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?
What is Life Cycle Assessment

LCA Framework

Goal & Scope definition

Inventory

Impact assessment

Source: ISO 14’040 (2006)

CO₂ emission
CH₄ emission

... 

GWP
AP

... 

Application
What does Life Cycle Assessment

- 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

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

**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

Extraction of lithium carbonate from Atacama (CL), one of the most important worldwide $Li_2CO_3$ producers
Compilation of numbers and graphics: Empa
Cu foil is coated with graphite → anode

Al foil is coated with LiMn2O4 → 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
Li-ion battery cell (Mn$_2$O$_4$)

Components:

- Only about 1% of a Li-ion battery is Li (5% Li$_2$CO$_3$) i.e. 0.08 kg Li per kWh energy content
- about 40% of a cell are Al (~23%) and Cu (~13%) (supporting film and conductor)
- about 40% of a cell is the active material (cathode: LiMn2O4 ~24%, anode: Graphite ~16%)
- about 20% is the electrolyte (lithium hexafluorophosphate LiPF6, 1M solution in ethylene carbonate)
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%
LCA of Li-Ion battery for electric mobility

Car production

ICE Vehicle

Glider

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

Drivetrain


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

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 CO₂/100 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)
Results: Mobility

- Resource depletion
- Global warming
- Cumulative energy
- Overall environmental impact (EI 99)

BEV
ICEV

Environmental burden (%)
0 20 40 60 80 100 120 140

20 – 40%
5 – 15%
45 – 80%

LCA of Li-ion battery for electric mobility
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)

WORLD BROAD BASE LITHIUM RESERVES
Contribution of Li-Ion Batteries to the Environmental Impact of Electric Vehicles

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Received December 9, 2009. Revised manuscript received June 16, 2010. Accepted June 24, 2010.

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 (LiMn2O4). Spinel type LiMn2O4 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

DOI: 10.1021/es903729a