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

Cannes 2010; Batteries 2010 Conference

1. **Devil and Angel**
2. **Vehicle Concepts**
3. **Scientific publication on Life Cycle Assessment (LCA) of a Li-ion battery**

5 g Gold

Source: Seppo Lajonnen, Module KONSUM: Background Information, Fig. 16

2000 kg ecological rucksack

D. Notter, M. Gauch, R. Widmer, P. Wäger, A. Stamp, R. Zah, H.J. Althaus

marcel.gauch@empa.ch

TSL Technology and Society Lab @ EMPA

Schweizerische Materialprüfungs- und Forschungsanstalt

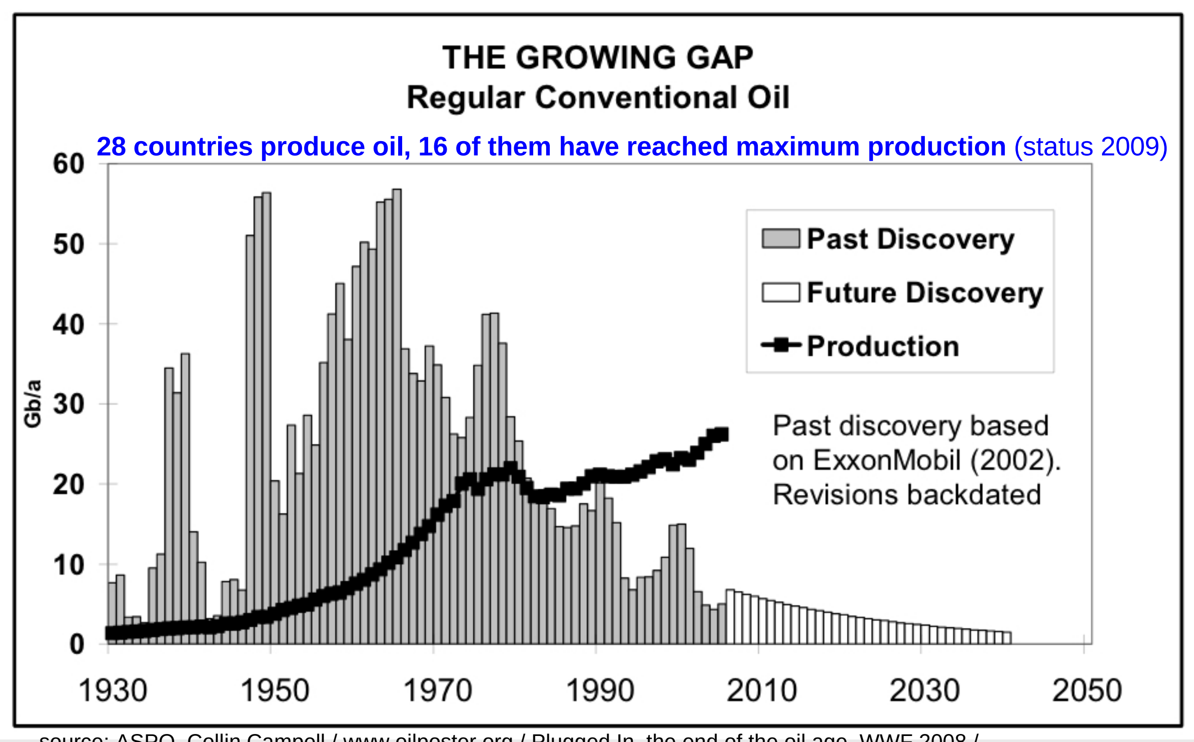
Swiss Federal Laboratories for Materials Science and Technology

EMPA

Materials Science & Technology

Mobility: The devil and the angel

- **Global warming** -> Reduction of CO_2-Emissions
  IEA: „Limiting temperature rise to 2°C requires a low-carbon energy revolution"
- **Peak Oil**, limited availability of fossil resources -> price increase, fight for oil
  IEA: „Let's leave oil before it leaves us"
- Transition **from fossil to non-fossil age**
  -> Live with **energy flows** instead of using **energy reserves**
- **BUT: Peak Lithium? Peak Neodym? Electricity scarcity? Emotions? …**



source: ASPO, Collin Campell / www.oilposter.org / Plugged In, the end of the oil age, WWF 2008 /

What you buy...

graphics: Internet

... is not what you get!

