Potential cost-degression of Lithium-ion batteries

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DLR battery cost model

In order to be able to assess future cost developments of Lithium ion batteries, a new cost model has been developed

	Cell	**Module**	**Pack**
Raw materials	▪ Anode material ▪ Cathode material ▪ Electrolyte ▪ Separator ▪ Casing ▪ Connectors ▪ …	▪ Module casing ▪ Terminal ▪ Connectors ▪ Safety components ▪ Balancer ▪ …	▪ Battery casing ▪ Cooling system ▪ Safety components ▪ Electrical connectors ▪ Battery management system ▪ …
Production	▪ Production of electrodes ▪ Assembling of cell ▪ Filling and closing ▪ Charging ▪ Testing…	▪ Testing of cells ▪ Assembling of module components ▪ Testing ▪ …	▪ Charging of modules ▪ Integration into pack-unit ▪ Assembling and electrical connection of pack components ▪ …
Overhead	▪ Research and development ▪ Logistics ▪ …	▪ Logistics ▪ Cost of financing ▪ …	▪ Marketing ▪ Profit ▪ …

For each individual field of the matrix:

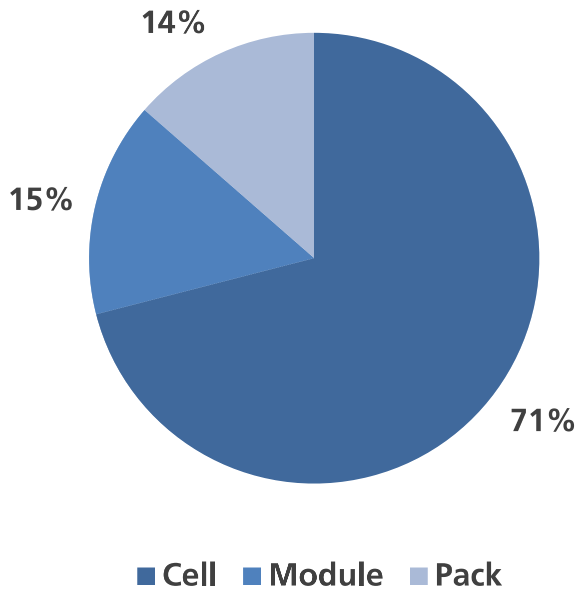
Overall cost in €/kWh

Learning rates in %

Spill-over-effects

Results – distribution of cost

Results show that cell cost account for over 70% of the entire battery production cost

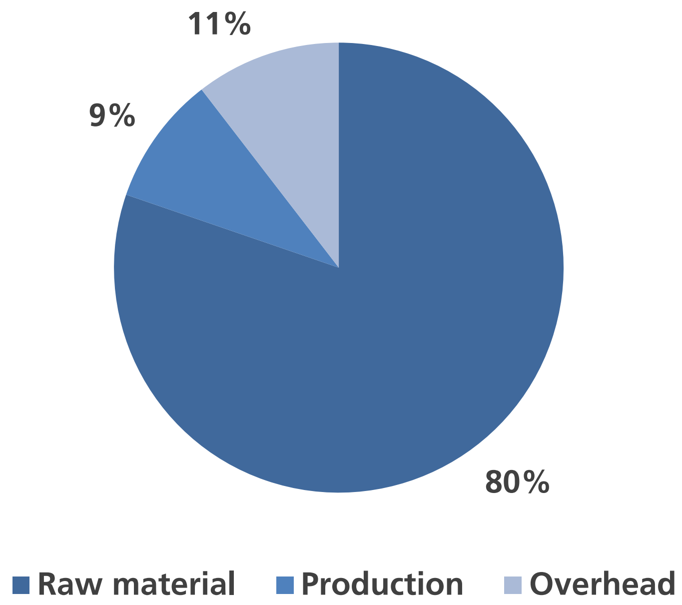


Comments

- Results are shown for an exemplary battery pack:
  NMC vs. graphite,
  HE-configuration,
  36 kWh,
  32 pouch cells per module (16 in parallel) à 34 Ah,
  9 modules,
  100,000 pack per p.a.
- Nearly 3 fourths of all cost are caused on cell-level
- Cost for modules and the pack-components show an even share of about 15%

