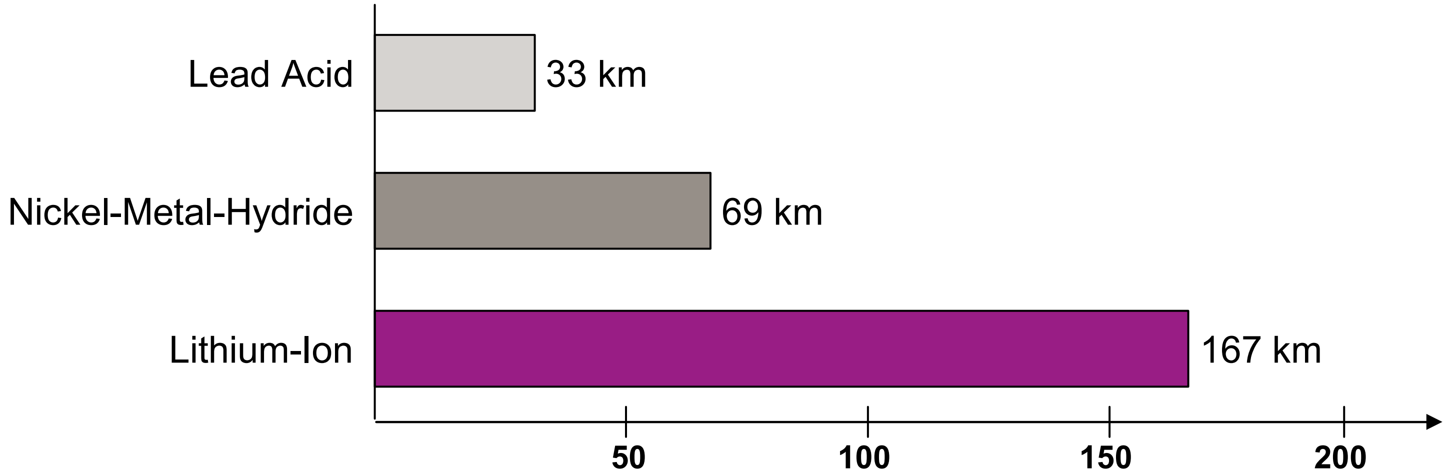
Version 2.0

With Lithium-Ion-Technology cruising ranges of greater than 150 km are first time possible

