LCA of Li-Ion Batteries for electric mobility

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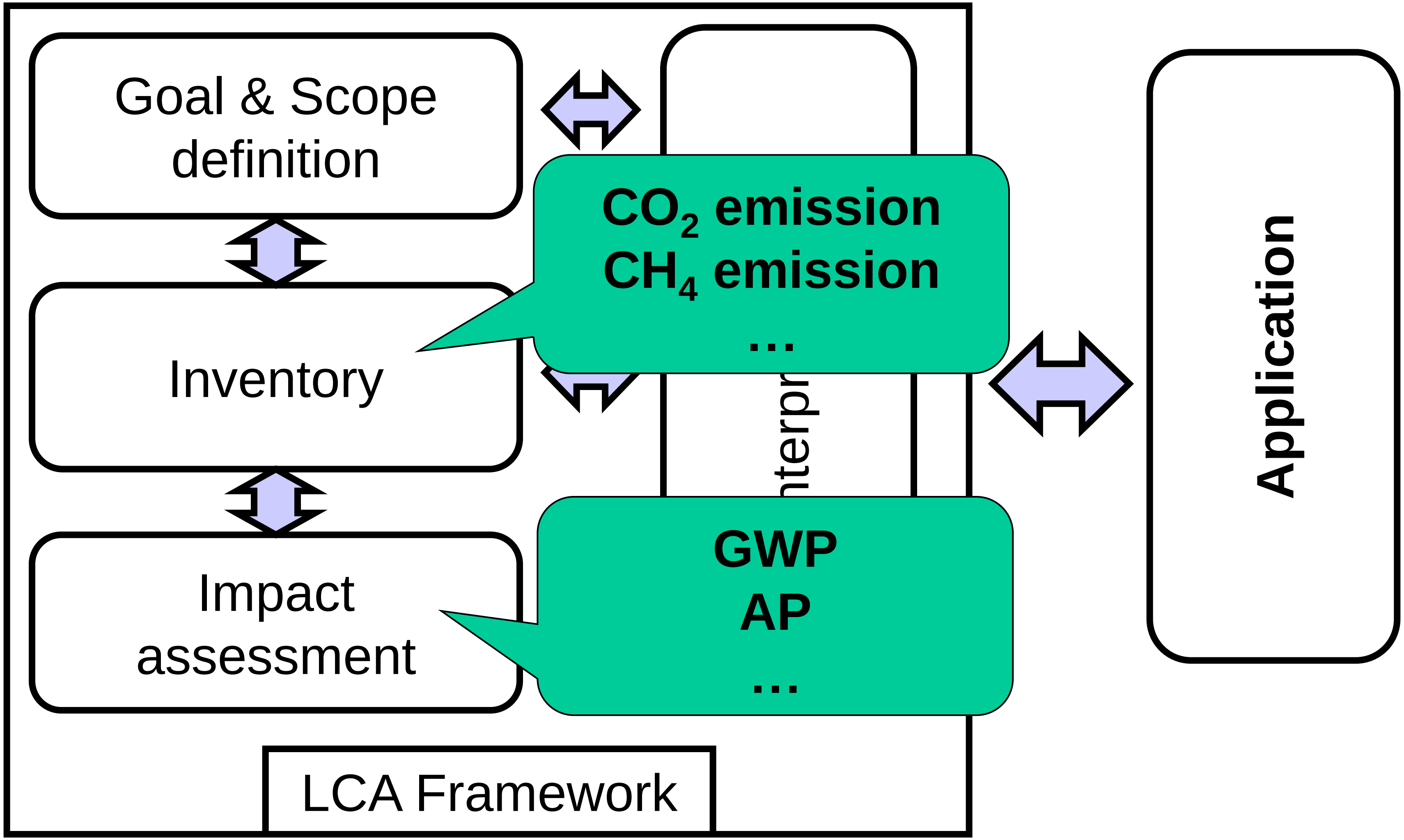
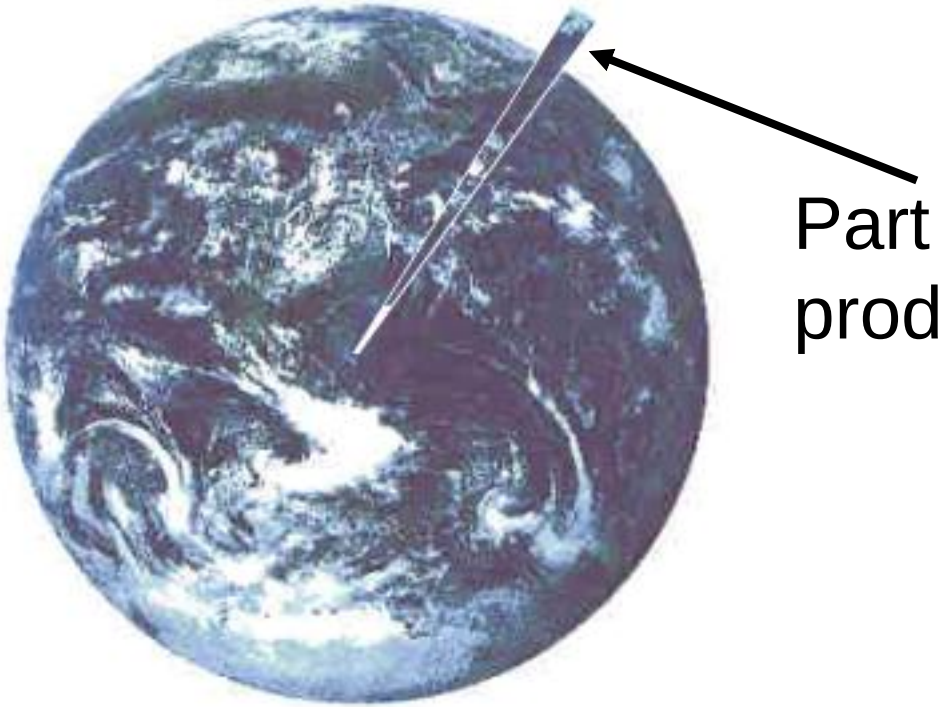
Outline