Results – distribution of cost

Purchasing and transportation cost of raw materials account for 80% of the entire battery costs



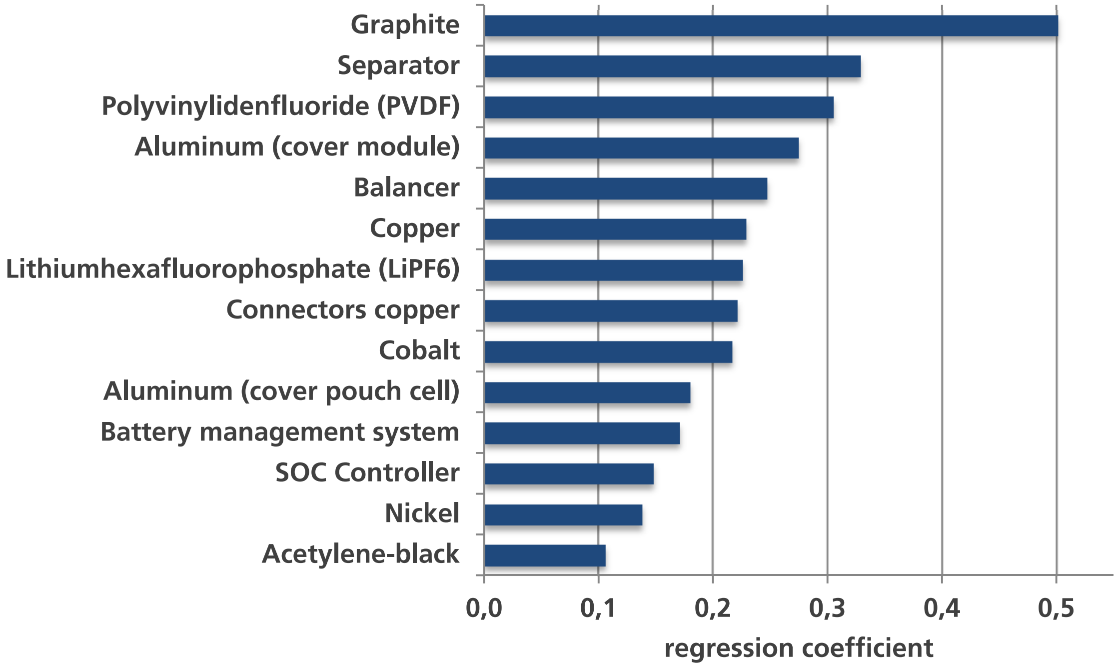
Comments

- Again, results for the exemplary NMC battery pack are shown
- Purchasing cost account for 4 fifths of the overall pack cost
- Assembling / production cost and overhead cost shown an even share
- Nearly 75% of the raw material cost are caused by cell manufacturing

Results – cost influence on pack-level

Of all raw materials, Lithium has nearly no impact on the overall battery cost

Influence of raw materials on the cost of a battery pack[1]