Ranges in km with a 125 kg battery

Lead Acid	Nickel-Metal-Hydride	Lithium-Ion
		
ca. 5 kWh 0.5 l Diesel	ca. 10 kWh 1.0 l Diesel	ca. 25 kWh 2.5 l Diesel

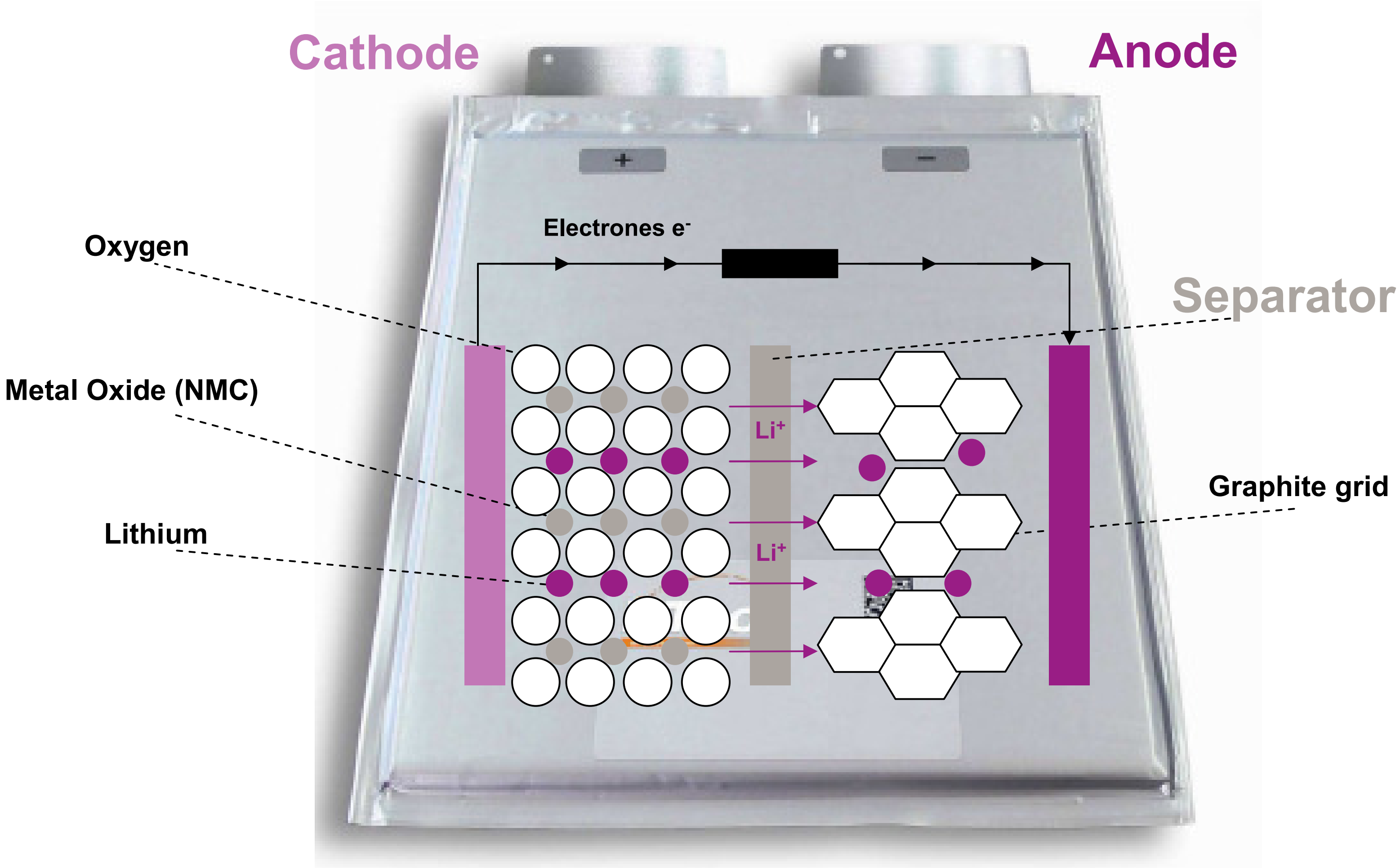


The energy input per 100 km relates to 1.5 l Diesel

Source: Science-to-Business Center Eco² (February 2011) , Li-Tec

At the charging process Lithium-Ions are stored into the graphite grid

Charging of battery cell



Source: Science-to-Business Center Eco² (February 2011) , Li-Tec

The pairs of electrodes determine the possible cell voltage

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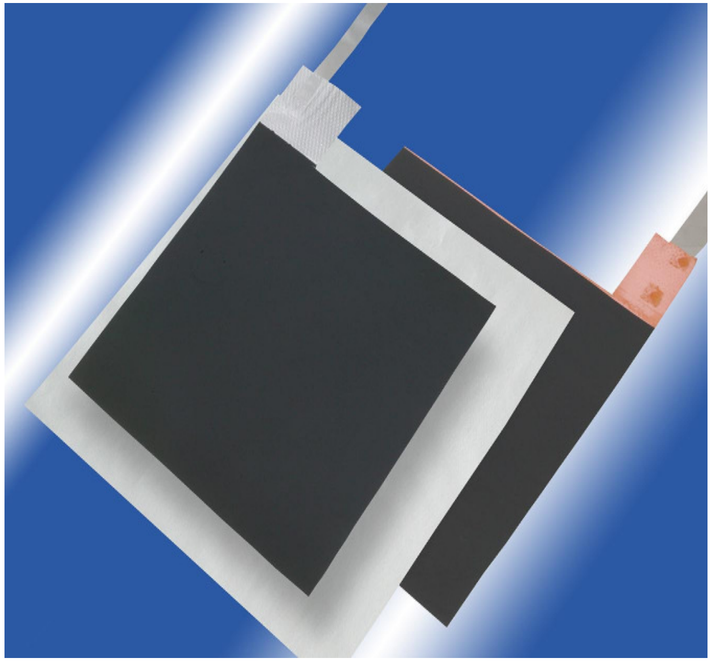
LITARION® Electrodes

Type / Specifications	LITARION® AC 1411	LITARION® AC 3521
Cathode **Anode**	NMC Hard Carbon	NMC Graphite
Capacity	1.4 mAh/cm²	3.5 mAh/cm²
Current stability/C-Ratio	> 20C	> 5C
Cycle stability	> 5,000 Cycles	> 3,000 Cycles
Typical applications	*Premium* High Power	*Premium* High Energy / Medium Power

NMC : $LiNi_{1/3}Mn_{1/3}Co_{1/3}O_2$



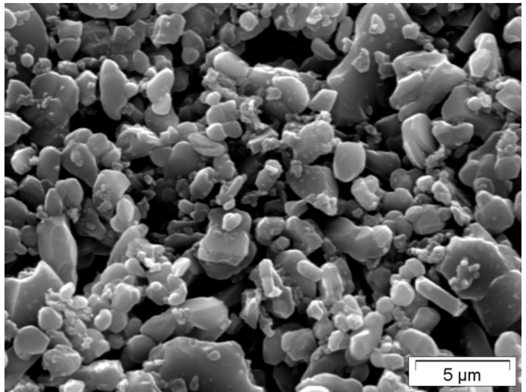
Source: Science-to-Business Center Eco² (February 2011) , Li-Tec

SEPARION® is the technological pacer for large-format cells

Composition of separator

Continuous ceramic coating
(alumina, zirconia, silica)

Polymeric non-woven support
(polyethylene terephthalate)



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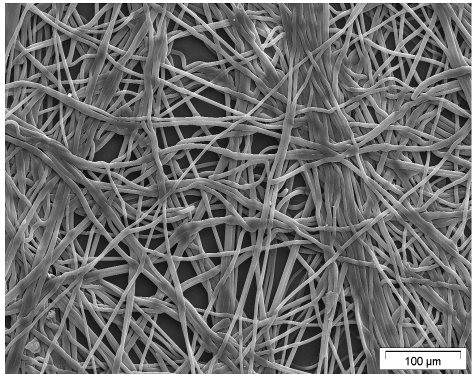
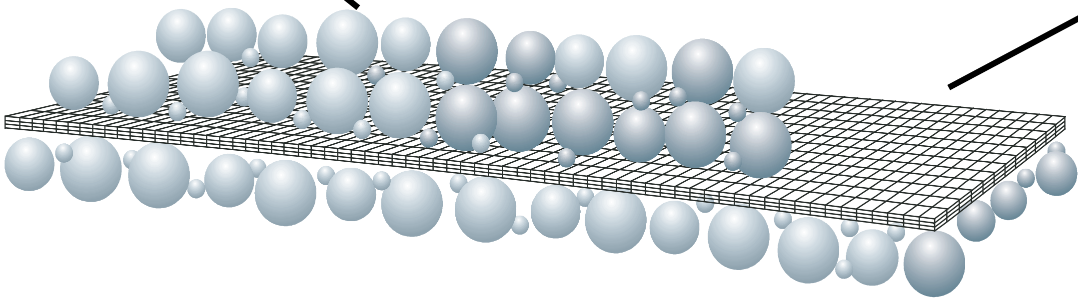




SEPARION®
flexible ceramic battery separator

Source: Science-to-Business Center Eco^2 (February 2011) , Li-Tec

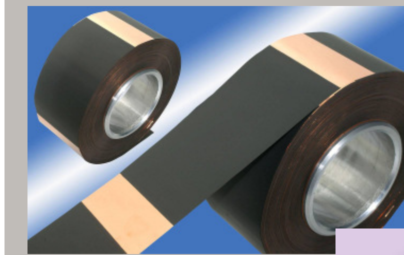
Lithium-Ion-Technology allows for direct electricity storage

Characteristics of Lithium-Ion-Technology

Technology advantage

- High power / energy density
- High cycle stability
- Short response time
- High efficiency (> 95%)
- Broad load range without battery damage
- High safety due to ceramic separator - SEPARION®
- Low self discharge (< 1 % per month)
- High cell voltage (3.6 V)
- Moderate temperature window

