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The outlook for EVs and future potential demand for graphite

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Pro**Graphite**

PROFESSIONAL GRAPHITE SOLUTIONS

The outlook for Electric Vehicles (Evs) and future potential demand for graphite

1. Introduction ProGraphite GmbH
2. EVs: current market situation
EVs: market outlook
3. Battery technology for EVs
Graphite in the Anode of Li-Ion Batteries
4. Future potential demand of Flake Graphite



Consulting

- Competent expert assistance of graphite projects
- Independent evaluation and determination of potentials of graphite projects and companies
- Neutral evaluation of studies for banks, investors...
- Planning input for production lines for natural graphite e.g. for flotation plants; plants for spherical graphite for Li-Ion-batteries

Lab Services

- Performance of neutral analysis according to graphite industry standards in our own labs
- Competent interpretation of analytical results
- Development of applications according to lab results
- Guidance, execution and supervision of special graphite tests in labs or in pilot plants at external institutes

Trade

- Trade with different Carbon and Graphite products
- Natural graphite, synthetic graphite and other carbon products; focusing on specialties like expandable graphite, GNP...
- Close cooperation with several producers
- Development of tailor-made grades



FAST-TRACKING PREMIUM QUALITY GRAPHITE TO DEVELOPMENT

kibaran
resources

ASX: KNL

- **World-class graphite assets in Tanzania**
Epanko Graphite Project
 - Bankable Feasibility Study completed
 - Off-take agreement signed with ThyssenKrupp for 20,000tpa
 - Off-take agreement signed with major European graphite trader for 10,000tpa
 - Annual production of 40,000tpaMerelani and Tanga as further projects

The outlook for Electric Vehicles (EVs) and future potential demand for graphite

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EVs: current market situation

Arrangement of propulsion concepts into classes

	Combustion Engine				Hybrids			Electric Vehicle			
	Diesel, Otto, optimized engine, alternative fuels. Concepts A, B, C, D				Full Hybrids, Mild Hybrids Concepts E, F			PHEV, REEV, BEV Concepts G, H, I			
	A	B	C	D	E	F	G	H	I	J	K
Identifier	SI engine, conventional	CI engine, conventional	(HEV) Subhybrid	HEV Microhybrid	HEV Mild Hybrid	HEV Full Hybrid	PHEV Full Hybrid	PHEV Range Extender ICE	EV	PHEV Range Extender Fuel Cell	Fuel Cell Hybrid
Drivetrain Structure											
Primary Energy Source	Hydrocarbons	Hydrocarbons	Hydrocarbons	Hydrocarbons	Hydrocarbons	Hydrocarbons	Hydrocarbons	Electricity (from grid)	Electricity (from grid)	Electricity (from grid)	Hydrogen
	Advanced, high efficiency si- and diesel technology; alternative fuels: CNG, LPG and even more		Additionally to A or B: start-stop-function by conventional equipment	Additionally to A or B: start-stop-function, with belt driven starter-alternator	Additionally to A or B: regenerative braking, acceleration assistance by integrat. SA	Instead of E: electric launch, acceleration assistance electric driving	Additionally to F: larger battery, plug-in-capability	Propulsion energy stored in the battery, only small ICE to recharge onboard	No onboard recharge unit.	Energy stored in the battery, only small fuel cell and hydrogen to recharge	PEM fuel cell produces electricity from hydrogen

Data source : wikipedia/hastdutoene

EVs: current market situation

Facts*:

- in January 2012 globally less than 100 000 electrical powered cars on the roads
- in January 2015 globally over 740 000 electrical powered cars on the roads
- Most popular el. cars are Nissan Leaf (150 000 sold cars), Chevrolet Volt (75 000), Toyota Prius (60 000) and Tesla S (50 000)
- Nissan Leaf, Tesla S and Mitsubishi Outlander Plug-In headed up the registration statistics in 2014
- Beginning of 2015, in the US 290 000 electrical cars were registered , country No. 2 was Japan (100 000 units) followed by China (95 000)
- Germany: 30 000 el. cars
= 0,07% of all cars
- Norway: 44 000 el. cars
= 1,6% of all cars
- What the leading countries have in common is having market incentives in place

* only full electric drives, range extenders and plug-in hybrids are considered in this facts overview