Comments

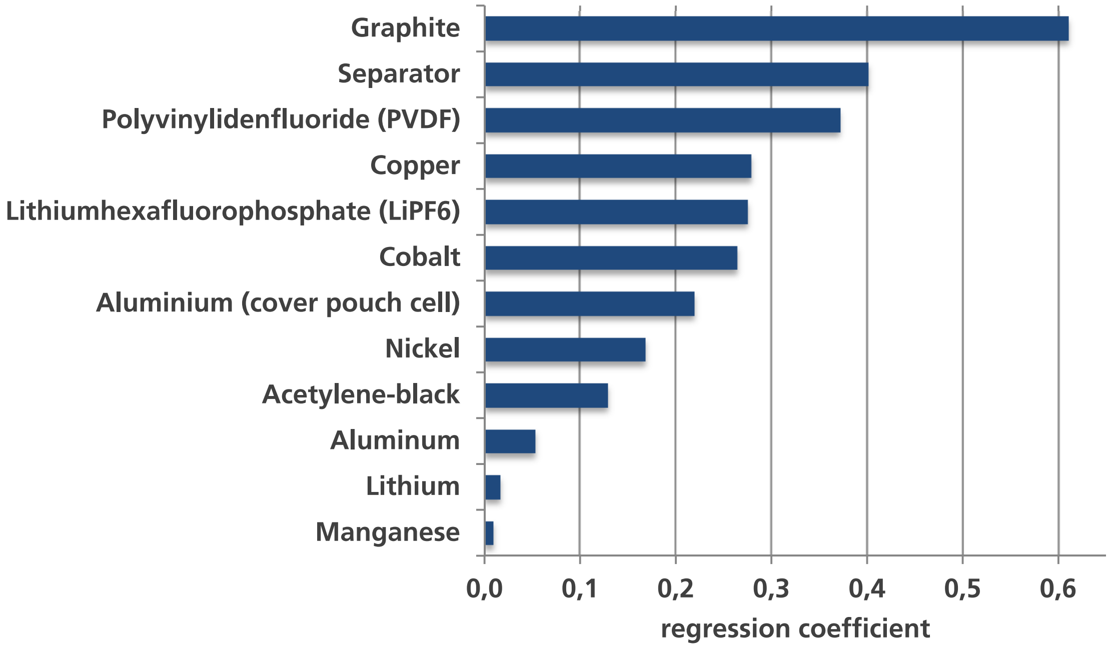
- A Monte-Carlo-simulation shows the influence of different raw materials on the production cost of an entire battery
- Graphite has a very strong impact on the overall battery cost
- Basically, non-active materials have a stronger influence on the production cost

1: please note: results shown for an exemplary battery pack:
NMC vs. C, HE-configuration, 36 kWh, 32 pouch cells per module (16 in parallel) à 34 Ah, 9 modules, 100,000 pack per p.a.

Results – cost influence on cell-level

Even for one individual cell, Lithium has nearly no impact on the cost development

Influence of raw materials on the cost of a single cell[1]



Comments

- Lithium has only a marginal influence for a single cell, too
- Graphite shows an even more significant cost impact on cell-level
- Cobalt shows the strongest cost influence of all cathode materials
- Again, non-active materials show a very strong impact

1: please note: results shown for an exemplary battery cell:
NMC vs. C, HE-configuration, pouch cell, 34 Ah, 100,000 pack per p.a.

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Results – electrode materials

The share of raw material costs differs significantly between different types of cell-chemistries

		Cell-chemistry				
		NMC	NCA	LFP	LMO	average
Lithium	g/kWh	142	130	91	86	112
	€ /kWh	0.71	0.66	0.44	0.46	0.57
Graphite	g/kWh	852	901	888	986	907
	€ /kWh	1.97	2.08	2.28	2.05	2.10

Comments

- Results are shown for high-energy configurations for a 36kWh battery pack with cell capacities of 34 Ah and a mass production of 100,000 units p.a.
- The mass and cost shares of Lithium and graphite vary significantly
- The absolute cost of both materials account on average for 2.67 €

Results – electrode materials

For all 4 analyzed cell chemistries, the cost influence of Lithium is negligible, regardless whether a high power or a high energy configuration is used

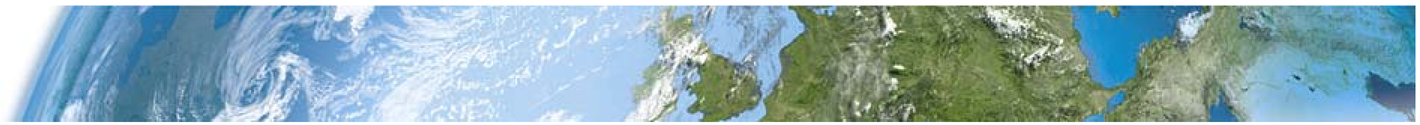
High Energy[1]		Graphite	Lithium	Nickel	Manganese	Cobalt	Iron	Aluminum	Copper
Cell chemistry	NMC	0.62	0.02	0.17	0.01	0.27		0.05	0.28
	LMO	0.60	0.01		0.04			0.06	0.31
	NCA	0.64	0.02	0.38		0.11		0.05	0.24
	LFP	0.65	0.01				0.03	0.06	0.30