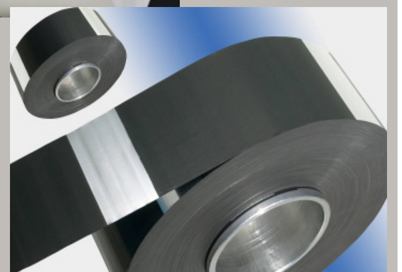
Cell components



LITARION™ A
Ready to use anodes

SEPARION®
ceramic separator

LITARION™ C
Ready to use cathodes



Source: Science-to-Business Center Eco^2 (February 2011) , Li-Tec

Besides deployment in mobile applications also stationary ones have great potential

From E-mobility to stationary applications

E-mobility

Lithium-Ion-Technology

Stationary applications

Source: Science-to-Business Center Eco² (February 2011) , Li-Tec

Trends in electricity supply demand for measures in the electrical network

Trends		Measures
Expansion of renewable energies	Removal of conventional energy generation	Load management
Decentralized energy generation	North-South-decline of wind	Network expansion
Increasing energy prices	Trigeneration	Smart Grids
E-mobility	More competition?	Virtual combined power plants
…	…	…
		Storages!?

Trigeneration: Combined-heat-cold-power-plants

Source: Science-to-Business Center Eco² (February 2011)

Manifold fields of applications exist for stationary storages result

Areas of applications

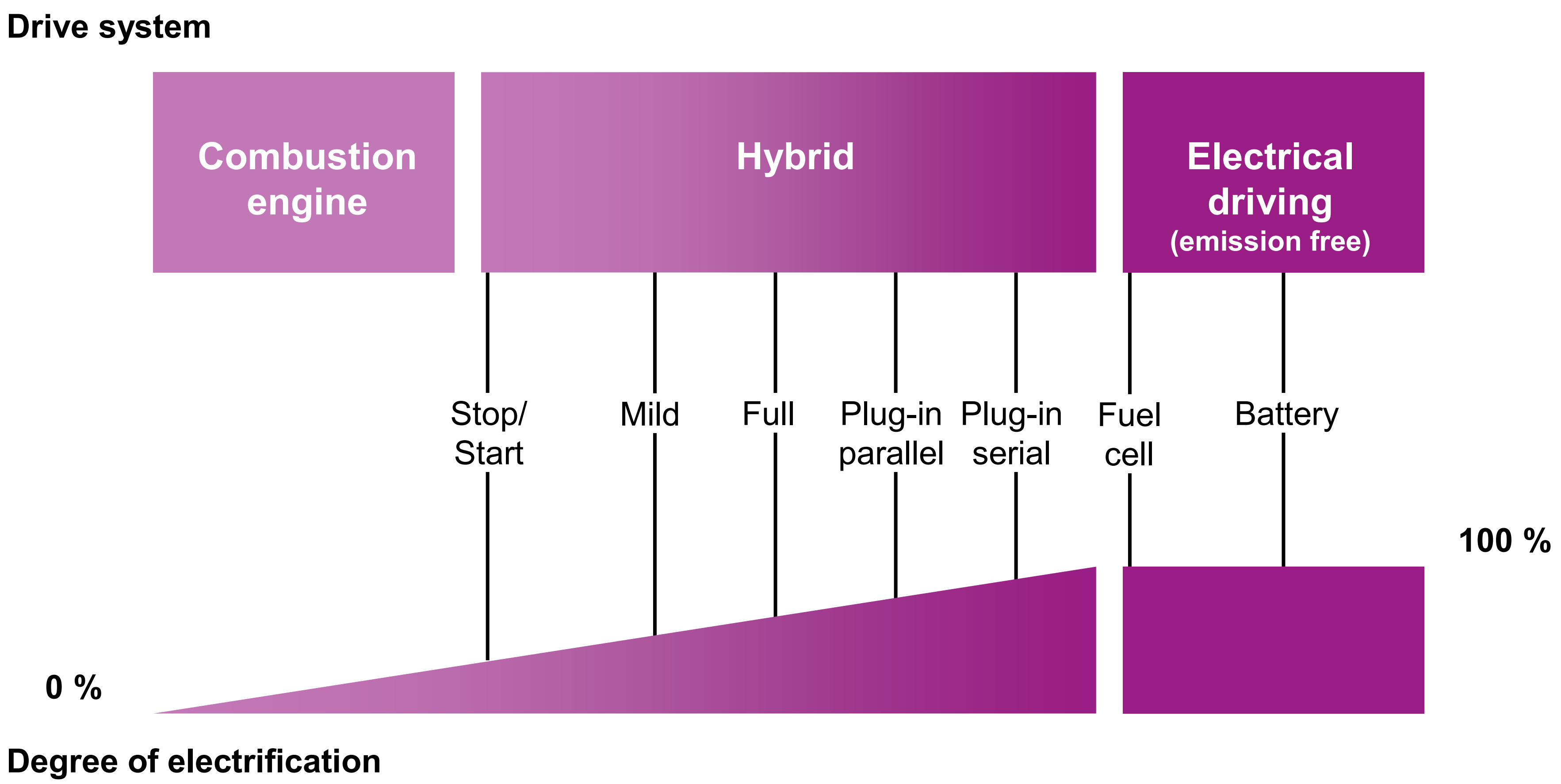
- UPS
- Control power
- Increase of grid quality / grid stability
- Grid relief, switching / avoiding network extension
- Peak shifting, peak shaving, optimization power supply
- Use of „excess current“ especially from RE (longer duration)
- Keeping RE-prognoses
- Balancing fluctuating resources (base-load-capabilities)
- Allocation of reactive power
- …

UPS: Uninterruptible power supply, RE : Renewable energies

Source: Science-to-Business Center Eco² (February 2011)

Future mobility is indicated by electrification of the drive chain

Electrification of drive chain



Source: Science-to-Business Center Eco² (February 2011) , Li-Tec

Mobile and stationary applications have common ground but also distinctions

Differences

E-mobility

- Storage capacities and power vary by order of magnitude of one
- Power and energy density leading
- More intense changing boundaries (e. g. temperature)
- Shock
- Crash ⇔ Safety
- Added value higher (?)
- …

Stationary applications

- Storage capacities and power vary by order of magnitude of four
- Low energy prices ⇔ low added value (per cycle)
- High number of possible applications and combinations (⇔ however different and changing demands)
- …

