Lithium-Ion Batteries: Possible Material Demand Issues

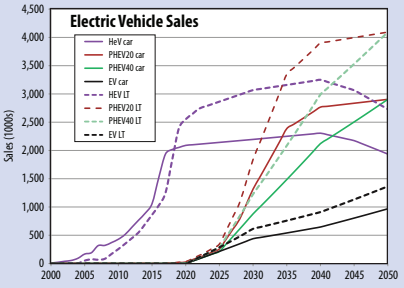
Argonne NATIONAL LABORATORY

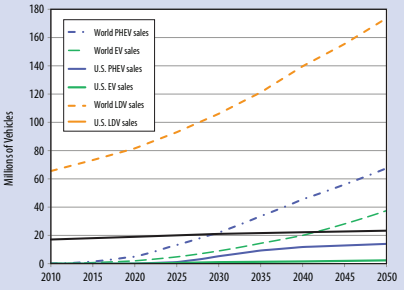
Overview

How much lithium would be required if hybrids, then plug-in hybrids, and then pure electric vehicles expanded their market share extremely rapidly? We estimated an upper bound on the quantity that could be required by using four promising lithium-ion battery chemistries. To evaluate the adequacy of future supply, we compared total demand to (1) estimates of production and reserves and (2) the quantity that could be recovered by recycling.

How Many Vehicles Will Be Sold in the United States and Worldwide?

- U.S. light-duty vehicle sales by type were projected out to 2050 by using a very optimistic scenario for market penetration of electric-drive vehicles, including hybrids, plug-in hybrids, and pure battery electric vehicles. In this scenario, 90% of sales (or 21 million vehicles) have electric drive in 2050, and sales to that date total 465 million.





- The International Energy Agency (IEA) projected world light-duty vehicle sales, which grow much faster than U.S. sales, on the basis of World Bank economic and United Nations population projections. This graph shows the IEA scenario for the growth in electric-drive vehicles that would be required to meet IPCC CO_2-reduction goals. Pure EVs (as opposed to hybrids) were assumed to account for over 20% of global sales by 2050 (vs. 10% in Argonne's optimistic scenario).

What Kind of Batteries Might They Use?

- We considered four promising battery chemistries, all of which contain lithium in the cathode and electrolyte, and one of which uses lithium in the anode as well.
- We estimated how much material would be needed if all batteries for electric-drive vehicles were made from each chemistry.
- The battery material masses and chemical compositions were combined to give the total quantity of contained lithium in each battery pack. The maximum quantity of lithium contained is 13 kg, and it is much less for most chemistries and vehicles considered.
- Lithium makes up less than 3% of battery mass.

Battery Chemistry

Electrodes \ System	NCA Graphite	LFP (phosphate) Graphite	MS (spinel) Graphite	MS Titanate
Positive (cathode)	$LiNi_{0.8}Co_{0.15}Al_{0.05}O_2$	$LiFePO_4$	$LiMn_2O_4$	$LiMn_2O_4$
Negative (anode)	Graphite	Graphite	Graphite	$Li_4Ti_5O_{12}$

Calculated Lithium Required per Battery Pack (kg contained Li)*

Battery Type	NCA-G				LFP-G				LMO-G				LMO-TiO			
Vehicle range (mi) at 300 Wh/mile	4	20	40	100	4	20	40	100	4	20	40	100	4	20	40	100
Li in cathode (kg)	0.34	1.4	2.8	6.9	0.20	0.80	1.6	4.0	0.15	0.59	1.18	3.0	0.29	1.2	2.3	5.8
Li in electrolyte (kg)	0.04	0.10	0.20	0.55	0.045	0.14	0.26	0.66	0.03	0.09	0.17	0.43	0.05	0.17	0.34	0.85
Li in anode (kg)	0	0	0	0	0	0	0	0	0	0	0	0	0.30	1.21	2.4	6.1
Total Li in battery pack (kg)	**0.37**	**1.5**	**3.0**	**7.4**	**0.24**	**0.93**	**1.9**	**4.7**	**0.17**	**0.67**	**1.4**	**3.4**	**0.64**	**2.5**	**5.1**	**12.7**