High Power[1]		Graphite	Lithium	Nickel	Manganese	Cobalt	Iron	Aluminum	Copper
Cell chemistry	NMC	0.23	0.01	0.06	0.00	0.10		0.10	0.53
	LMO	0.21	0.00		0.01			0.10	0.54
	NCA	0.28	0.01	0.16		0.05		0.10	0.51
	LFP	0.23	0.00				0.01	0.10	0.53

Comments

- Neither the cost for high energy nor for high power battery configurations are significantly influenced by the price for Lithium
- Furthermore, cathode materials have a weaker influence than graphite
- For high power batteries, the impact of current collectors increases significantly

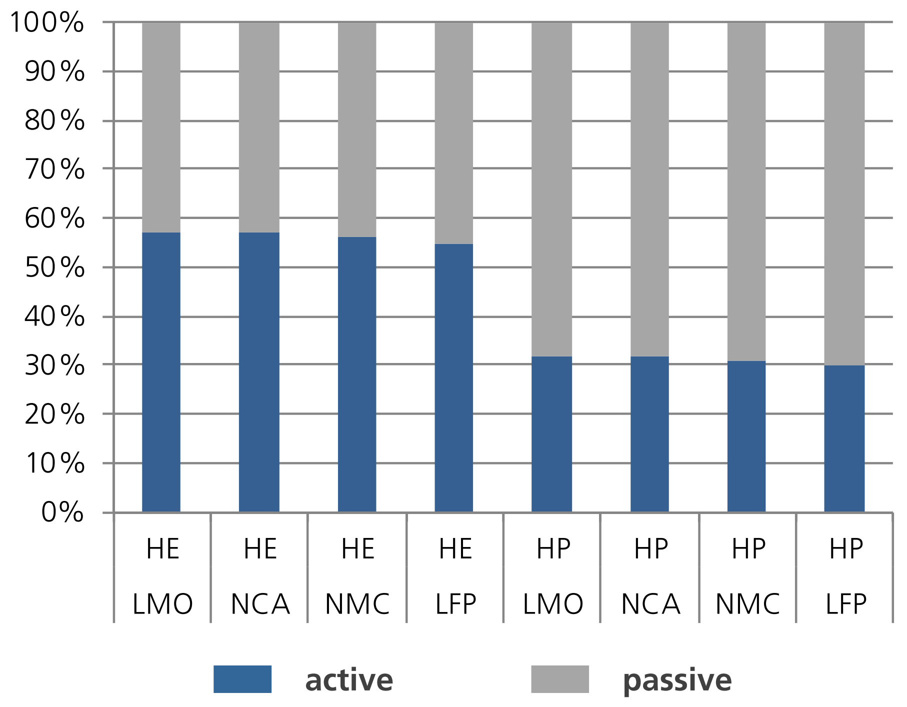
1: numbers shown represent linear regression coefficients



Results – active vs. non-active materials

The cost-shares of active and passive materials show a clear differentiation between high-energy and high-power battery configurations