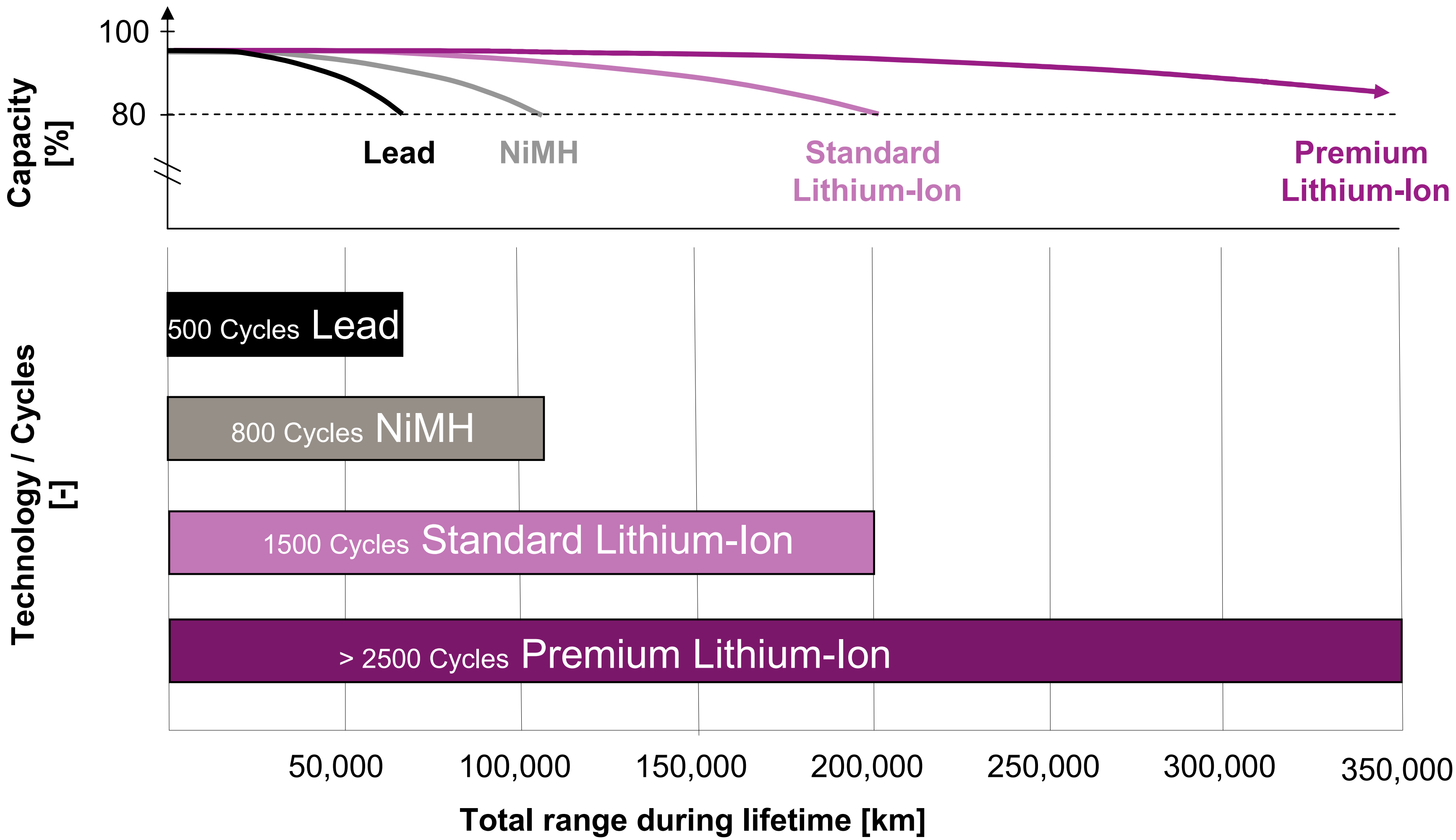
$\neq$

LIT: Lithium-Ion-Technology

Source: Science-to-Business Center Eco² (February 2011) , Li-Tec

Number of possible cycles decides on total range

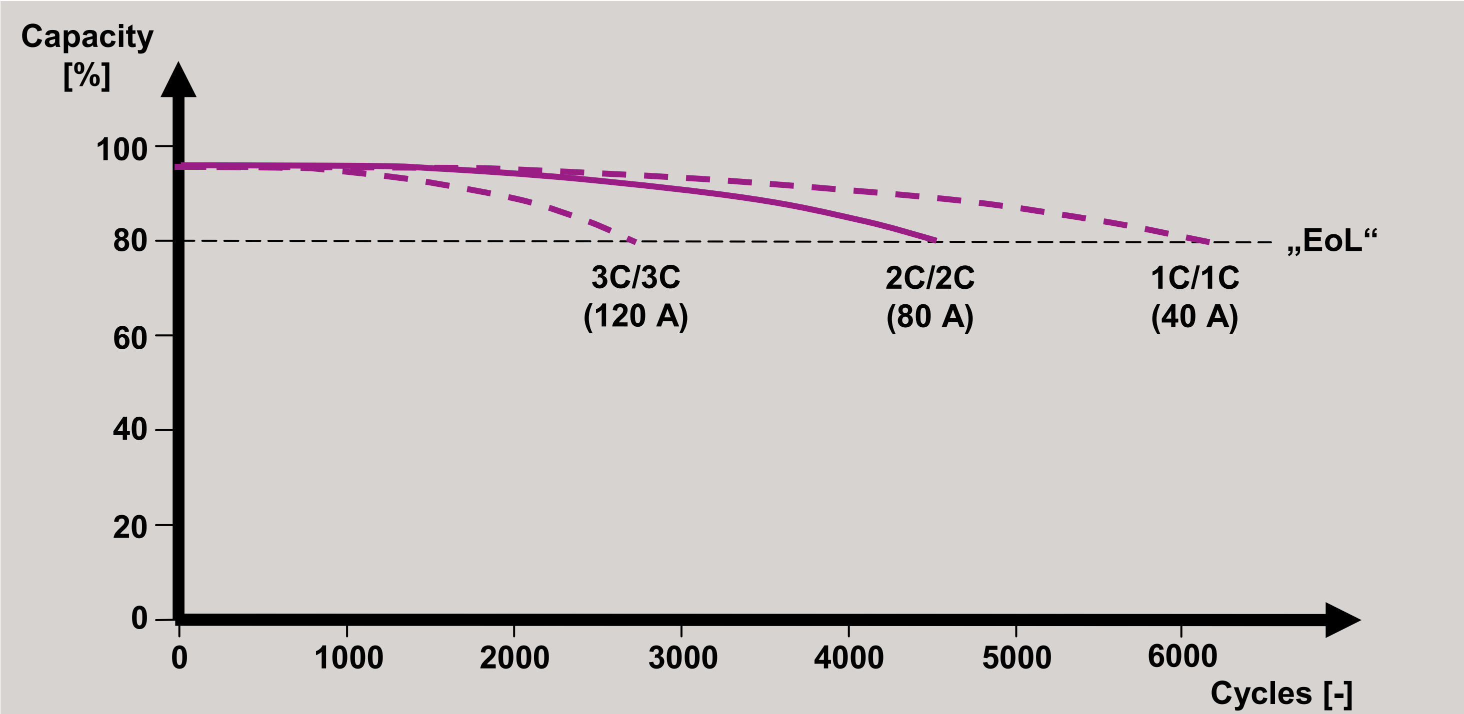
Cycles of different storage technologies



