Modeling the Feedback of Battery Raw Material Shortages on the Technological Development of Lithium-Ion-Batteries and the Diffusion of Alternative Automotive Drives

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Abstract: expected diffusion of alternative drives

Increasing energy prices due to limited availability of fossil fuels in combination with ambitious reduction targets of combustion gas emissions, particularly in urban areas, will force the diffusion of alternative drives such as hybrid and battery electric vehicles in the automotive market in near and midterm future. However, the increasing need of rechargeable batteries with high energy densities strongly affects the demand for specific battery raw materials like lithium and cobalt.

Introduction: alternative drive technologies and the need for lithium-ion-batteries

In this study, we present a system dynamics approach which combines a fleet model of the global automotive market with a material flow model of cobalt as a key battery raw material. This combined model enables the simulation of effects of increased battery demand on the cobalt market and the potential feedback of raw material shortages on the development of battery technology and the diffusion of alternative drives which once again affects the demand for cobalt. This modeling approach may serve as a tool for getting a better understanding of future raw material markets influenced by emerging technologies and the feedback of raw material availability on the technological development.

The following technologies are taken into account:

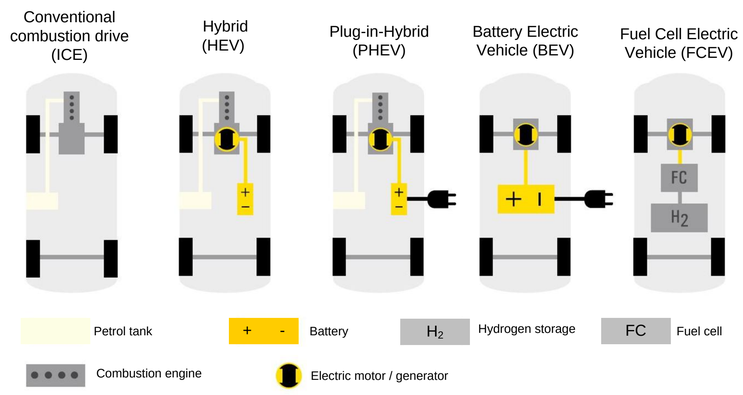


Figure 4: Considered technologies of the Global Mobility Model (GloMo)

- **Injection combustion engine (ICE):** Combustion engine for gasoline, diesel, compressed natural gas (CNG), liquefied petroleum gas (LPG) and bio fuels
- **Hybrid drive:** Hybrid technology recovers energy from every breaking process, which is stored in a battery and used for the electric drive.
- **Plug-in-hybrid drive (PHEV):** Also combines a combustion engine with an electric drive. In addition, it is possible to charge the battery.
- **Battery electric vehicles (BEV):** Electric drive that sources its energy from a large battery.
- **Fuel Cell:** The fuel cell transfers energy from hydrogen to electricity through a chemical reaction. Fuel cells are usually combined with electric drives.

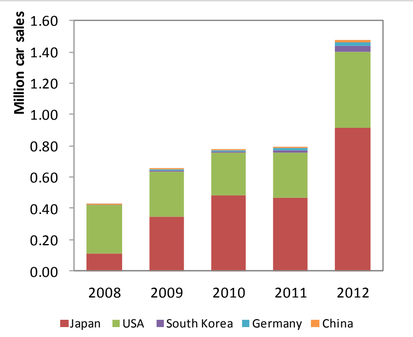


Figure 1: Absolute sales of vehicles with alternative power trains (dominated by hybrid technology) in key automotive markets

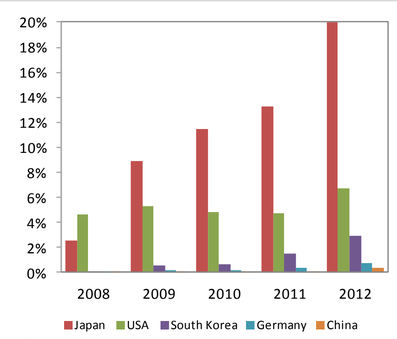


Figure 2: Relative market shares of alternative drives (dominated by hybrid technology) in key automotive markets