Share of active vs. non-active materials on pack-level



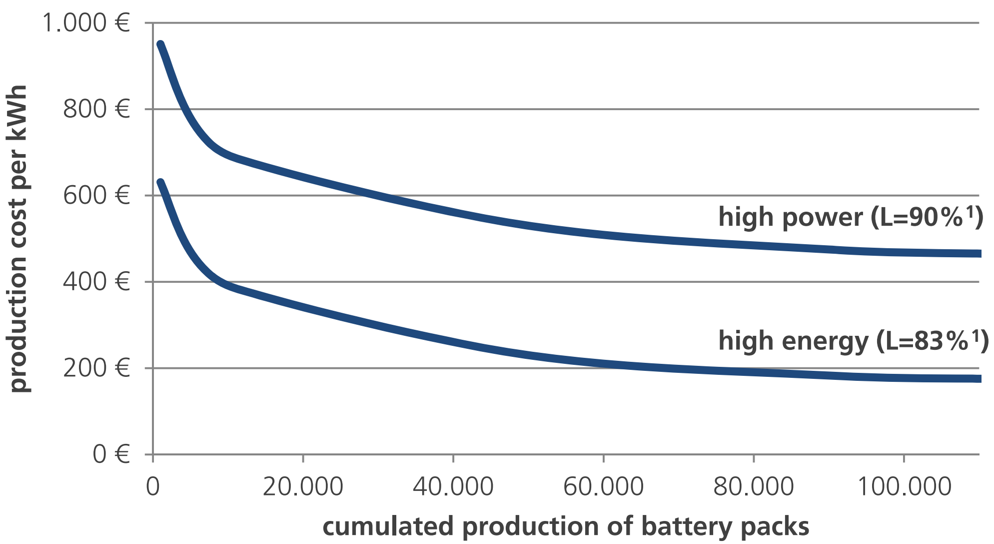
Comments

- The comparison of active vs. non-active materials shows a clear variation between high-energy and high-power battery configurations
- This variations holds true for all analyzed cell chemistries
- Due to thinner electrode coatings, high-power batteries show a higher share of non-active materials

Results – mass production

For mass production, high power battery configurations show slower cost-degression rates than high energy batteries

Cost-degressions due to mass production



Comments

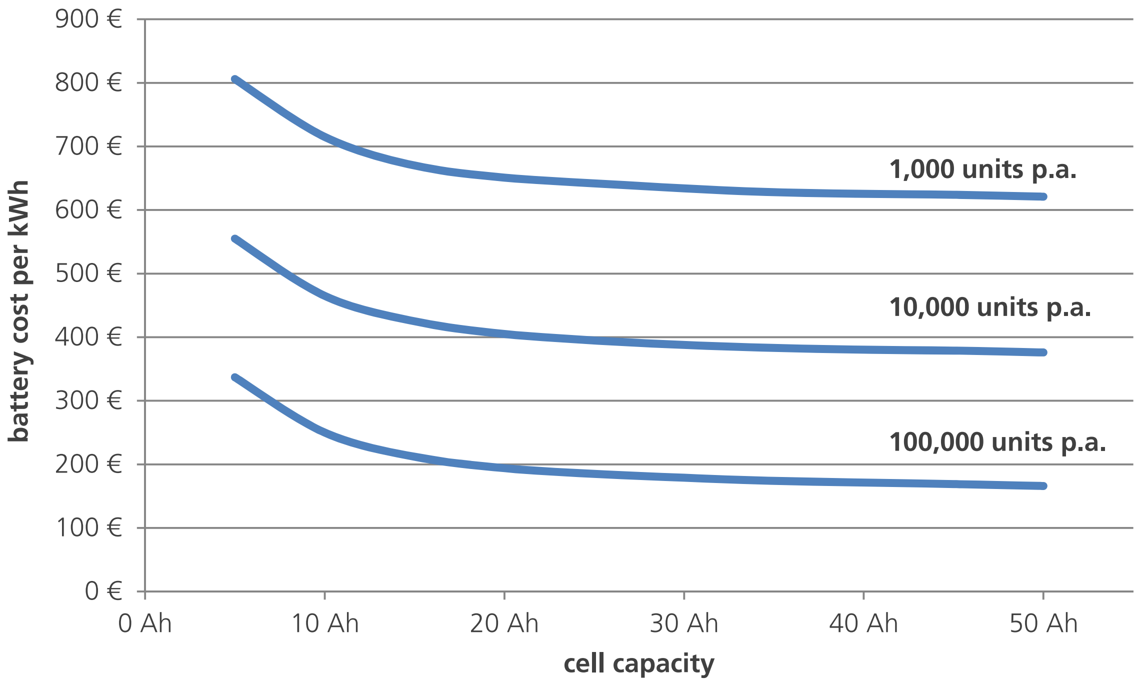
- Results are shown for an NMC 36 kWh battery pack
- Due to a higher share of non-active materials, high power batteries show a slower cost degression
- For the exemplary battery configuration, the absolute learning rates are within typical ranges