- What is LCA?
- Life Cycle of a battery
- Production of a battery / cell: Life cycle model
- LCA results of battery production
- Use of batteries in cars: Life cycle model
- LCA results of electric driving
- Li Resource: scarce?



Source: ISO 14'040 (2006)

- LCA attributes responsibility for the state of the world to a functional unit of a product system



Part of state due to production of 1 t lithium

→ for identifying contributions to the overall burdens of products in their life cycle.

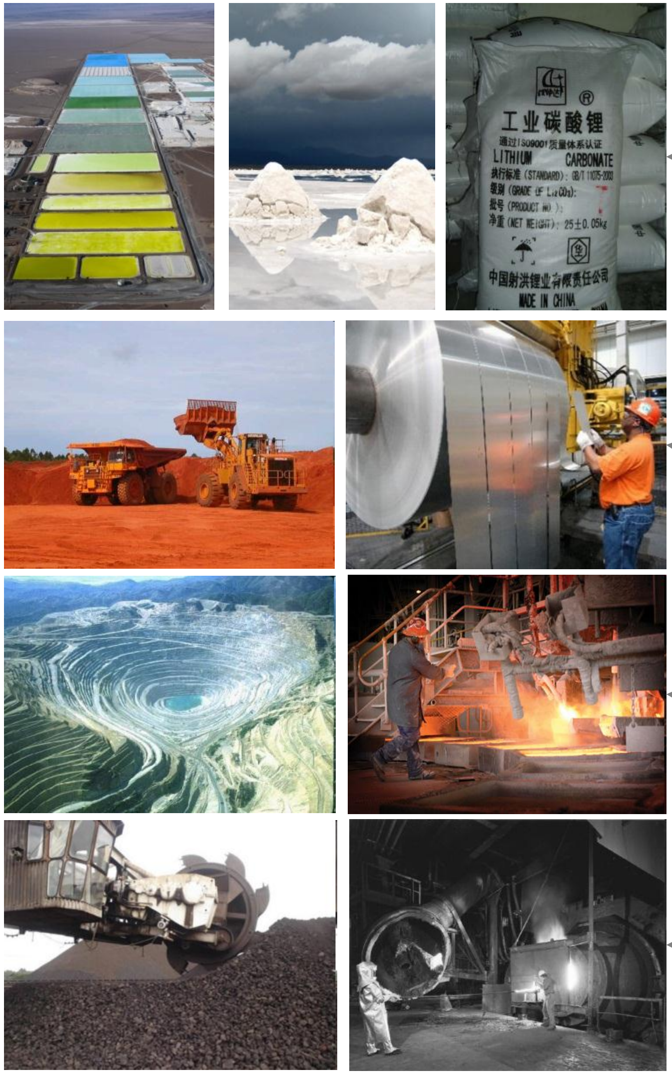
Life Cycle of a Li-Ion battery

Li

Al

Cu

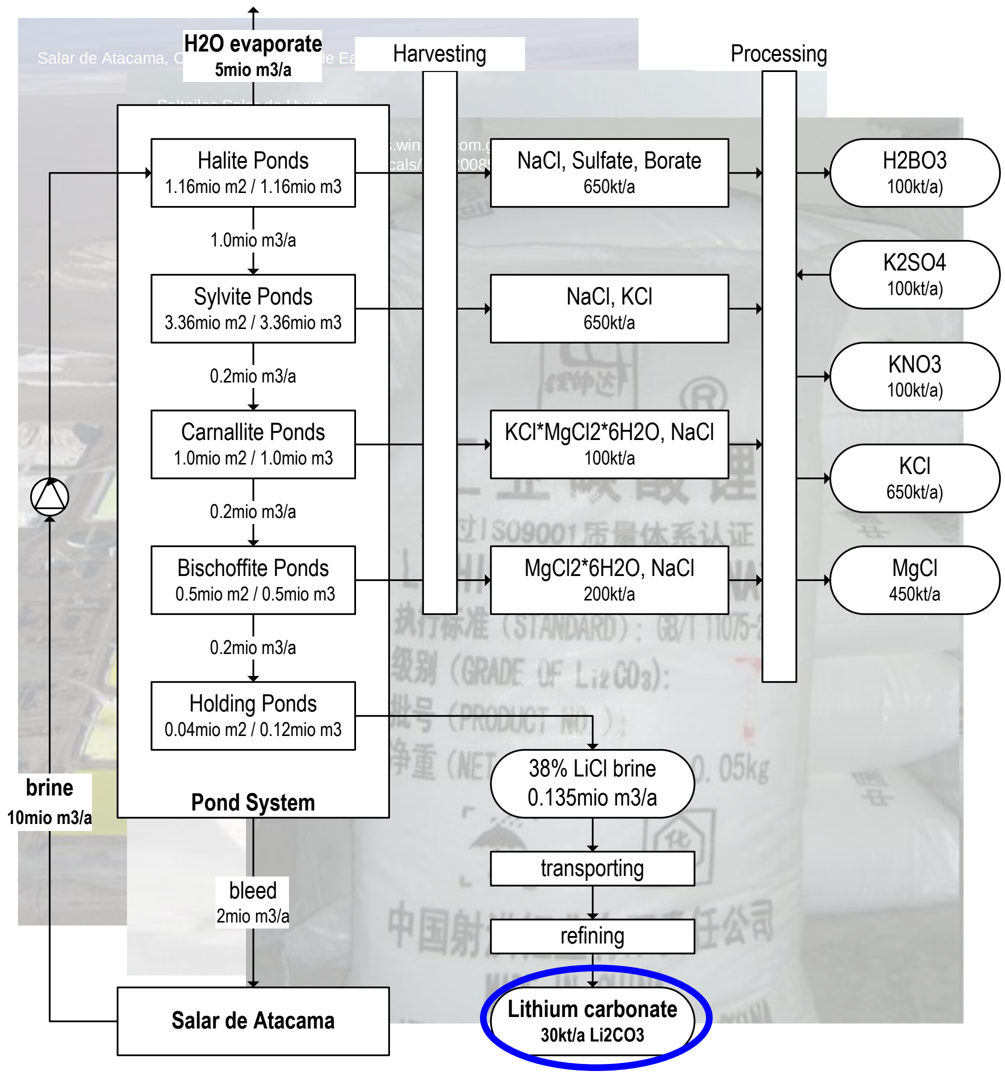
Fe



Recycling:

- Recycling today typically in Cu-smelter
- Cu, Mn, Co, Ni , Fe are recycled
- Al, Li, Graphite, and electrolyte are oxidised and lost in the process
- Technologies to regain Al and Li will be feasible if more Li-batteries will be available for recycling

