The competition between vehicle-to-grid, second-life batteries, and new batteries in providing electricity storage

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Abstract

Future low-carbon societies will need to store vast amounts of energy to power electric vehicles (EVs) and to stabilize electricity grids that are increasingly fed by intermittent wind and solar energy. Lithium-ion batteries (LIBs) are expected to play an important role for both functions. Passenger vehicles have a low utilization rate and are expected to generate large volumes of end-of-life batteries over time. Therefore, the batteries produced for EVs can provide storage to electricity grids through vehicle-to-grid (V2G) and second-life batteries (SLBs). The feasibility of these options and their consequences for overall raw and recycled material use are critical factors for developing a sustainable and resilient LIBs infrastructure, which is needed for a reliable supply of electricity storage. Here, we develop a demand-constrained dynamic material flow analysis model to determine how V2G, SLBs, and new batteries can meet the expected needs for stationary battery storage of the European Union and we analyze the consequences for primary and secondary material use. We reached the following conclusions: (1) electric vehicles require three orders of magnitude more battery storage than the European electricity grids, (2) V2G and SLBs each have the potential to exceed the expected needs for stationary storage, and (3) V2G and SLBs may therefore compete with each other. Compared to SLBs, V2G can be deployed faster, requires less space, and leads to a lower total primary material consumption because it allows EV batteries to satisfy both transport and stationary storage needs simultaneously. On the other hand, SLBs can provide more storage in the long term and are independent of the individual behavior of EV owners. Compared to new batteries, SLBs can reduce the total material demand but increase the primary material demand. Since V2G and SLBs can each exceed the expected needs for stationary battery storage, they may reduce the needs for other forms of storage and play a greater role in future low-carbon societies. Understanding the respective potential and relative constraints of V2G and SLBs is an imperative for industry stakeholders to take informed strategic decisions and for policymakers to ensure the security of material supply for reliable e-mobility and electricity grids.

Key Figures

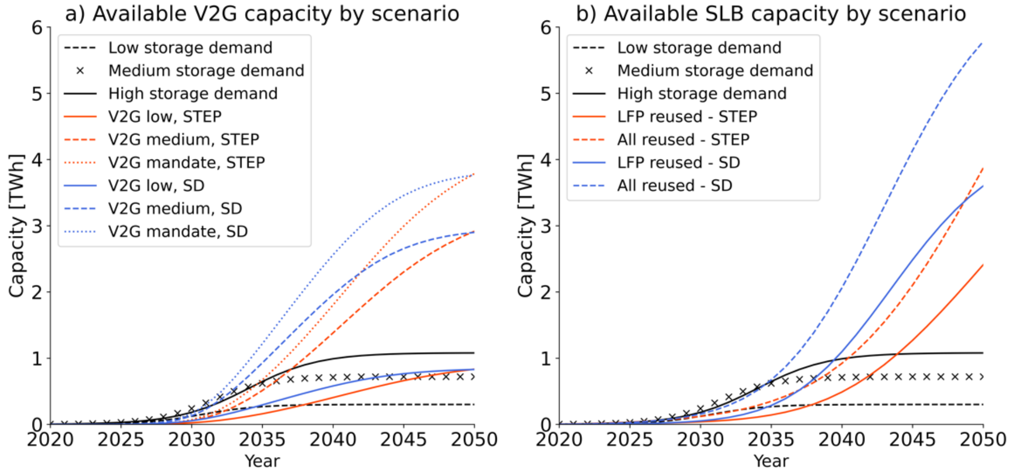

Figure 1: Volumetric analysis of the potential capacity that can be offered by a) V2G, and b) SLB under different scenarios. STEP is the projected EV penetration under current policies and SD is an accelerated EV penetration scenario.

Core messages in Figure 1:

1. V2G and SLBs both have the potential to meet and exceed the demand for stationary energy storage by up to a factor three under most scenarios.
2. V2G can be deployed faster but SLBs can provide more storage in the long term.
3. V2G and SLBs may compete in the stationary energy storage market.