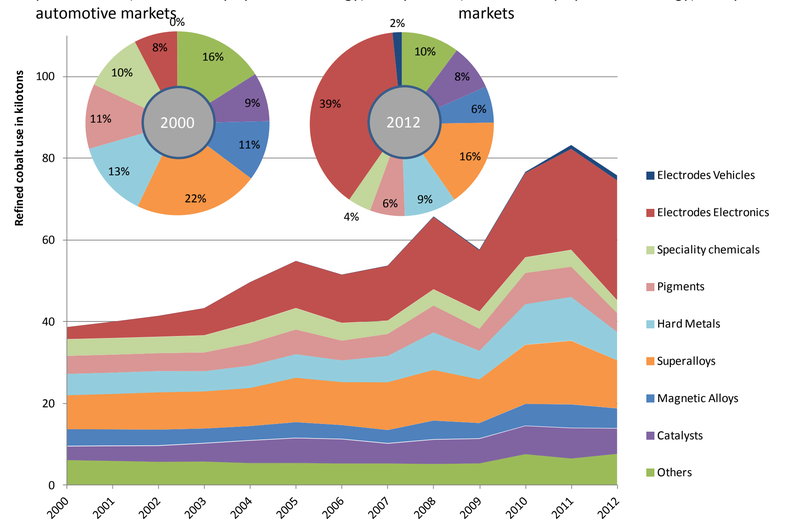


Figure 3: Cobalt market development in the previous decade: today, around 40% of global refined cobalt goes into batteryproduction of which batteries for electric vehicles currently play a minor role. Source: CDI (Porri 2013)

Model description and results: linking a global fleet model and a material flow model for cobalt as a key battery raw material

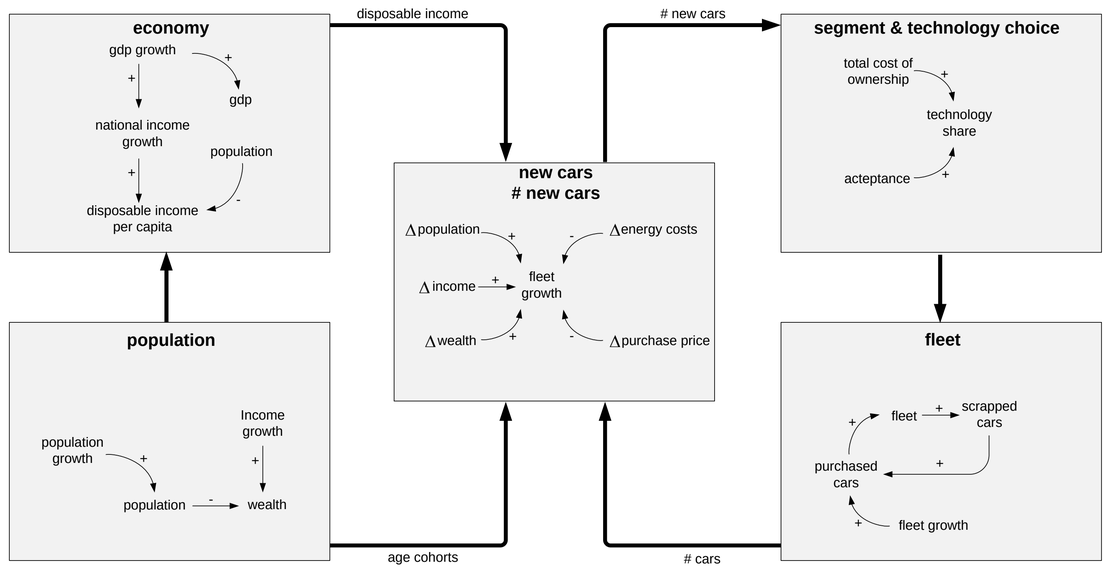
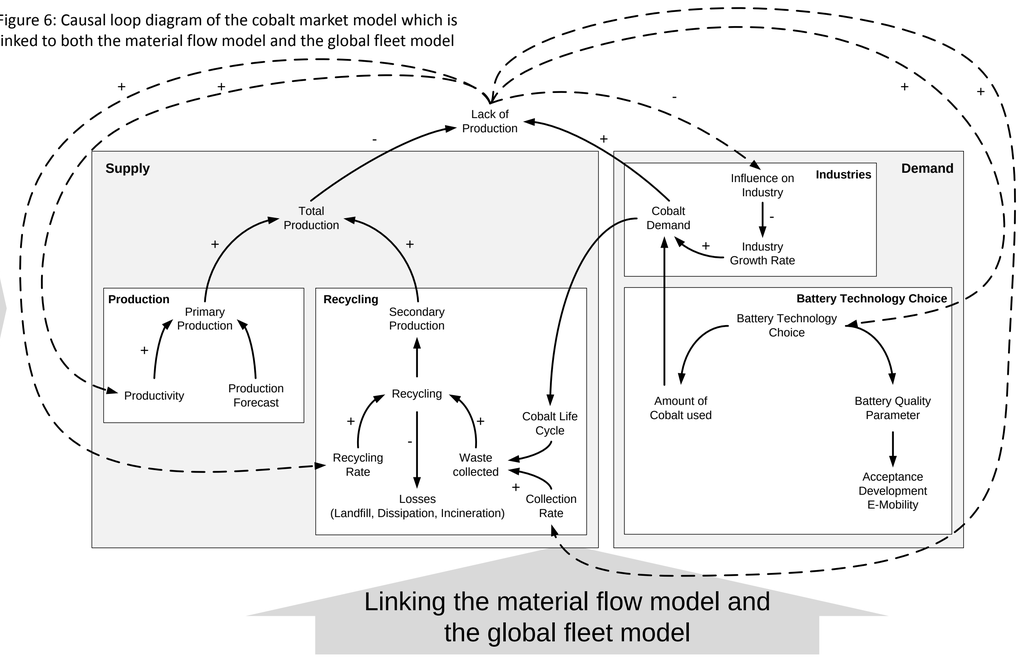