Lithium: Properties and production



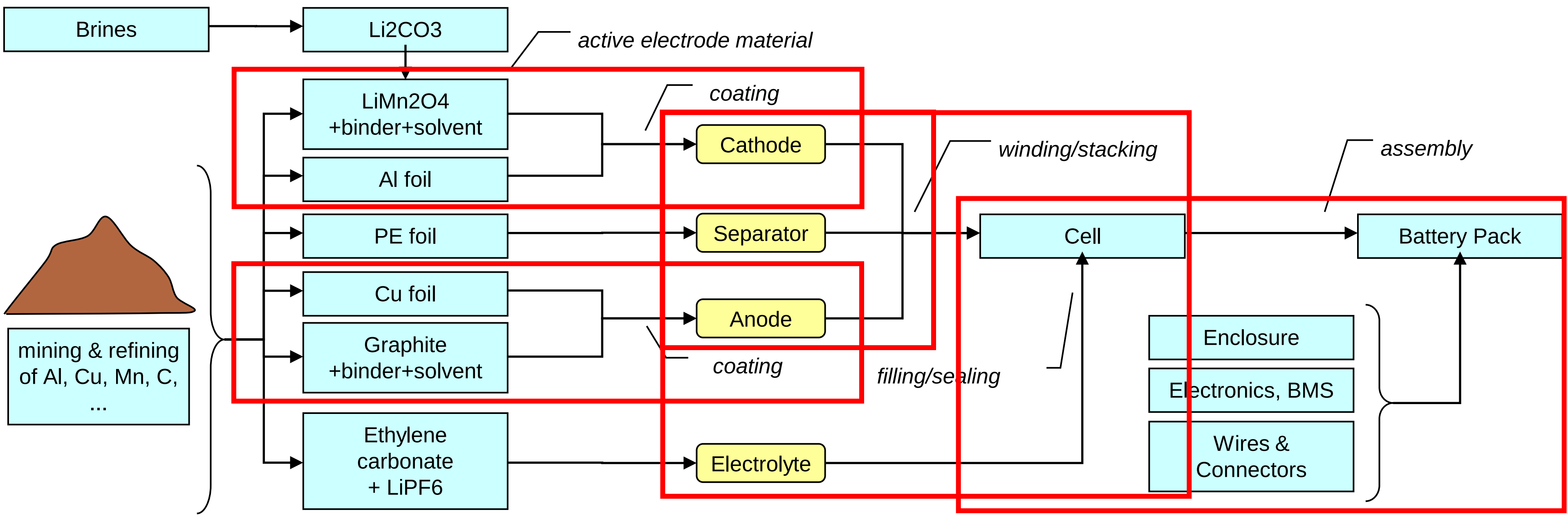
Extraction of lithium carbonate from Atacama (CL), one of the most important worldwide Li2CO3 producers
Compilation of numbers and graphics: Empa

Properties

- Lightest metal (density 0.543 kg/l)
- Highest electrochemical potential
- Not toxic (used as medicine)
- Not scarce (e.g. more abundant than Cu, 0.17 ppm in sea water)
- Highly reactive in metallic form (burns!)

Production

- Mainly won from salt lakes in the Andes (Chile, Bolivia) or in China (Tibet)
- Mainly solar energy used for production
- Refined to Lithium carbonate (Li_2CO_3) near the saline
- Co-production with many other salts, mainly used as fertilizers



- Cu foil is coated with graphite → anode
- Al foil is coated with Li Mn2O2 → cathode
- Anode and cathode are stacked (separated by ion-permeable plastic foil) and folded
- The Stack is packed in a bag which is filled with electrolyte (Li-salt solution) and sealed → cell
- Many cells are packed in an enclosure and electrically connected to a battery management system (BMS) → battery

graphics: Empa

Li-Ion battery cell (Mn_2O_4)