Foto: Delhi India

-> Prospective studies about future impacts are needed

-> Life Cycle Assessment (LCA) is a tool which helps to analyse these impacts

Publication on batteries and their impacts, Aug. 2010

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DOMINIC A. NOTTER,* MARCEL GAUCH, ROLF WIDMER, PATRICK WÄGER, ANNA STAMP, RAINER ZAH, AND HANS-JÖRG ALTHAUS

Technology and Society Laboratory, Swiss Federal Laboratories for Materials Science and Technology (Empa), Ueberlandstrasse 129, 8600 Duebendorf, Switzerland

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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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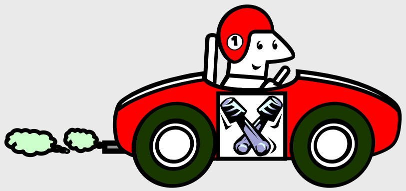
Vehicle concepts

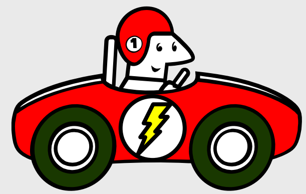
Fuels from fossil and biogenic sources



Internal combustion engine (ICE)

- Fossil fuels
  - natural gas
  - gasoline
  - diesel
- Biogas (Methane) from:
  - biowaste (CH)
- Bioethanol (Alcohol) from:
  - sugar cane (BR)
  - wood waste (CH)
- Biodiesel (Methylester) from:
  - palm oil (MY)

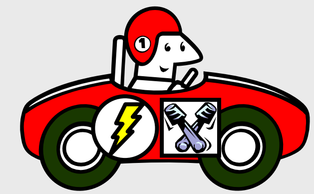
Electricity from different sources



Electric drive with battery (BEV)

- nuclear CH (28 g/kWh (plug))
- PV-Mix CH (74 g/kWh)
- plug-mix CH (134 g/kWh)
- modern NatGas combined cycle CHP plant (444 g/kWh (plug))
- plug-mix EU (UCTE, 593 g/kWh)
- coal power plant mix EU (1095 g/kWh (plug))

Mixed forms, hybrid drives



Hybrid (HEV) ‘Prius’

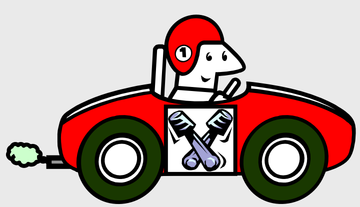
- gasoline

Plug-In Hybrid (PHEV) ‘Volt’

- plug-Mix CH (134 g/kWh)
- gasoline

Fuel Cell cars (FC)