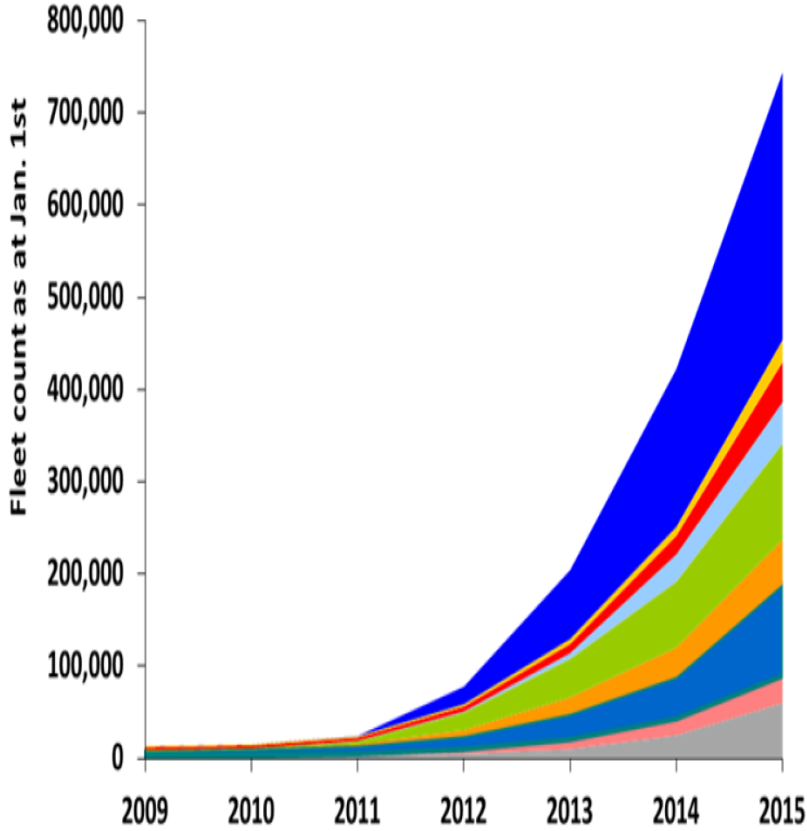
Data source: ZSW Germany

TESLA GIGAFACTORY

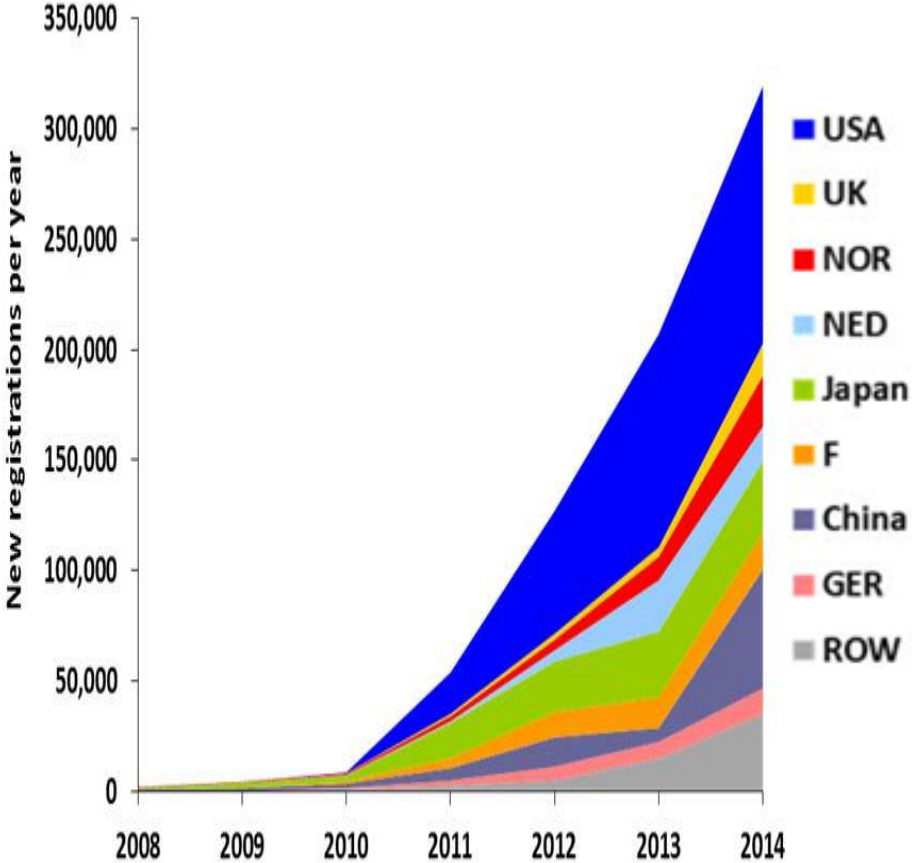
50 GWh in annual battery production by 2020
Enough for 500,000 Tesla cars
Employing 6,500 people
Powered by renewable energy
Net zero energy factory