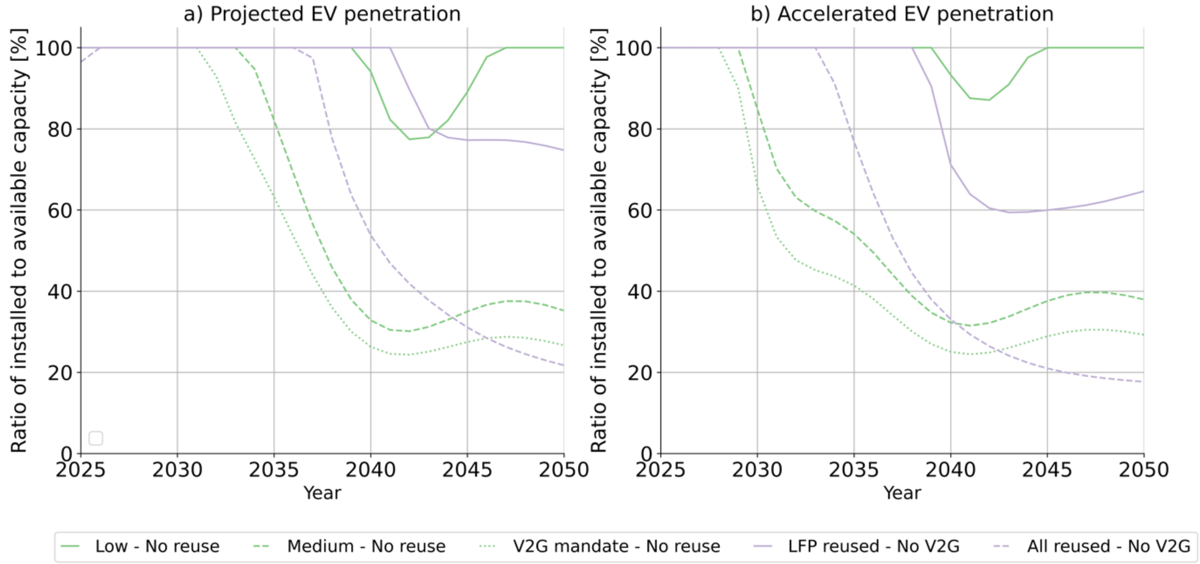

Figure 2: Ratio of installed to available capacity for V2G and SLBs in the high demand scenario under a) the projected EV penetration and b) an accelerated EV penetration.

Assumption: In every year, the newly installed capacity of V2G and SLBs is limited by the storage demand minus the already existing storage capacity. Any missing capacity is met by installing new stationary batteries. Since the storage demand is non-decreasing, the total installed capacity is thus always equal to the storage demand.

Under this assumption, Figure 2 shows the ratio of the newly installed capacity of V2G and SLBs compared to the available capacity for installation.

Core messages in Figure 2:

1. Under the projected EV penetration, SLBs will be able to fully cover the need for new stationary storage from 2036 onward. If only LFPs are reused, then this point is delayed by 5 years. Under the accelerated EV penetration, these points occur 3 years earlier. Before these points, the needs for stationary storage exceed the amount of available SLBs.
2. Under the projected EV penetration and a V2G mandate, V2G will be able to fully cover the need for new stationary storage from 2031 onward. This point is delayed by 1 to 2 years for the medium V2G scenario. Under the accelerated EV penetration, these points occur 3 to 4 years earlier. In the low V2G scenario, V2G cannot fully replace new stationary batteries.
3. There is a considerable potential excess capacity of V2G and SLBs from 2035 onward, which may be used for strategic national electricity reserves to prevent blackouts and to mitigate vulnerability to fossil fuel supply shortages.