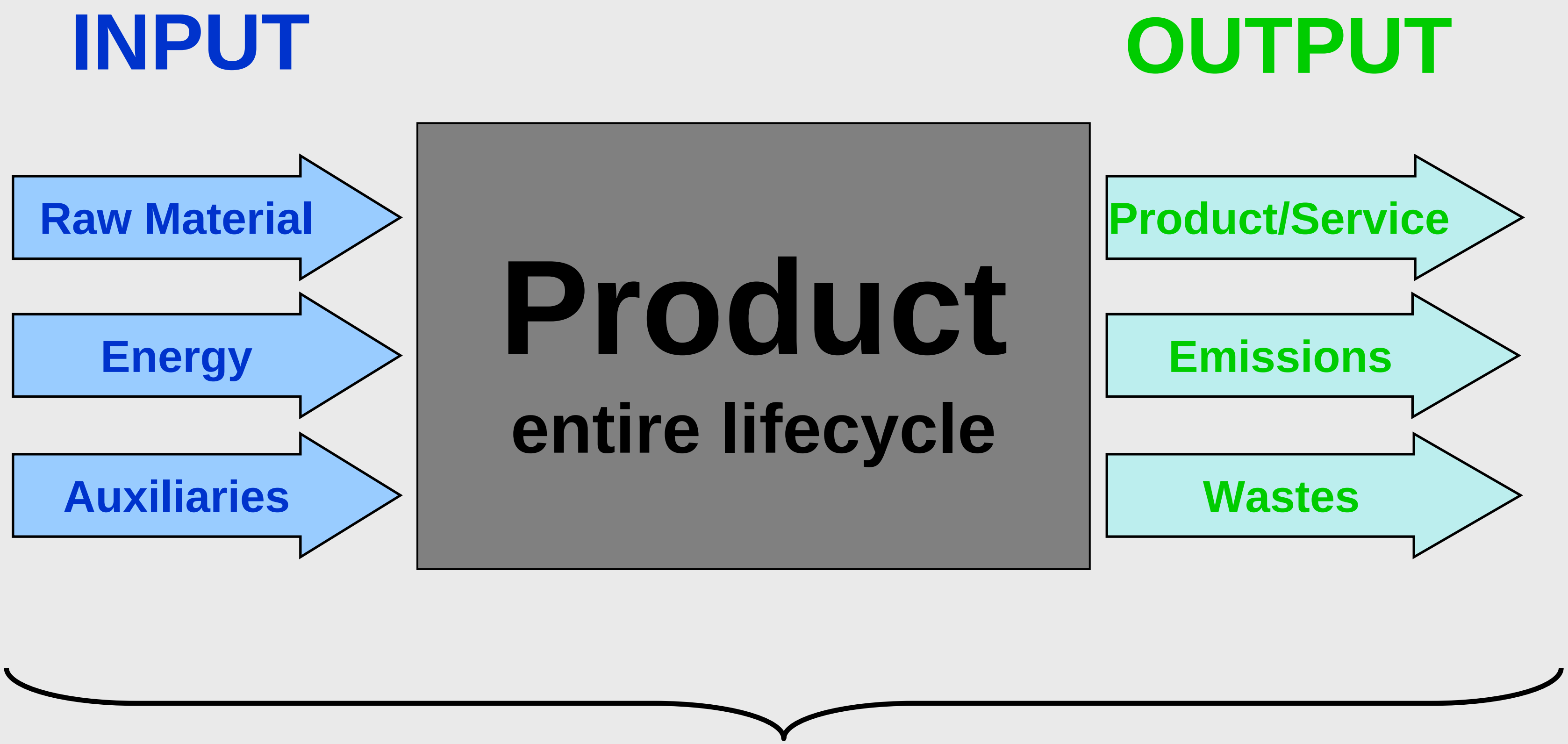
- hydrogen H_2



- Switch to other vehicle types, e.g. **public transport** or **2-wheelers**

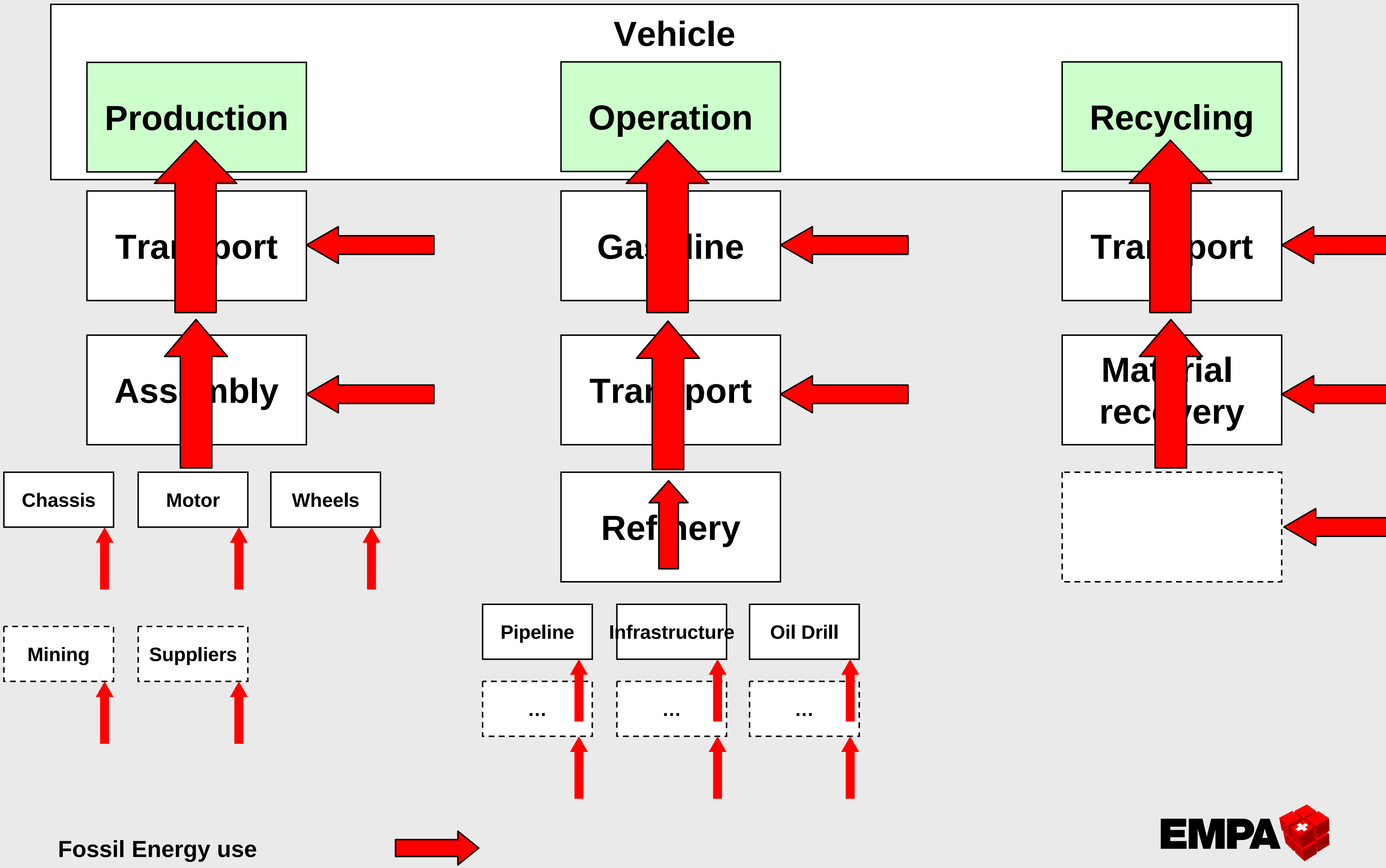
Research project eScooter
Supported by BFE and ASTRA.
Partners: Uni Bern / IKAÖ, Empa, Interface, Verkehrsplanung Schwegler, PSI

Life Cycle Assessment: The basic idea



& ecological assessment of flows

Vehicle – Lifecycle: Example Energy Consumption



Vehicle comparison

Car Production and Operation

Picture: VW, The Golf – Environmental Commendation Background Report, 2008

ICEV

6.1 l/100km
(5.2l/100km NEDC)

ICE Vehicle

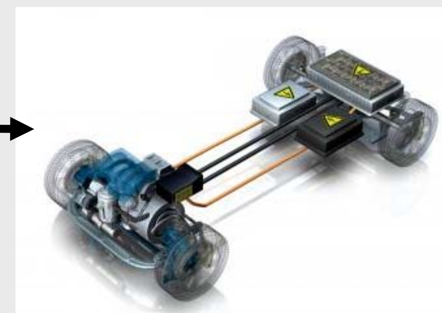
Glider

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.

Picture: VW 1.4T



Picture: Internet

Picture: Empa

BEV

17 kWh/100km
(14.1kWh/100km NEDC)

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

Life Cycle of a Li-Ion battery

Recycling:

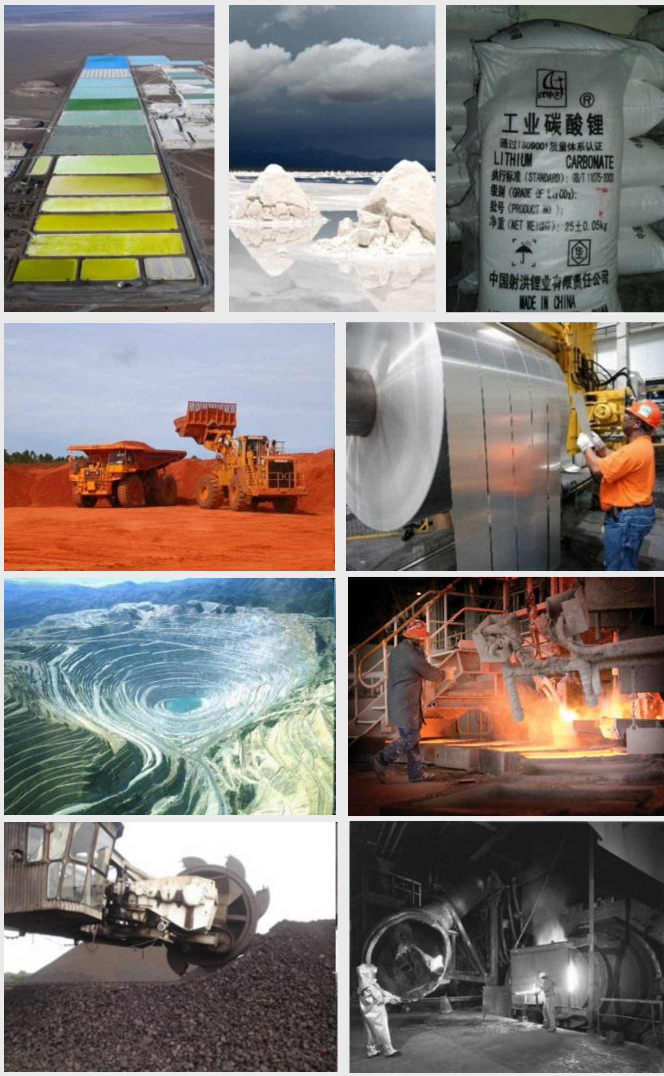
- Recycling today typically in Cu-smelter
- Cu, Mn, Co, Ni , Fe are recycled
- Al, Li, Graphite, and electrolyte are oxidised and lost in the process
- Technologies to regain Al and Li will be feasible if more Li-batteries will be available for recycling

Li

Al

Cu

Fe



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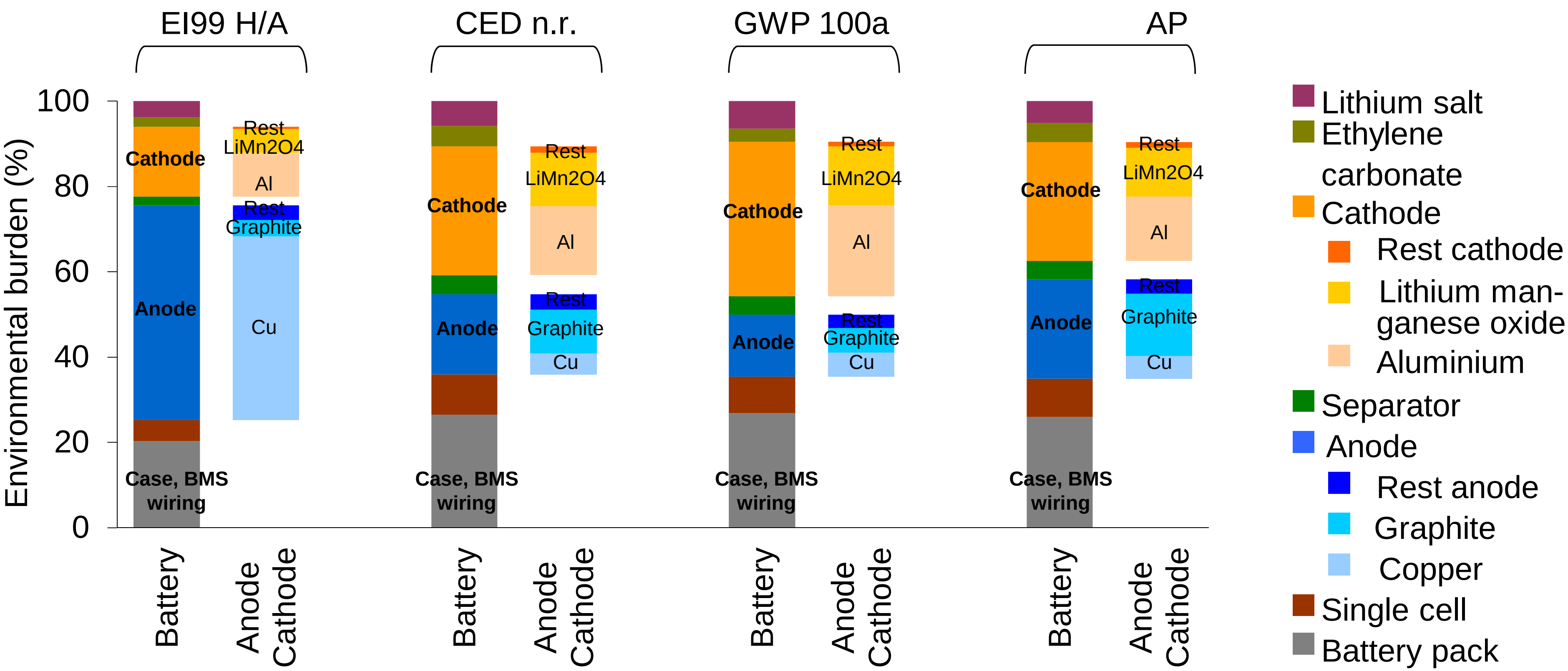
Results: Battery