1: L: learning rate; cost degression per cumulative units produced

Results – cell capacities

The capacity of an individual cell has a strong influence on the overall cost of a battery pack

Cost-degressions due to increasing cell capacities[1]



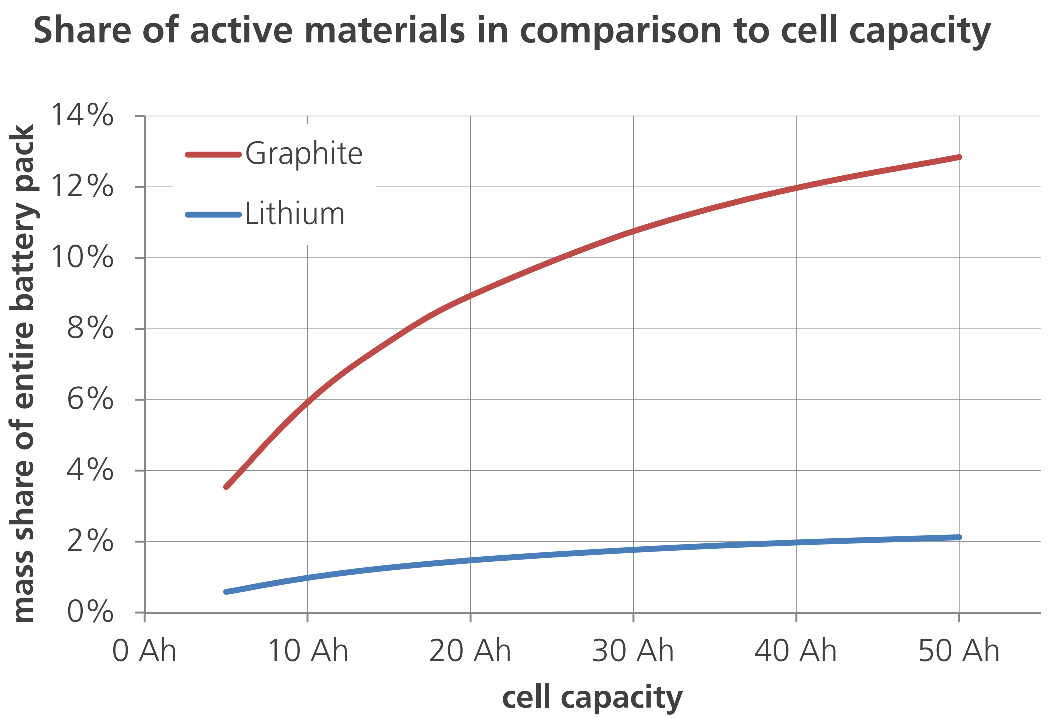
Comments

- A sensitivity analysis shows, that the capacity of a single cell has a strong impact on the overall cost
- The analysis shows clearly, that bigger cell have a cost advantage
- However, in combination with packaging restrictions, a cell-size of over 40 Ah seems unreasonable

1: please note: Results are shown for an 36 kWh NMC high energy battery pack

Results – cell capacities

With increasing cell capacities, the influence of active raw materials increases as well



Comments

- Results are shown for a 36 kWh NMC high-energy battery configuration
- Due to decreasing shares of casing, cell-balancing, electrical connectors, etc. the relative share of active materials increases
- However, the share of Lithium remains negligible even for higher cell capacities

Lessons learned

1. **In the long run and for mass-production, battery cost of around 170 € per kWh are achievable**
2. **For all types of batteries, Lithium has only a minor cost influence**
3. **High power battery configurations show slower degression rates than high energy batteries**
4. **Large cell capacities are – up to physical und packaging restrictions – significantly cheaper**

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