*To convert to carbonate equivalent, multiply by 5.3

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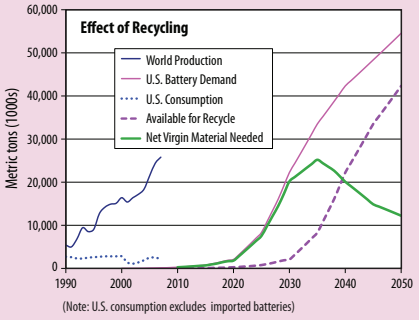
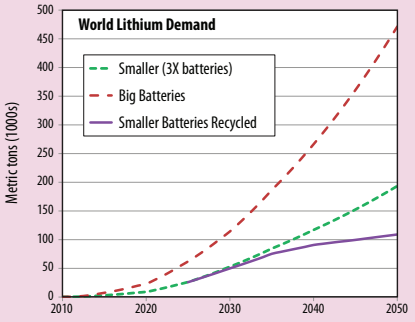
How Much Lithium Would Be Needed Each Year?

- We used the vehicle demand from the high-EV-penetration scenarios and quantities of lithium (using NCA graphite chemistry) per vehicle to estimate the potential demand for lithium, for the United States (right) and the world (below).



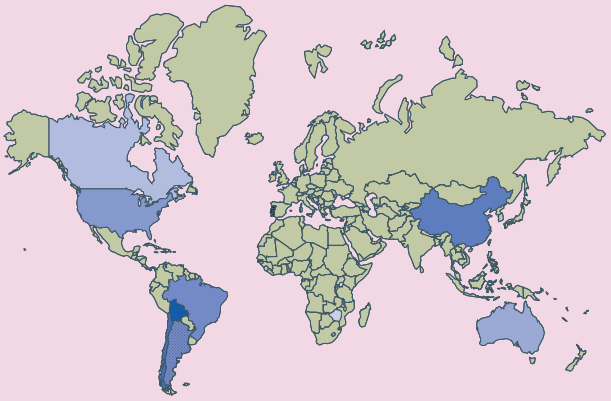
- The maximum quantity of lithium that could be available for recycling was estimated by assuming that all material could be recovered after a 10-year (United States) or 15-year (rest of world) service life.



- The availability of recycled material would reduce annual U.S. demand in 2050 from over 50,000 tonnes to about 12,000 tonnes, after a peak in the 2030s of 25,000 tonnes, which is approximately equal to current world production (top graph).

- The IEA assumed the vehicles would have large (12–18 kWh) batteries. Production of these batteries would cause world lithium demand to rise to 20 times the current level. But many new vehicles are likely to be city cars or even electric bicycles, which would drop 2050 demand to 8 times the current level. With material recycling, demand for virgin material in 2050 would be only about 4 times the current level.

Where is the Lithium?



Country	Reserve Base (tonnes)
Bolivia	5,400,000
Chile	3,000,000
China	1,100,000
Brazil	910,000
Argentina	not available
United States	410,000
Canada	360,000
Australia	220,000
Portugal	not available
Zimbabwe	27,000
World total (rounded)	11,000,000

How Does the Demand Compare to the Resource Available?

- Even by using the U.S. Geological Survey's (USGS's) conservative estimates of lithium reserves, the available material will not be depleted in the foreseeable future.

Category/Source	Cumulative Demand to 2050 (contained lithium, 1000 metric tons)
Large batteries, no recycling	6,474
Smaller batteries, no recycling	2,791
Smaller batteries, recycling	1,981
USGS Reserves	4,100
USGS Reserve Base	11,000
Evans and others	30,000+

- If new capacity is not built fast enough to match demand, the price could go up, but the problem will not be that there is no more lithium, at least for the next 40 years.

- Bottom line: Known lithium reserves could meet world demand to 2050.

Can Lithium-Ion Batteries Provide a Bridge to the Future?

- Lithium-ion batteries may not be the "silver bullet" that permanently solves all of the world's energy storage problems, but they can certainly make a large contribution for at least several decades, while the next breakthrough is sought.

- Reports that we are running out of lithium are premature.

- Lithium demand can be met, even with rapid growth of electric drive.
  - Scenarios extended to 2050; new technologies are likely in the next 40 years.
  - Better batteries, additional exploration could extend supply.

- Cobalt supply and price will reduce the importance of NCA-G chemistry.

- Batteries can be reused for lower-performance applications before recycling.

- Recycling processes are needed that:
  - Recover all recyclable materials to extend material supply and moderate prices,
  - Process all likely chemistries, and
  - Minimize energy and environmental impacts.

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