Source: Science-to-Business Center Eco² (February 2011) , Li-Tec

Cycle lifetime of Lithium-Ion-Cells are strongly dependent on load profile

Cycle lifetime of a 40 Ah cell at 100% DoD

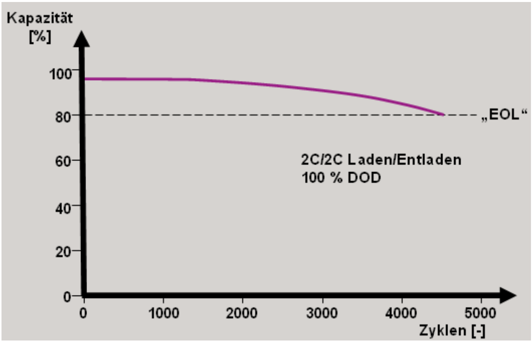


- C-Ratio ⇩ (≈ Power/Capacity ⇩) ⇨ Cycles⇧
- DoD ⇩ ⇨ Cycles⇧⇧ (also total energy conversion ⇧!)

EoL: End of Life
DoD: Depth of Discharge
Source: Science-to-Business Center Eco² (February 2011) , Li-Tec

Operation and particular application determine the specific costs – not only investment

Example



Specific costs of throughput energy (without capital costs)

- Investment: 1,000 €/$kWh_{installed}$
  Throughput energy: 4,000 $kWh_{throughput}/kWh_{installed}$
  ⇔ **25 €ct/$kWh_{throughput}$**
- Investment: 400 €/$kWh_{installed}$
  Throughput energy: 40,000 $kWh_{throughput}/kWh_{installed}$
  ⇔ **1 €ct/$kWh_{throughput}$**

Specific costs of retrieved power (without capital costs)

- C-Ratio: 1 h^{-1}
  Investment: 1,000 €/$kWh_{installed}$
  ⇔ **1,000 €/kW**
- C-Ratio: 20 h^{-1}
  Investment: 400 €/$kWh_{installed}$
  ⇔ **20 €/kW**

Source: Science-to-Business Center Eco^2 (February 2011)

LESSY (Lithium-Electricity-Storage-System) provides ancillary services

Project overview

Goal:

Proof of **technical** and **economical feasibility** of large-format stationary electricity storages on the basis of **Lithium-Ion-Technology** at the example of the application „**Primary Control Power**"

GEFÖRDERT VOM

Bundesministerium für Bildung und Forschung

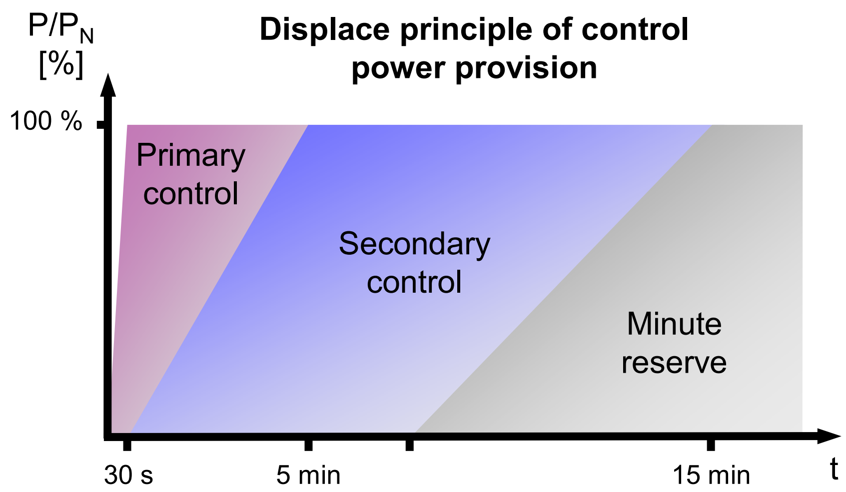

Power Plant Fenne (Evonik Power Saar)

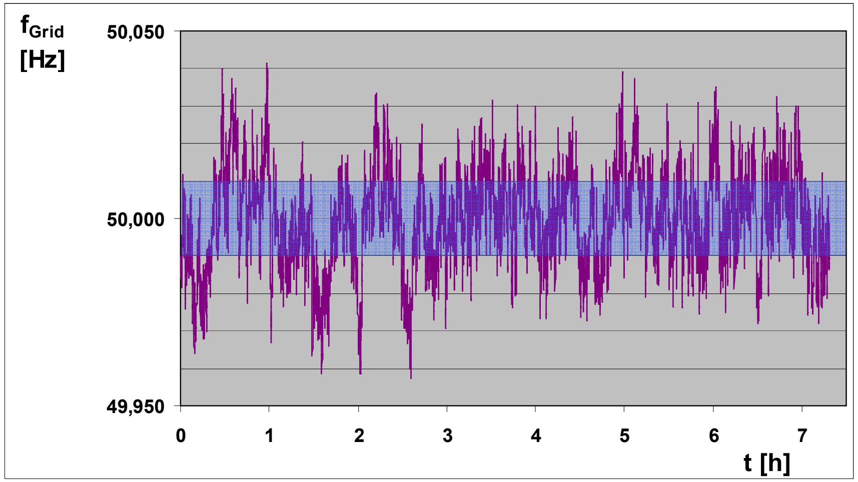
Duration:	3 years
Control power:	+/- 1 MW
Storage capacity:	700 kWh
Project volume:	4.91 Mil. €

