Future prospects of energy storage batteries 14 kWh

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The numbers are based on market demand forecasts for 2021-2030 (refs. 7,8,9,11,13) and 2030-2040 (refs. 10,12) combined with a forecast of market share of cathode chemistries14. All market data and calculations can be found in Source Data Fig. 1. NCA, nickel-cobalt-aluminium.

The SSP is a framework of possible narratives for possible the future of humanity until the year 2100 (ref. 15). Five different possible futures of humanity are described, that is, sustainability (SSP1), middle of the road (SSP2), regional rivalry (SSP3), inequality (SSP4) and fossil fuel (SSP5)15. For the future demand for batteries, scenarios SSP1, SSP2 and SSP5 are the most important10.

To further improve battery cells, new types of battery cells, such as PLIB cells, are being developed. One group of PLIB cells is metal-ion battery cells, in which lithium is replaced by, for example, sodium, magnesium, aluminium or zinc25. Another group of PLIB cells uses lithium metal on the anode side instead of graphite or silicon or silicon/graphite. Some examples include solid state battery (SSB) cells with a sulfidic, oxidic or polymer-based solid electrolyte (SE). Other PLIB cells with lithium metal are lithium/sulfur battery (LSB) and lithium oxygen/air battery (LAB) cells. Within these cell chemistry classes, a wide range of various PLIB types are possible.

To produce today"s LIB cells, calculations of energy consumption for production exist, but they vary extensively. Studies name a range of 30-55 kWhprod per kWhcell of battery cell when considering only the factory production and excluding the material mining and refining31,32,33. A comprehensive comparison of existing and future cell chemistries is currently lacking in the literature. Consequently, how energy consumption of battery cell production will develop, especially after 2030, but currently it is still unknown how this can be decreased by improving the cell chemistries and the production process. This is essential, as energy is a valuable resource and probably will continue to be for the foreseeable future.

In this Analysis, our aim is to determine how much energy is required for the current and future production of LIB and PLIB cells on a battery cell level and on a macro-economic level. Material mining and refining were excluded from this study due to their complexity.

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The analysis was conducted as follows: First, it was determined how the energy consumption in production would change relatively if PLIB cells were produced instead of LIB cells. Then it was calculated how much energy is needed to produce 1 kWhcell of cell energy according to the current state of the art. Subsequently, it was analysed how techno-economic effects will affect future energy consumption. On this basis, it was then calculated how much energy is needed to produce 1 kWhcell of cell energy in the future. Finally, it was calculated how much energy is needed to produce the worldwide demand for batteries from today until 2040.

In the first step, we analysed how the energy consumption of a current battery cell production changes when PLIB cells are produced instead of LIB cells. As a reference, an existing LIB factory model was used31,34, which is provided in Supplementary Fig. 1 and Supplementary Table 1. How future PLIB production technology routes might look and which technology routes we used as references in this study are shown in Supplementary Fig. 2. However, to be able to quantify the percentage of the change in energy consumption between LIB and PLIB cell production, we conducted workshops in which experts rated each single production step. Details about this work are provided in Methods and in Supplementary Note 1. The results that were obtained are shown in Fig. 2.

The different sizes of the circles represent the different sums of energy (kWhprod) of electricity and natural gas. Detailed numbers can be found in Source Data Fig. 3. The main bars show the calculated mean value. The error bars show the s.d. resulting from the uncertainties in the expert assessments. Sixty experts were interviewed (n = 60). Any battery materials are excluded from the assessment. EOL, end of line; Tdp, dew point temperature. Wel., welding; Pac., packaging; Fil., electrolyte filling; Clo., closing.

Detailed numbers can be found in Source Data Fig. 4. The main bars show the calculated mean value. The error bars show the s.d. resulting from the uncertainties in the expert assessments. Sixty experts were interviewed (n = 60).

We assumed that battery cell production will be improved markedly in the future, so the demand for energy will decrease. The most important effects are technology improvements, use of heat pumps, learning effects and economies of scale35. The calculations are in Source Data Fig. 5.