Figure 5: Structure of the global mobility model (GloMo)

Linking the material flow model and the global fleet model

Figure 6: Causal loop diagram of the cobalt market model which is linked to both the material flow model and the global fleet model



Linking the material flow model and the global fleet model

System boundary: global material flow model of cobalt

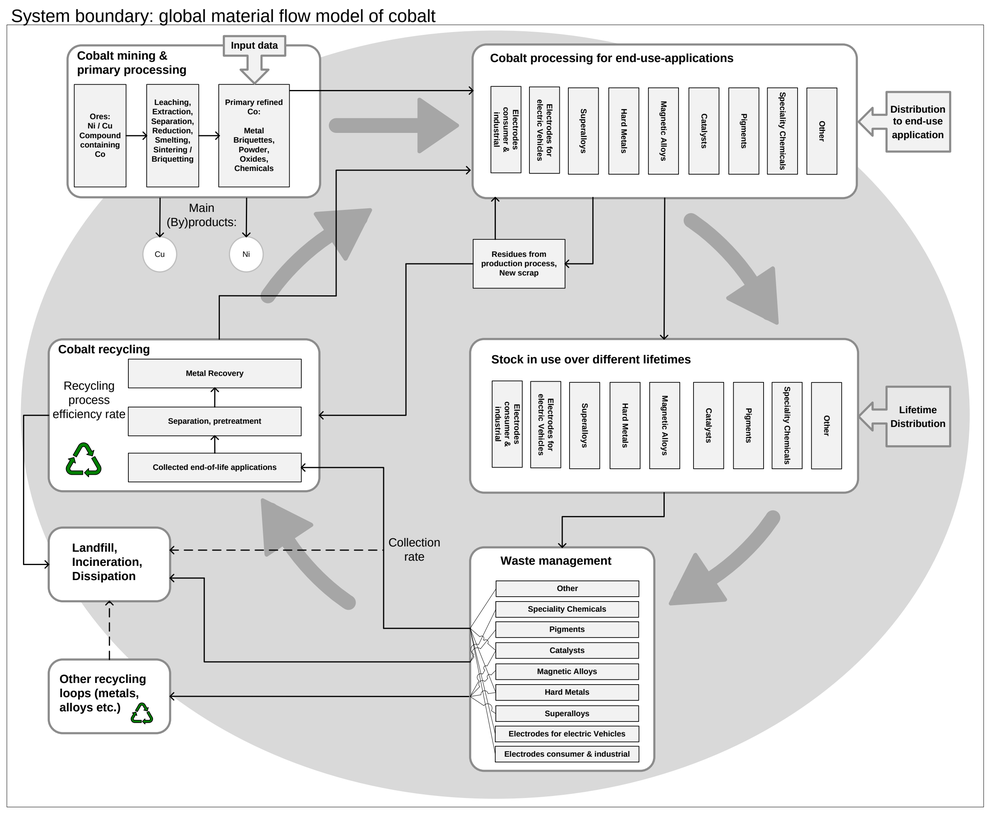


Figure 7: Dynamic material cycle of cobalt the way it was implemented into a system dynamics software

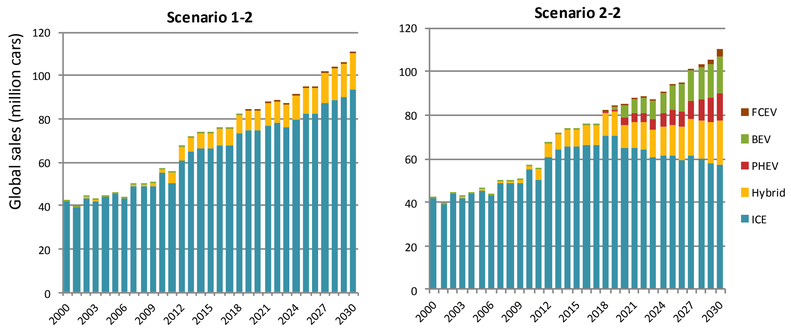


Figure 8: Diffusion of alternative drive technologies based on the GloMo scenario and influenced by a lack of cobalt based variation in the choice of battery technologies

Results & Findings:

- System Dynamics is a suitable approach for modeling both material flows and market dynamics
- Electro mobility diffusion will affect the cobalt market
- Alternative battery technologies with less or no cobalt will gain increasing importance for electric vehicles
- Hence, the affect of potential cobalt shortages on the diffusion of alternative drives is expected to be moderate.