Source: Science-to-Business Center Eco^2 (February 2011)

Control power supports the stability of the electrical network frequency

Explanation of provision of control power





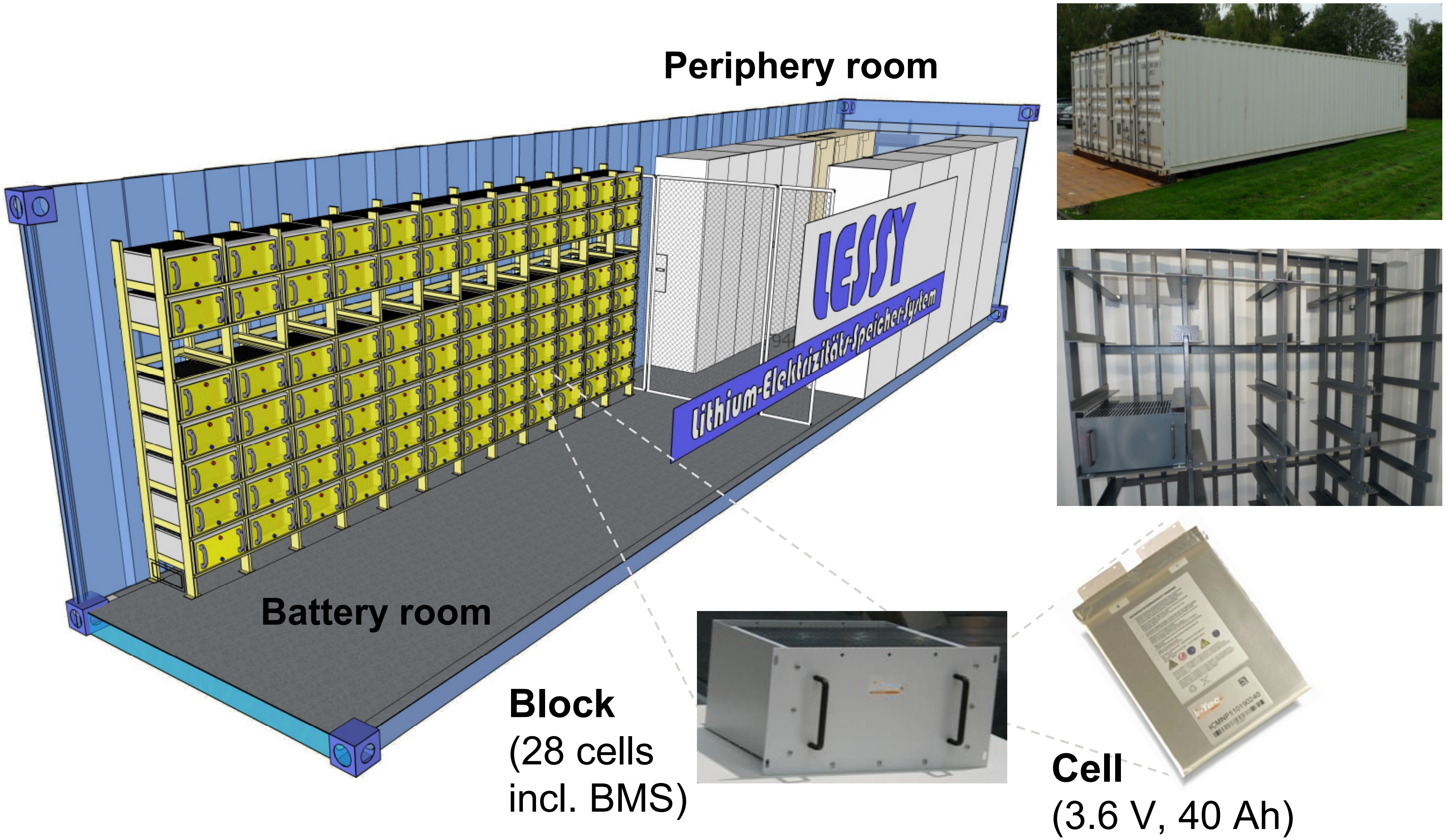
Requirement of control power:

- High load gradients
- Frequent change between power acceptance and discharge
- Quick response
- High availability

Source: Science-to-Business Center Eco² (February 2011)