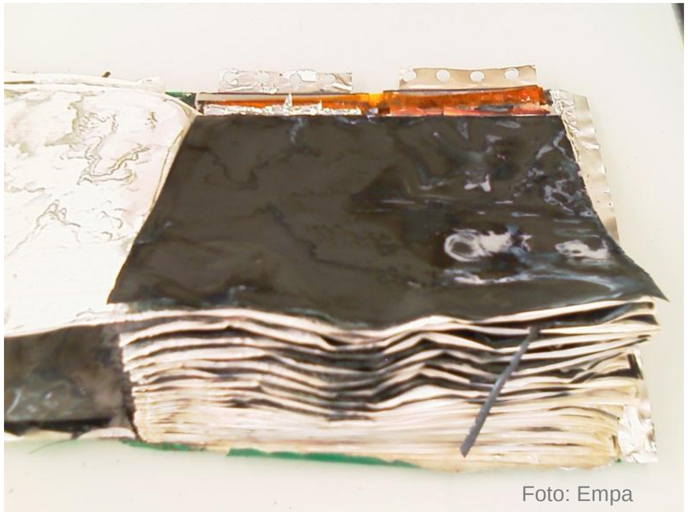


Foto: Empa

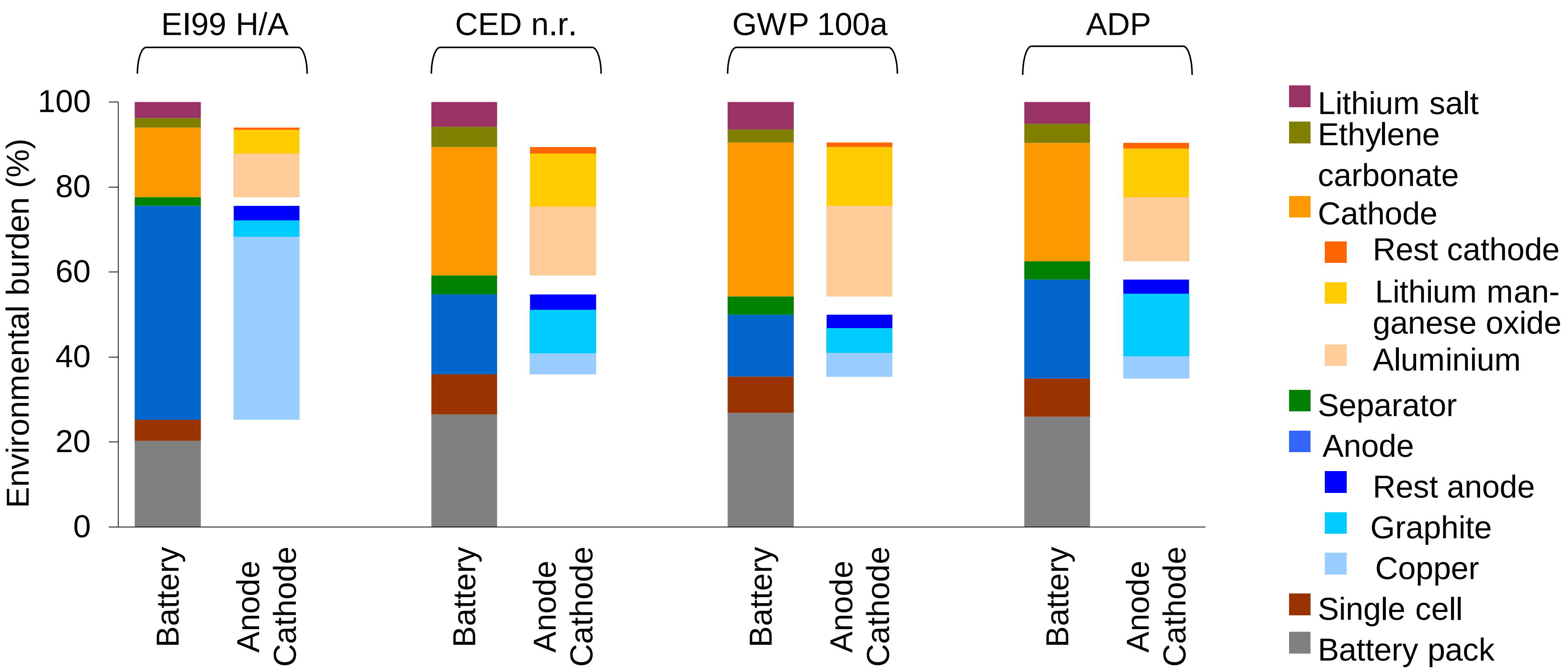

Foto: Empa

Components:

- Only about 1% of a Li-Ion battery is Li (5% Li_2CO_3) i.e. 0.08 kg Li per kWh energy content
- about 40% of a cell are Al (~23%) and Cu (~13%) (suporting film and conductor)
- about 40% of a cell is the active material (cathode: LiMn2O4 ~24%, anode: Graphite ~16%)
- about 20% is the elecrolyte (lithium hexafluorophosphate LiPF6, 1M solution in ethylene carbonate)

Data: measurement Empa

Results: Battery



- Anode and cathode important (50-80%)
- Cu foil of anode up to 43%
- Battery pack (steel case , BMS and wiring) not negligible (20-30%)
- Lithium salts (in cathode and electrolyte) contribute only 10-20%

Car production

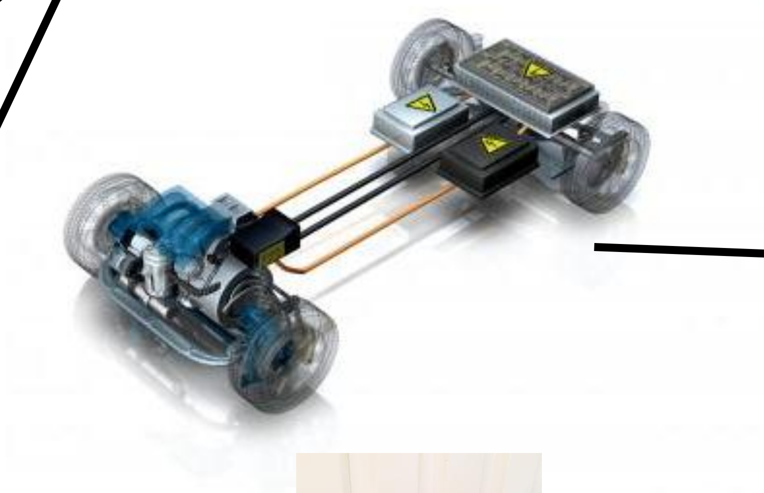
ICE Vehicle

Glider

Body and Frame,
Axle, Brakes, Wheels,
Bumpers, Cockpit,
A/C System,
Seats, Doors, Lights
Entertainment etc.

Drivetrain

Engine, Gearbox,
Cooling System,
Fuel System,
Starting System,
Exhaust System, Lubrication
etc.



Battery Vehicle

Glider

Body and Frame,
Axle, Brakes, Wheels,
Bumpers, Cockpit,
A/C System,
Seats, Doors, Lights
Entertainment etc.

Drivetrain

El. Motor, Gearbox,
Controller, Charger, Cables,
Cooling System etc.

