

SETTING RECYCLING TARGETS FOR METALS IN A LI BATTERY

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ABSTRACT

In the EU APPLES project, a new Li ion battery is developed. An LCA model including weighting was developed for this battery and a reference. Simulations were made with different materials and recycling rates.

The results indicate that if all cars are BEVs or HEVs, global mining of Li, Ni and Sn may have to increase several times. There will also a significant increase in the demand of Cu and Mn. If the electricity used for charging the batteries is made by non-fossil methods, such as water power, management of metal resources are a prime sustainability factor. The optimal recycling rate depends highly on the recycling technology, but also on the weighting methods used.

INTRODUCTION

In the EU APPLES project (APPLES 2013), a Li ion battery based on a cathode of $\text{LiNi}_{0.5}\text{Mn}_{1.5}\text{O}_4$ on Al and an anode of Sn-carbon on Cu is developed. The battery has good potential in terms of performance, but a full scale use of the battery for propulsion of cars has a significant impact on the use of metal resources and therefore requires efficient recycling processes. A question arises if this battery is better than other Li ion batteries and how to integrate recycling options and targets in this comparison.

There are several comparative LCA studies of batteries used for propulsion in literature (Hawkins 2012), but to our knowledge, none of them has addressed the question of what is an acceptable recycling rate. To do so, one has to be able to handle trade-offs between different environmental issues and other issues. The picture is complicated by the fact that recycling methods are not well developed yet. In this study, we will add some information that can be used for setting recycling targets by using an analysis of global mass flows and estimate monetary measures for environmental impacts. Monetary measures may be used to assess which cost increase that is acceptable for recycling processes.

METHODS

An LCA model including weighting was developed and simulations made with different materials and recycling rates. The LCA was supported by a MFA (Mass Flow Analysis) of global metal flows needed in Battery Electric Vehicles (BEV) scenarios.

If considering long term economy aspects like in the EPS method, we can deduce an optimal recycling rate dependent on recycling cost from the following calculation, where the present virgin metal price is V and K is a cost increase factor so the acceptable price of the metal is $K \cdot V$. N is the natural capital value of the metal ore, recycling cost is R , recycling efficiency is E and number of cycles is C .

$$\text{Then } C = 1/(1-E) \text{ and } KV = (N+V)/C + R, \text{ or } E = (N+R-V(K-1))/(N+V)$$

If we assume that the acceptable price is equal to the present market price V , the $K=1$ and we get $E = (N+R)/(N+V)$

RESULTS

The results indicate that if all cars are BEVs, Global flows of Li, Ni and Sn may increase several times, and that there also is a significant increase in the use of Cu and Mn. (Table 1) The results also indicate that if the electricity used for charging the batteries is made by non-fossil methods, such as water power, management of metal resources are the prime sustainability factor (figure 1). The optimal recycling rate depends highly on the recycling technology but also on the weighting methods used including their assumptions about the future. The picture is complicated by technology bridging aspects, e.g. the most sustainable solution may not be economically feasible in the short term and thus not contributing to a real improvement. Therefore recycling technology options in terms of costs and efficiencies become important factors in setting recycling targets for metals in Li batteries.

Table 1 Global metal flows if all cars in the future were propelled by APPLES batteries. The figures for natural capital are estimated by using the EPS 2000d method (Steen 1999).

Metal	Present virgin global production ton/yr	Estimated use if all cars were BEV and driven by APPLES cells ton/yr	Recycling market value \$/yr	% of virgin global production used by APPLES cars without recycling	Natural capital in ore \$/ton	Natural capital used for metal production \$/ton	Use of natural capital without recycling \$/yr
Al	2,50E+07	2,46E+06	4,92E+09	9,8	4,39E+02	9,40E+03	2,32E+10
Cu	1,62E+07	3,78E+06	3,01E+10	23	2,08E+05	2,68E+05	1,01E+12
Li	2,53E+04	6,29E+05	2E+10	2490	1,00E+02	1,01E+04	6,36E+09
Mn	1,08E+07	6,22E+06	3,48E+09	58	5,64E+03	7,28E+03	4,53E+10
Ni	1,45E+06	2,28E+06	4,47E+10	158	1,60E+05	2,06E+05	4,71E+11
Sn	2,60E+05	2,59E+06	5,44E+10	997	1,19E+06	1,53E+06	3,98E+12

As shown in table 1, the global production of Li and Sn has to increase several times in order to satisfy the demand for batteries of APPLES types. Li is an abundant element and large amounts are available in sea water, but even with 80% recycling there may be problems of increasing the global production fast enough to satisfy the demand if all cars use Li batteries for propulsion (Kushnir and Sanden 2012).