The large format storage shows compact design

Design of LESSY storage

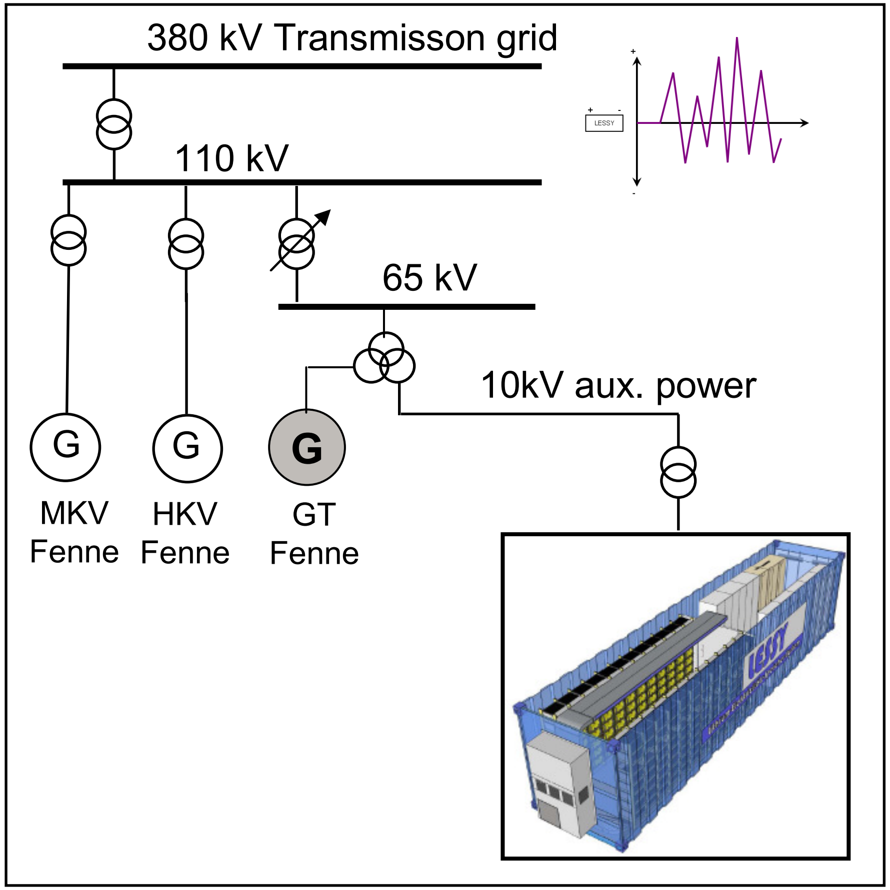


Source: Science-to-Business Center Eco² (February 2011) , Digatron

Besides primary control power also other ancillary services will be tested

Focus during test operation

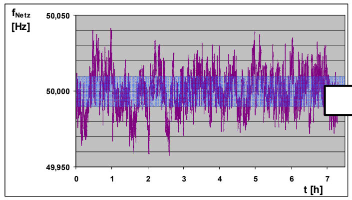
- **Primary control**
  - Stand alone
  - In combination with power plant
- **USP**
- **Realization of black start capability**
- **Compensation of reactive power**



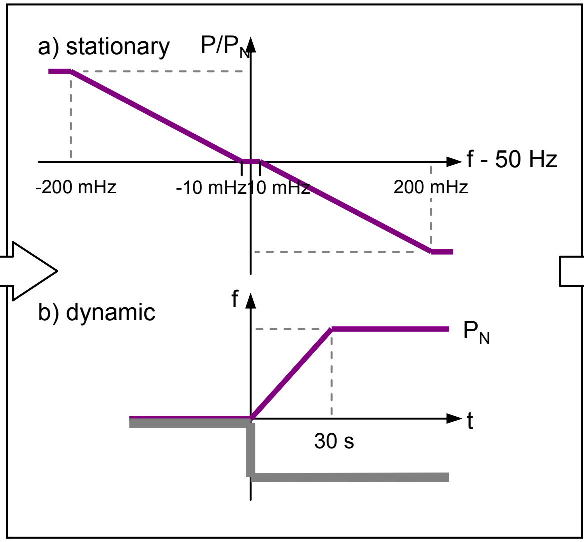
GT : Gas Turbine
MKV : Modellkraftwerk Völklingen, HKV : Heizkraftwerk Völklingen
Source: Science-to-Business Center Eco² (February 2011)

Statistic analyses of load profile provide the design basis

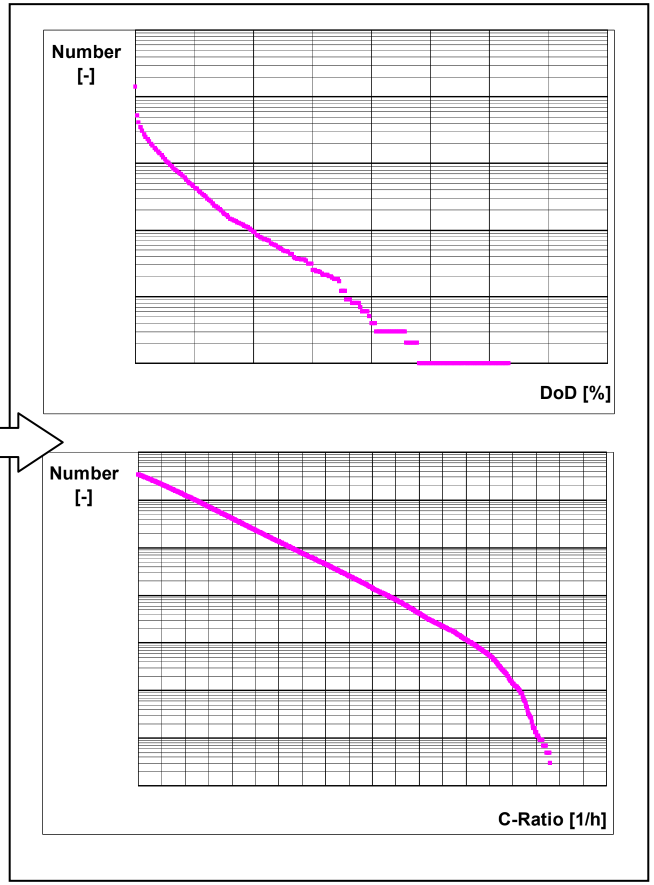
Examination of load profile



Frequency data



Transmission Code



Statistic analyses

⇨ Operation at provision of primary control power demands for detailed comprehension of ageing procedures

Source: Science-to-Business Center Eco[2] (February 2011)

Tasks and challenges resulting from the size of the battery storage system

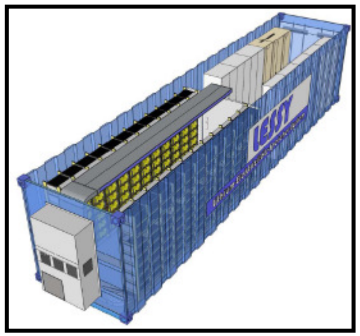
Main project tasks

- Availability / reliability
- Battery management system (BMS)
- Battery architecture
- Safety concept
- Grid connection
- Power electronics – adjustment of existing technologies
- Examination of cell deterioration and optimized layout for “real world conditions”
- Charging time velocity and dynamics of battery storage system

some cells

100 cells

5,000 cells

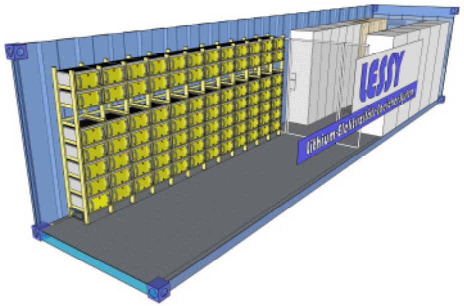


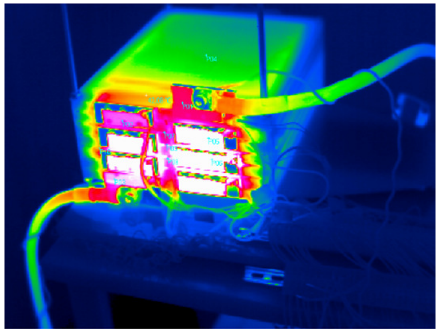
Source: Science-to-Business Center Eco² (February 2011)