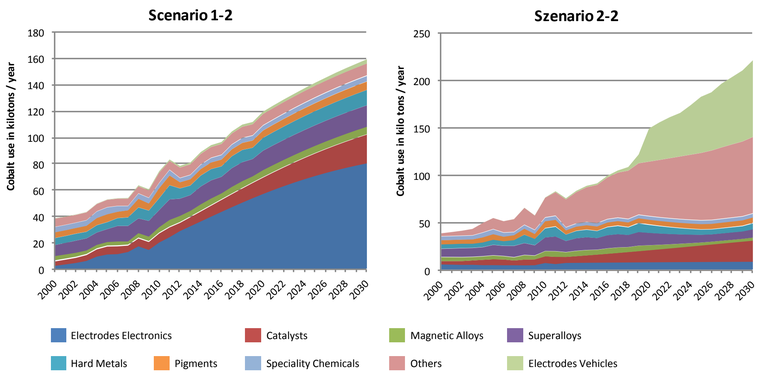


Figure 9: Development of cobalt demand of major industries in case of a pessimistic (Scenario 1-2) and a strong diffusion of alternative drive technologies (Scenario 2-2)

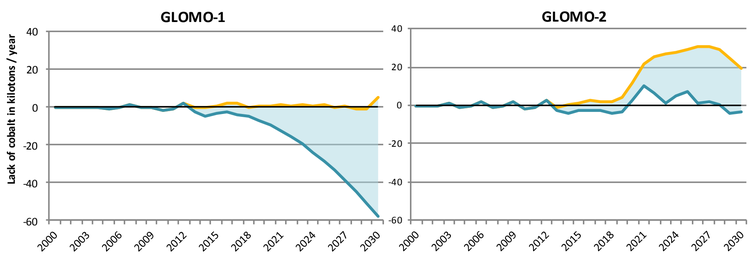


Figure 10: Maximum (orange) and minimum (blue) expected deviation of cobalt demand and supply depending on the diffusion of alternative drive technologies

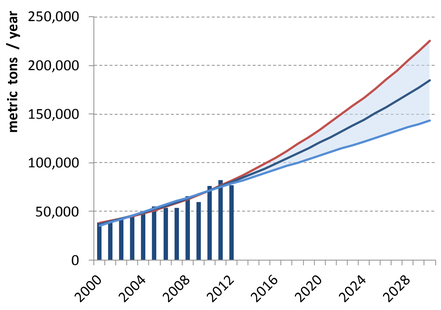


Figure 11: Forecast of cobalt mining with a linear regression function and a polynomial trend

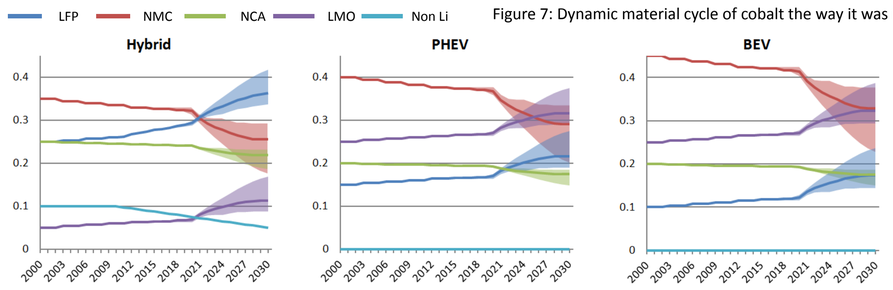


Figure 12: Cobalt scenario based diffusion of battery technologies in case of a strong diffusion of alternative drive technologies

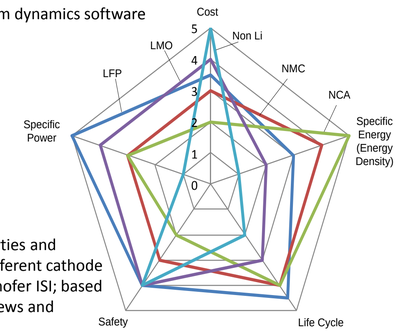


Figure 13: Properties and advantages of different cathode materials (Fraunhofer ISI; based on expert interviews and literature data)

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