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

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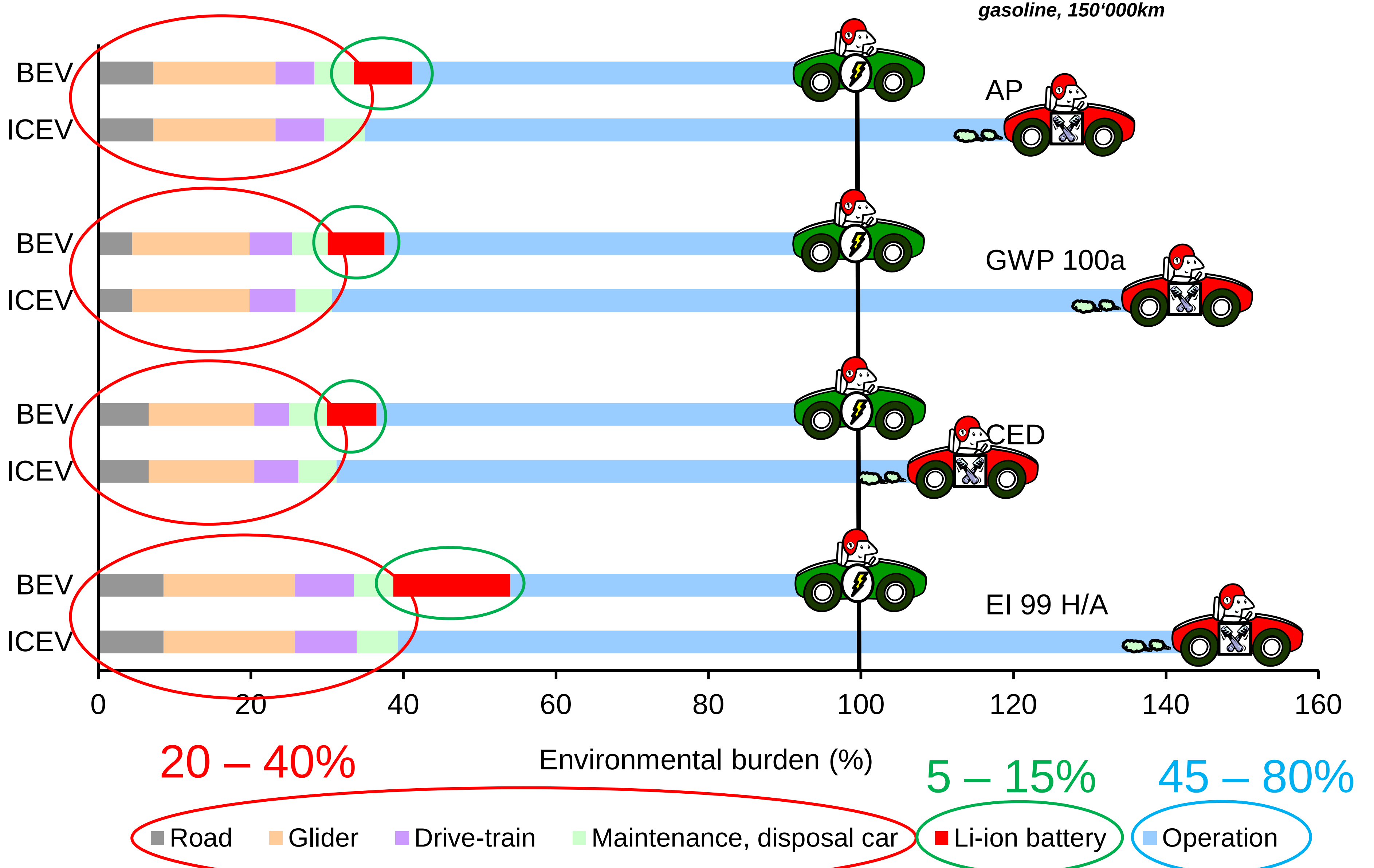
Results: Mobility over lifetime