Battery

Li-Ion battery 300 kg

Car maintenance / use

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Use ICE car

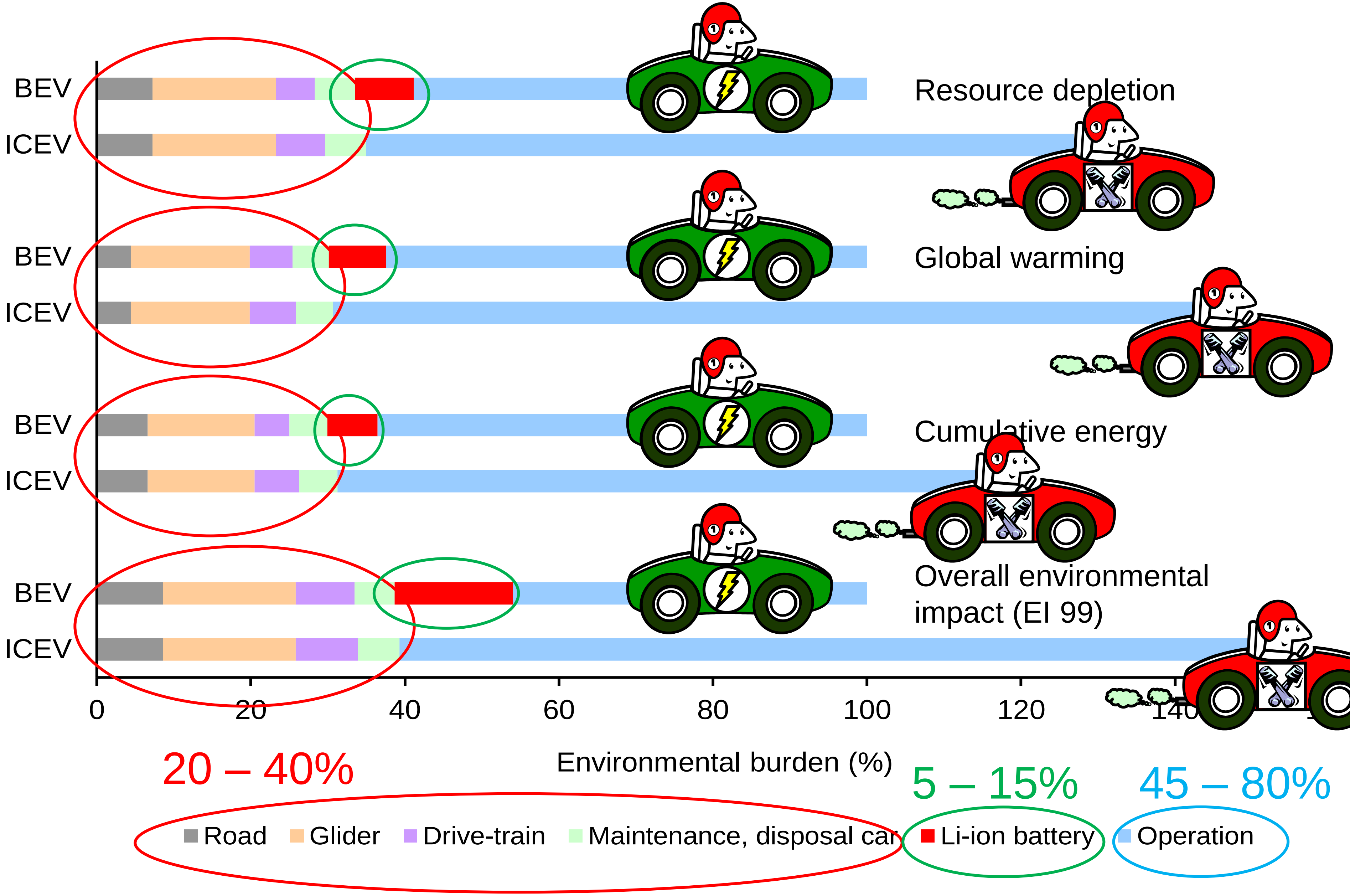
- 160'000 km
- Fuel: petrol
- NEDC consumption: 5.2 l/100 km
- 0.9 l/100 km fuel consumption for air conditioning, light,…
- 0.14 kg CO_2/100 km (direct emission)

Use electric car

- 160'000 km
- Fuel: UCTE power
- NEDC consumption 14.1 kWh/100 km (80% overall efficiency)
- 2.9 kWh/100 km power consumption for heating, air conditioning, light,…
- 90% reduced brake emissions because of recuperation

Maintenance (both)

- Materials for replaced components (e.g. tyres, clutch, brake pads,…)
- Replaced fluids (incl. disposal) (e.g. oil, cooling water,…)
- ICE car only: Replacement of Pb-Battery
- Replacement of LI-Ion Battery of electric car is considered in scenario for prolonged life (240'000 km)


BEV
ICEV
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BEV
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Resource depletion
Global warming
Cumulative energy
Overall environmental impact (EI 99)
0
20
40
60
80
100
120
140
Environmental burden (%)
20 – 40%
5 – 15%
45 – 80%
Road
Glider
Drive-train
Maintenance, disposal car
Li-ion battery
Operation