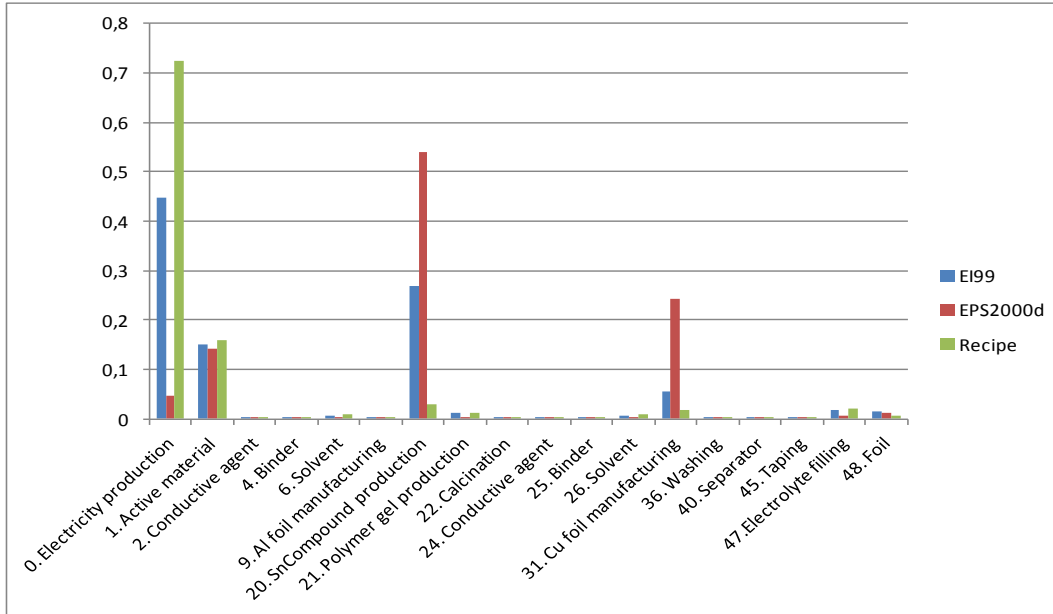


Figure 1 Relative contribution to weighted impacts in APPLES cell according to three methods when electricity comes from water power (Goedkoop 1999, Steen 1999, Goedkoop 2008). Full life cycle, no material recycling.

The results in figure 1 indicate, as expected, that electricity production is an important factor in the battery life cycle, but also that manufacturing of active material, Sn and Cu for the electrodes give significant contributions to the overall impact. It also shows that there are significant variations in priorities between the weighting methods. EPS2000d is more focused on resources due to longer temporal system boundaries than the other methods. Using different LCA weighting methods may therefore significantly influence which recycling rates that will be optimal. Figure 2 shows the optimal recycling rate using N and V values of table 1.

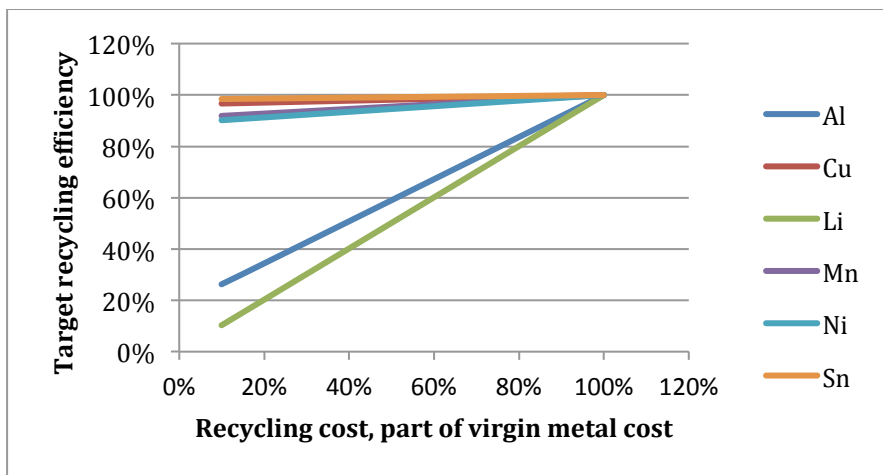


Figure 2 Target recycling efficiency as a function of recycling cost in a scenario with present metal prices.



DISCUSSION

Development of sustainable technology involves several assumptions about the future, assumptions about technical issues as well as assumptions about what will constitute sustainability. Our assumption about the future is not necessarily that all cars will be propelled by APPLES batteries, but we find it meaningful to investigate that scenario. The main advantage with using Sn-C in the anode is a significant increase in storing capacity compared to conventional C anodes. This will in turn lead to lower battery weight and costs, and may help to bridge the technology gap between electric and conventional cars. If so, the exact sustainability performance of the tin-based APPLES battery may not be critical.

CONCLUSIONS

From a sustainability point of view recycling should be focused on Cu, Li, Ni and Sn. Al and Mn may be recycled as motivated by current economics or as required by law. The target for recycling rates seem to be in the >90% region, but the exact optimum depend on weighting methods and how recycling technology evolves. Considering the significance of the resource issue and the need for replacing fossil fuels, weighting methods and recycling technology should be higher up on the agenda.

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