BEV: ***17 kWh/100km (14.1kWh/100km NEDC)***
EU-mix, 150'000km

ICEV ***6.1 l/100km (5.2l/100km NEDC)***
gasoline, 150'000km



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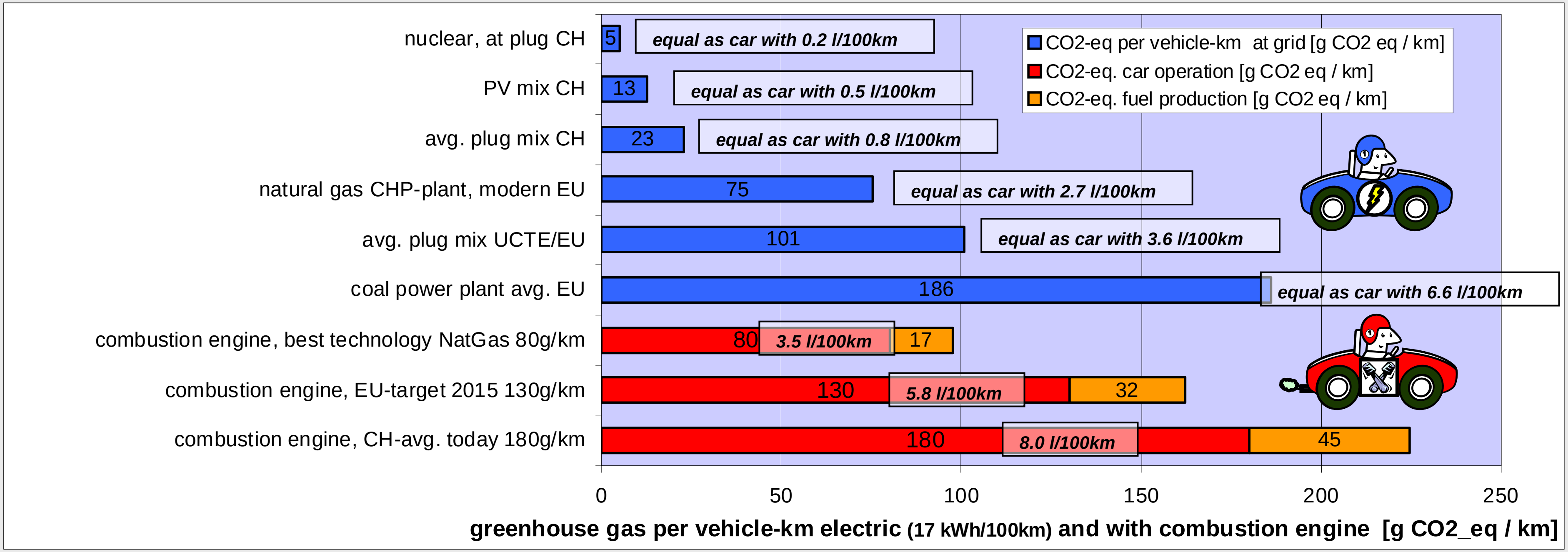
Operation: Electricity or Gasoline? Global warming [CO2-eq./km]

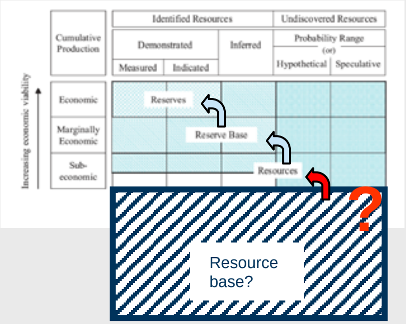
The type of electricity is key



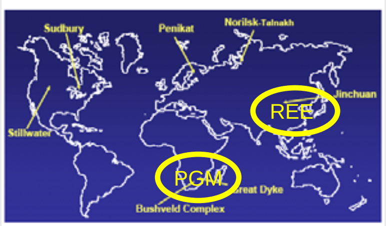
- Efficient conventional cars (approx. 130g/km car, 162 g/km total) can be cleaner than electric cars driven with ‘dirty’ electricity (coal power, 186g/km)
- The best vehicles actually on the market (Toyota Prius 2010, 89 g/km car, 108g/km total) drives about as clean as an electric car with the european electricity mix (101g/km)
- An electric car, driven with the CH mix, is about 7x cleaner (23g/km) than an efficient conventional car (130g/km car, 162g/km total)

