Availability of the elements for scaling up batteries for grid and transportation energy storage

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There is much discussion about scaling up battery production for electric vehicles and storing energy on the grid. However, to date there has been no systematic study of the availability of the elements for scaling up batteries for these applications. In this analysis we carry out such an analysis for 27 battery couples, focusing on the availability of the elements for making active materials (and neglecting, for now, the balance of system materials). We consider five main classes of batteries: aqueous electrolyte, Li-based (Li-ion and Li metal), high-temperature, redox-flow, and metal-air, although of course there is some overlap in these categories.

For the 27 battery couples in our study we first distinguish those which are suitable for transportation applications by considering their practical and theoretical specific energy. The Department of Energy has set a target of 200 Wh/kg on the system level for an electric-vehicle battery and many of the couples in our study will never reach such a specific energy, making them suitable for grid-storage but not transportation applications. We find that Li-based couples are currently closest and have the best potential (given their relatively high theoretical specific energy) to meet the 200 Wh/kg at the system level target, with only a few other couples (e.g., Zn/air) also strong candidates.

Our analysis on the availability of the elements builds on the United States Geological Survey Mineral Commodity summaries, and draws on annual production (representative of a "flow"), reserve base (representative of a "stock"), and cost numbers. The number of TWh that can be produced based on both annual production and reserve base is calculated (we call this the "battery energy storage potential"). To do so the limiting element in each couple is found; the limiting element is defined as the element that would run out first during production. We also calculate the $/kWh cost of the elements in each couple, taking all the elements into account.

We compare the battery energy storage potential against representative annual production and stock numbers for both grid and transportation applications. For example, for the transportation application we compare the battery energy storage potential based on annual production to the annual production of 1 million 40 kWh vehicle batteries, a plausible (though not assured) short-term (5-10 year) scale-up target. As another example, for grid applications we compare the battery energy storage potential based on the reserve base to the world's daily production of electricity in 2007. These comparisons allow an assessment of the availability of the elements in battery active materials with representative scale-up targets.

For battery cost we compare the $/kWh for the elements in the active materials alone to capital cost targets given by the Department of Energy (100 $/kWh). Some battery couples have elements in their active materials too expensive to meet the 100 $/kWh target.

We conclude that there are several battery couples (Na/S, Zn/Cl_2, and $FeCl_2/CrCl_3$) that can scale to meet both short- and long-term targets. However, these couples have a practical specific energy too low to meet EV specific-energy targets. At the present time Li-based batteries have the highest practical specific energy among rechargeable couples (the Zn/air couple also has a high value). Scaling to an annual production of 10 million 40 kWh Li-based batteries will require a significant scale-up of Li production. With the currently estimated reserve base of Li on the order of 1 billion 40 kWh Li-based batteries may eventually be produced. However, other industrial uses for Li compete with the use of Li for batteries (this is, of course, true of all the elements in our study), so these numbers should be seen as an upper estimate.

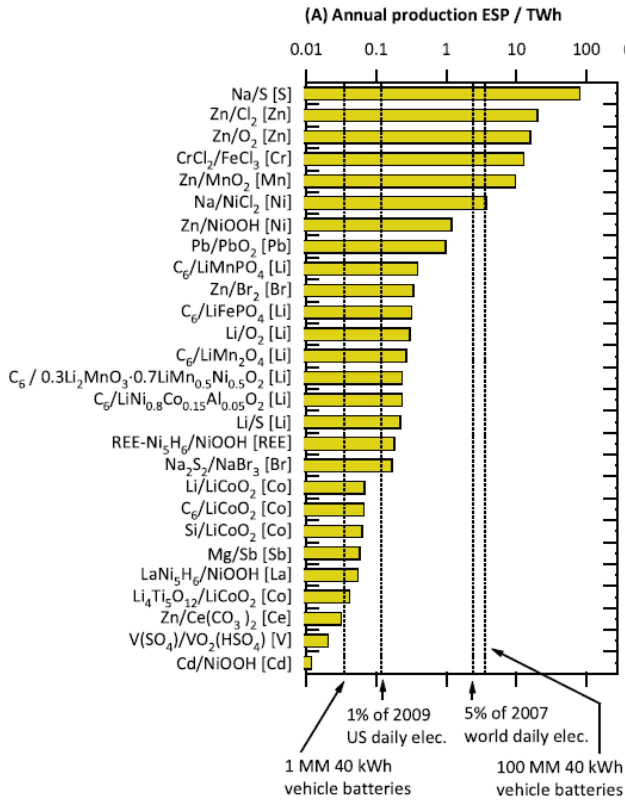

Figure 1. The energy storage potential (in TWh) of 27 battery couples. Representative "flow" targets for both the short and long term are also shown. The element in brackets at the right of each couple label is the limiting element in the couple.

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