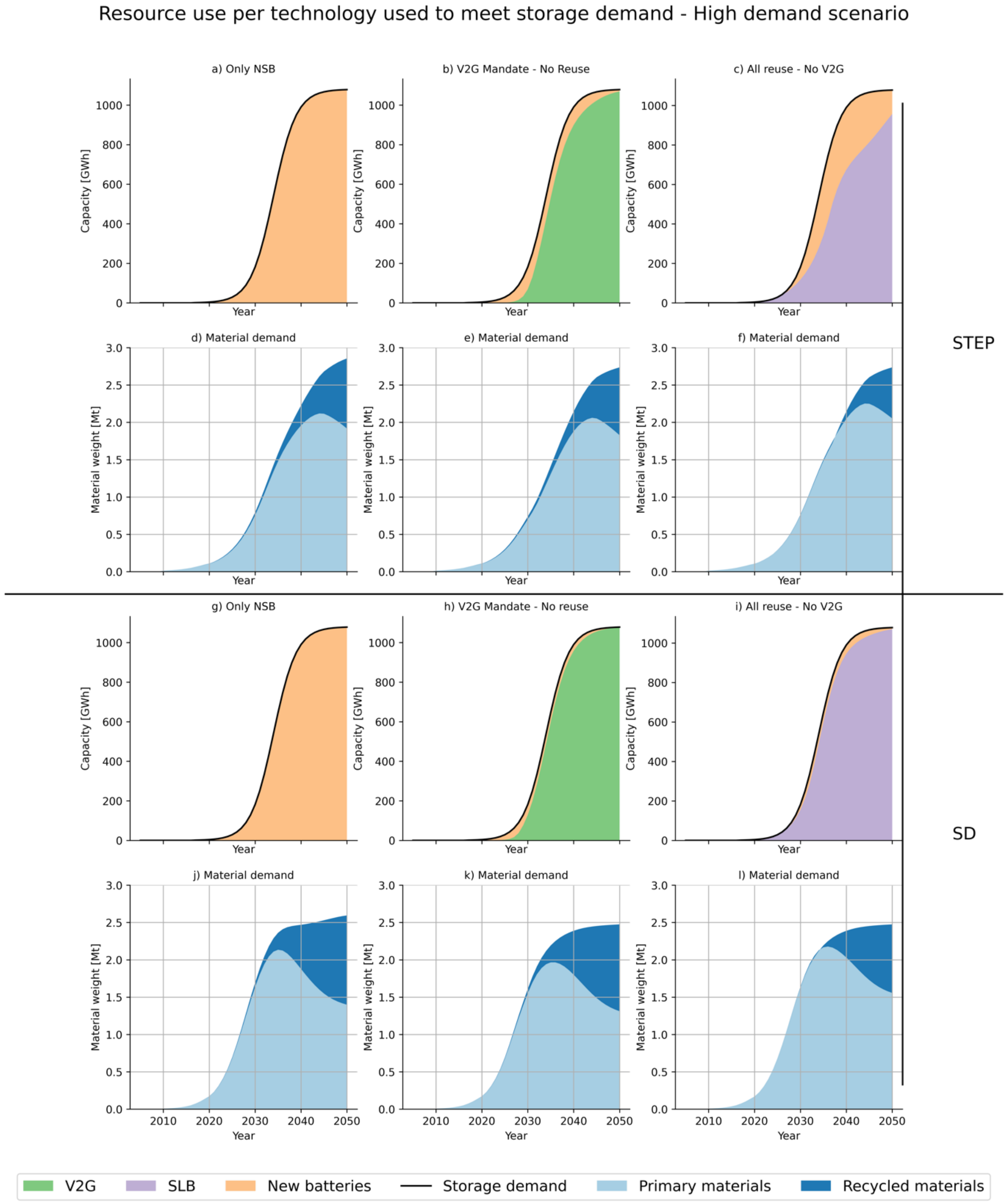

Figure 3: Primary and recycled resource use for no-V2G and no-SLB scenario, early V2G adoption scenario, and no-V2G and high reuse scenario for each EV penetration scenario and a high storage demand scenario. STEP is the projected EV penetration under current policies and SD is an accelerated EV penetration scenario.

Core messages in Figure 3:

1. Fast EV penetration helps SLBs more than V2G. V2G is less sensitive to the speed of vehicle electrification. (Compare B with H and C with I)

2. Until 2030, SLBs can cover most of the stationary storage demand. Afterwards, they cannot keep pace with the growth in storage demand, but V2G can. (Compare B with C and H with I)

For the following points compare D, E, F, and J, K, L.