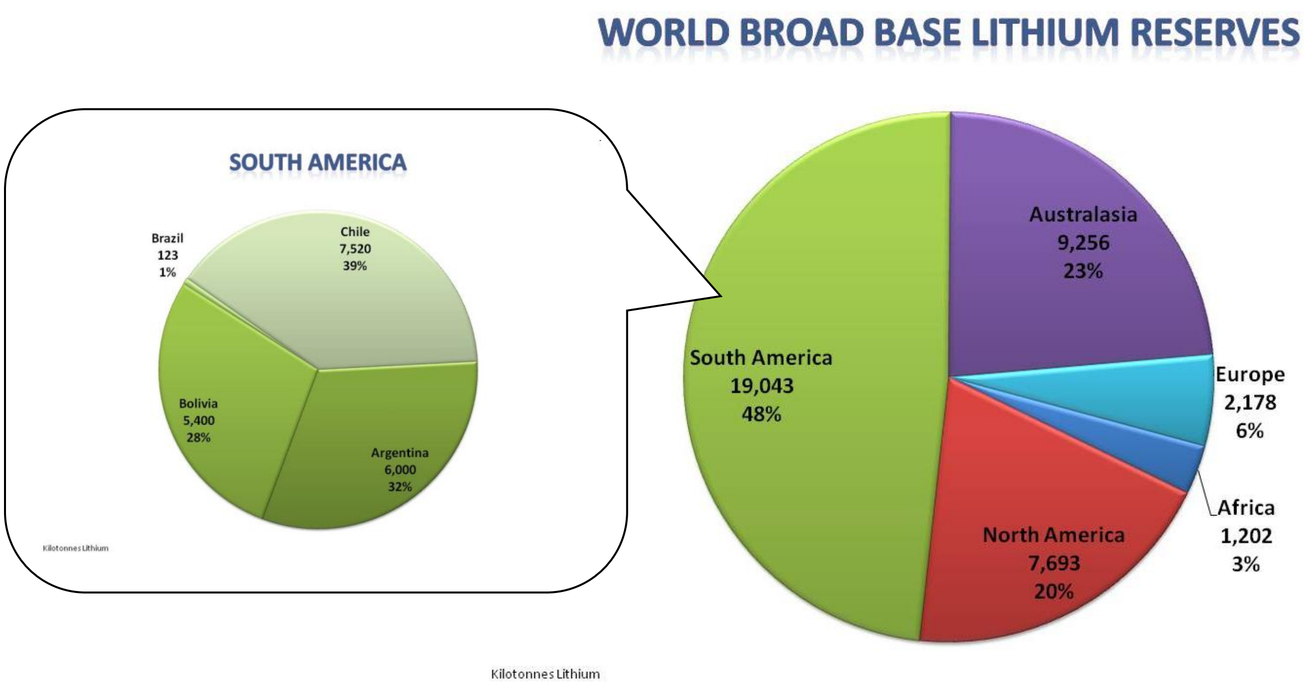
Scarcity of Lithium

30 kWh battery per vehicle -> 6 kg Li (Nissan Leaf: 24kWh battery -> 4 kg Li)

Today:	900 m vehicles x 6 kg	**5.4 m t Li**
Far future:	4 bn vehicles x 6 kg	**24 m t Li**

Li Production 2008: 27’000 t/a (source: USGS) (enough for 5.5 m vehicles/a)

Reserve base: 11 m t (source: USGS) 39.37 m t (Int. Lithium Alliance)



graphics: www.lithiumalliance.org

Source and collaborators

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Contribution of Li-Ion Batteries to the Environmental Impact of Electric Vehicles

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Battery-powered electric cars (BEVs) play a key role in future mobility scenarios. However, little is known about the environmental impacts of the production, use and disposal of the lithium ion (Li-ion) battery. This makes it difficult to compare

sodium–nickel–chloride (ZEBRA) batteries. New electric cars typically use lithium ion (Li-ion) batteries. Major reasons are the favorable material characteristics of lithium: it is the lightest of all metals and offers the greatest electrochemical potential, which results in a high power and energy density (*2*). Additionally, extensive experiences gained in the Information and Communication Technology (ICT) industry have led to safe, long-lasting, and affordable products. The Li-ion battery requires little maintenance, an advantage that most other battery chemistries cannot claim. There is no memory effect, little self-discharge, and no scheduled cycling is required to prolong the battery's life. Li-ion battery chemistries and cell construction are rapidly developing and changing: For instance, the commonly used, but expensive, cobalt is being replaced by chemistries using iron phosphate or manganese (*3*). Another development is the increase in the content of active material by, for example, using bipolar electrodes (*4*).

Commercial Li-ion cells are currently using various types of cathode materials (*5*); one of them is lithium manganese oxide ($LiMn_2O_4$). Spinel type $LiMn_2O_4$ is attractive for BEVs in many aspects, such as low cost, rather easy production process (*3*) and, last but not least, thermal safety (*6*). In addition, manganese is abundant in nature (*7*) and well

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