EVs: current market situation



Number of electric cars worldwide on January 1, 2015



New registrations per year

only full electric cars, range extenders and plug-in hybrids

Data source and Graph: ZSW Germany

EVs: market outlook

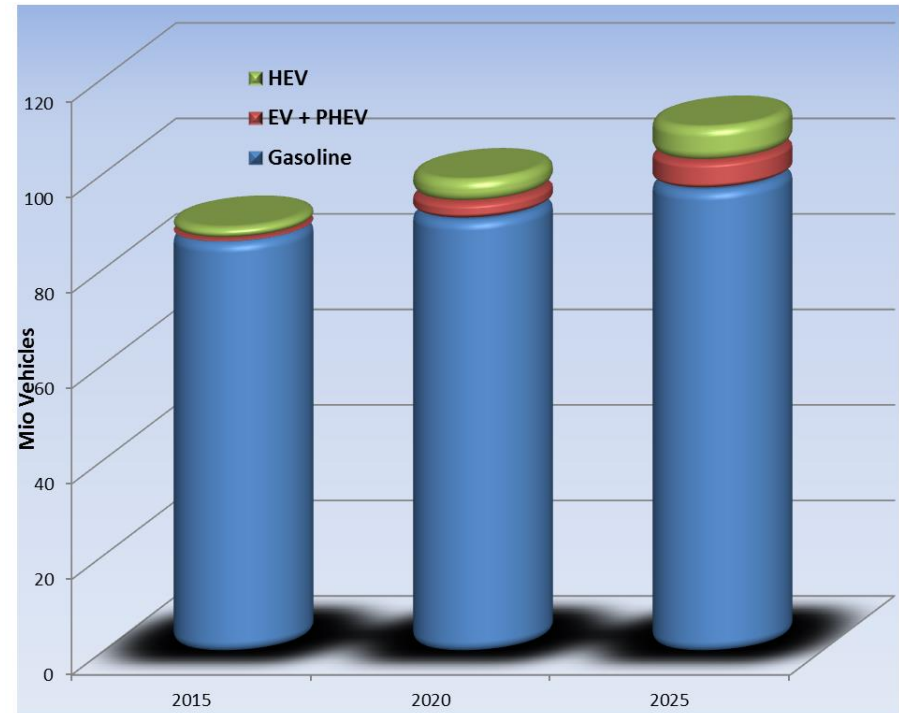
The author Mark Twain stated that "*The art of prophecy is very difficult, especially with respect to the future*". For EVs this is very true, especially because of the important influence of governmental market incentives and other factors like the price of oil, pressure for CO₂ reduction....

Many prognosis on the future market for EVs are available, the spread between the conclusions is enormous.

A balanced approach could look as follows:

	2015	2020	2025
	Mio	Mio	Mio
total new cars	89	99	110
Gasoline	85,8	90,4	96,7
EV + PHEV	0,8	3,9	6,2
HEV	2,4	4,7	7,1
Sum Evs	3,2	8,6	13,3
	%	%	%
Gasoline	96%	91%	88%
EV + PHEV	1%	4%	6%
HEV	3%	5%	6%
Sum Evs	4%	9%	12%

Market Development: Sales of cars



=> Even there are currently limiting factors for a wider spread of EVs (low range of battery, long loading time and high investment for EVs); the Number of sold EVs will almost triple within next 5 years; growth especially for pure EVs and PHEV