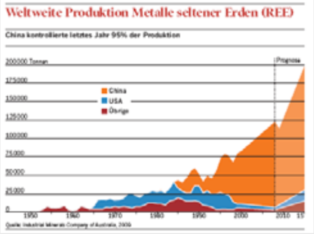
graphics: Empa, based on ecoinvent data

Five design considerations

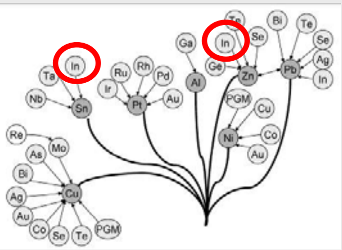


- **Reserves / Reserve Base (1/5)**
  - How much is available?
  - At what 'cost' in terms of USD and energy?

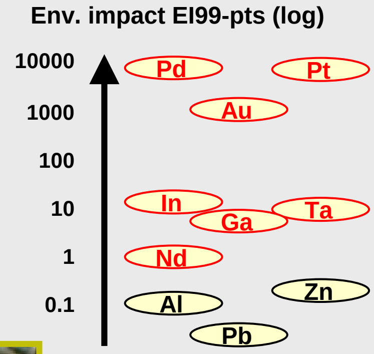




- **Geopolitical factors (2/5)**
  - > 95% of platinum group metals -> South Africa
  - > 95% of rare earth elements (Nd) -> China



- **Technological factors (3/5)**
  - Scarce metals are linked to commodity metals
  - Example: In to Zn/Sn, Ga to Al, Co to Cu/Ni



- **Ecological factors (4/5)**
  - Huge differences in environmental impact of different metals
  - low: Fe, Pb, Li ; high: platinum group metals

- **End of Life / Recycling (5/5)**
  - Is an EV to treat more like e-Waste or like an ICE car?
  - High recycling efficiencies are needed

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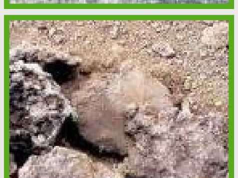
Recovery of precious metals from e-Waste, Umicore (Be)

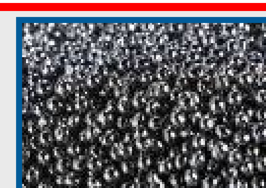
Fotos: umicore

1000kg Printed Wiring boards (PWB)
200g Gold

180.5g Gold
285kg base, precious und special metals



Recovery efficiency: >90%



Recovery of precious metals from e-Waste, India

1000kg Printed Wiring boards (PWB)
200g Gold

51g Gold

Recovery efficiency:

≈25%

Fotos: Empa

Conclusions:

- **EVs are ‚generally better' than ICEV.**
- **BUT: The Switch from ICEV to EVs will not save the planet**
  CO2-reducion is possible, but not to the required level.
  IEA: „Limiting temperature rise to 2°C requires a low-carbon energy revolution"
- **Other more efficient transport options besides cars must be considered**
  like public transport, 2-wheelers.
- **The production efforts for EVs must be reduced**
  Careful selection of materials, reasonable recycling options.
- **The transition from fossil to non-fossil electricity production is mandatory**
  IEA: „Let's leave oil before it leaves us"
- **With electricity from renewable sources,**
  EVs are ‚clearly better' than ICEV

Your questions are welcome…

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paper DOI: 10.1021/es903729a

Data now included in:

ecoinvent data v2.2

the most transparent LCI database today

ecoinvent Centre

Swiss Centre for Life Cycle Inventories

www.ecoinvent.org

Marcel Gauch
Technology and Society Lab @ Empa
Empa, Swiss Federal Laboratories for Materials Science and Technology
St. Gallen, Switzerland
marcel.gauch@empa.ch

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