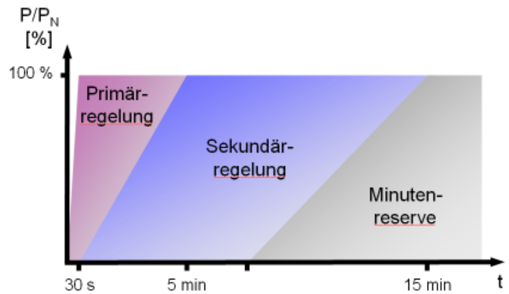
Besides only technical requirements also regulatory questions have to be solved

Development focus

- Optimization of low and part load operation
- SoC-/SoH-control, balancing between cells, blocks, strings
- Thermal management (especially at high power over longer time)
- Development business models
- Adjust and create formalities and conditions for provision of ancillary services
- Alternative applications ⇔ requirements





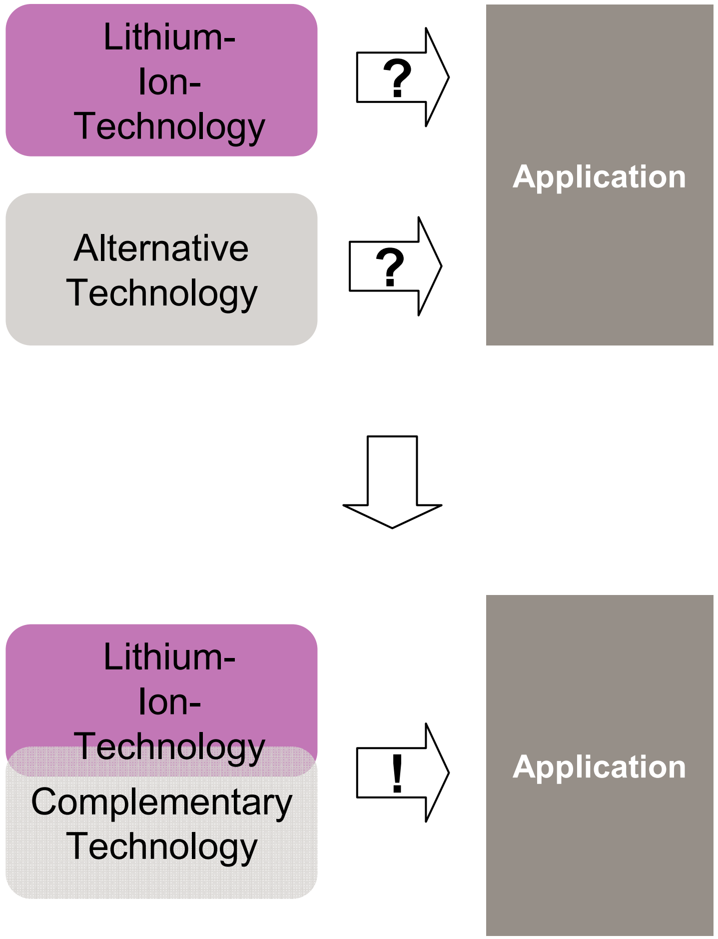


SoC: State of Charge
SoH: State of Health
Source: Science-to-Business Center Eco² (February 2011)

Complementary technologies must be understood and combined to system solutions

Alternative and complementary technologies

- Lead acid / gel batteries
- Sodium sulfur batteries
- Redox-Flow-Batteries
- NiMH-Batteries
- Supercaps
- Fly wheel
- High Power Lithium-Ion-Batteries
- Hydrogen
- Compressed air energy storage
- ...



Source: Science-to-Business Center Eco² (February 2011)

Mobile and stationary storages can provide a contribution to Smart Grid

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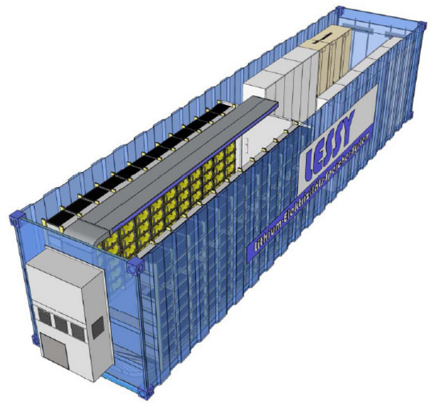
Preconditions and measures

Mobile

- Provision of charging infrastructure
- Grid integration of available EV
- Setup of ICT structures
- Development of V2G concepts

Stationary

- Integration of stationary storages
- Adopt market requirements
- Development of storage solutions

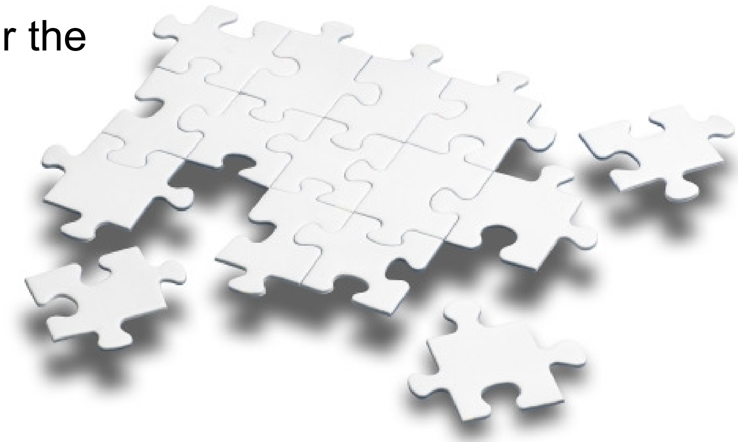


ICT : Information-Communication-Technologies
EV : Electrical vehicles
V2G : Vehicle to Grid
Source: Science-to-Business Center Eco² (February 2011)

Lithium-Ion-Technology as driver of E-mobility and stationary applications

Conclusions

- Lithium-Ion-Technology provides due to its characteristics acceptable **ranges with EV**
- **Mobile applications** establish **basis** for break through of storage applications
- Mass market accounts for **reduction of cell prices**
- **Stationary storages** will already provide at short notice **ancillary services** and a contribution to the integration of renewable energies
- **Mobile and stationary storages** will be needed for the realization of **decentralized, intelligent networks**



Source: Science-to-Business Center Eco^2 (February 2011)

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