3. An early and widespread adoption of V2G leads to the lowest peak primary material demand.
4. Peak primary material demand occurs about 10 years earlier in the fast EV penetration scenario than in the projected EV penetration scenario.
5. SLBs reduce total material demand but increase primary material demand.

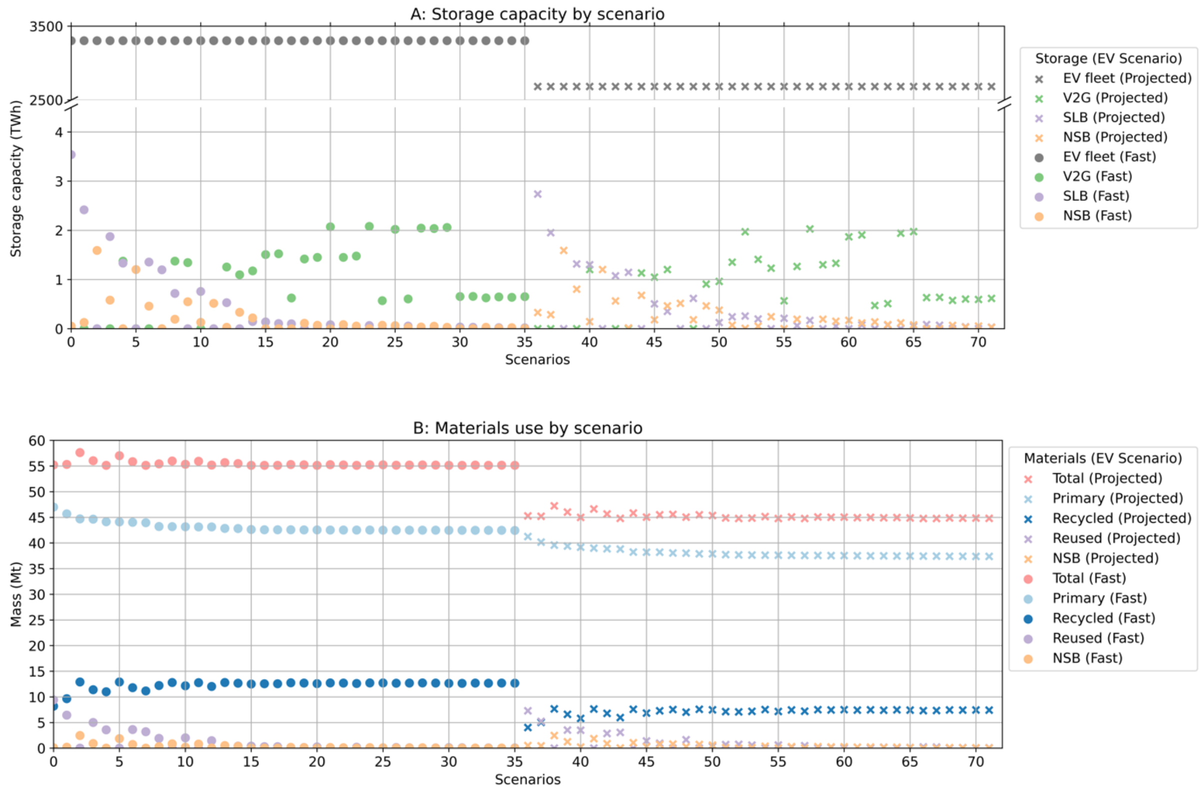

Figure 4: Scenario analysis of total resource use aggregated over the entire time horizon assuming hydrometallurgical recycling efficiencies. The cross markers refer to the projected EV penetration under current policies and the circular markers refer to an accelerated EV penetration scenario.

Core messages in Figure 4:

1. The storage needs of electric vehicles are about three orders of magnitude higher than the storage needs of the grid in all scenarios.
2. V2G can cover more than 60% of the storage needs of the grid in 71% of all scenarios and more than 95% of the storage needs in 20% of all scenarios.
3. V2G can reduce the primary material demand by about 10% in both EV penetration scenarios, which is similar to the difference in primary material demand between the two scenarios.
4. More SLBs lead to less secondary material availability, which decreases the total material demand but increases the demand for primary materials.