compiled with Data from : Avicenne, Bosch and others

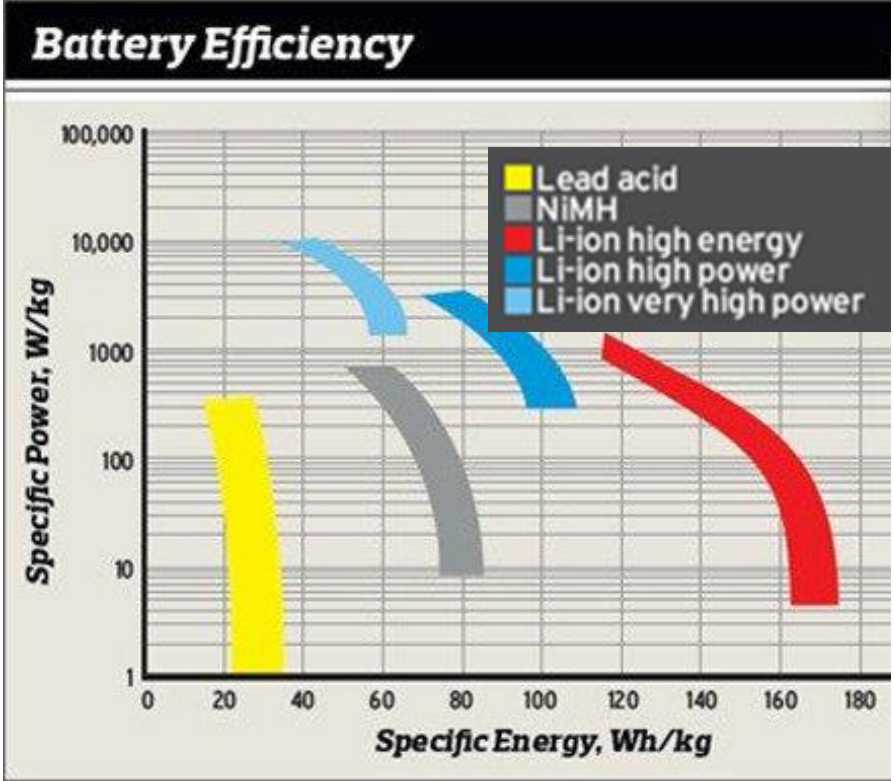
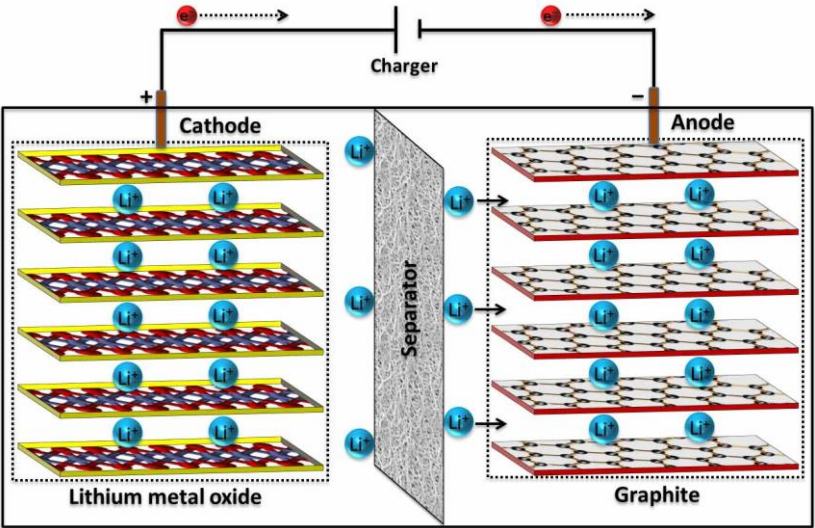
Battery technology for EVs

Which type of battery is most suitable for EVs?

Li-Ion-Batteries are most suitable for EVs

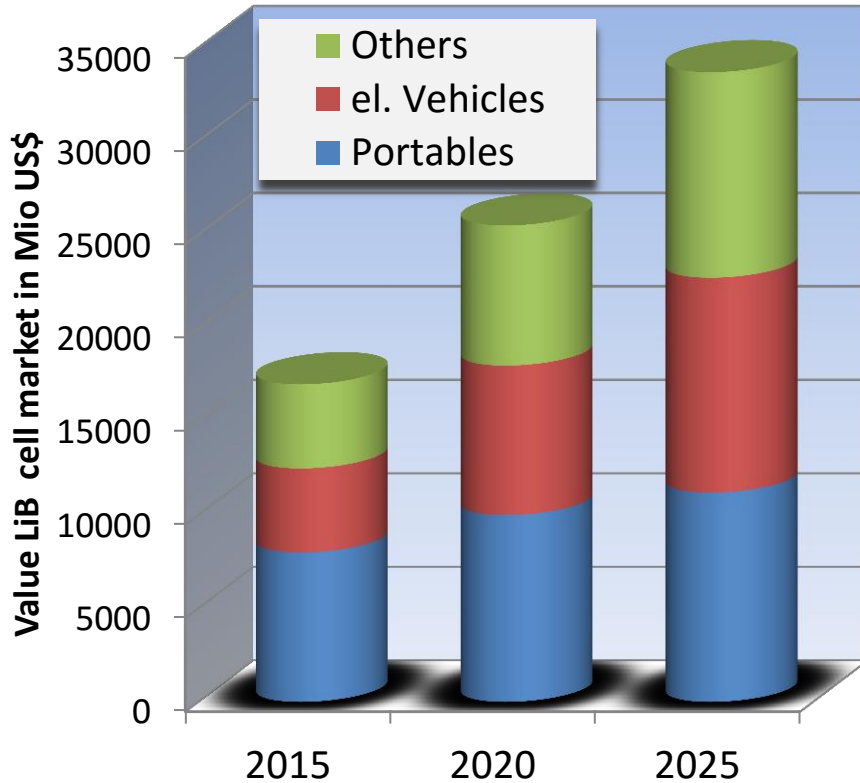
Criteria:

- high capacity
- low cost
- high energy density
- high safety
- reliability
- environmentally friendliness
- high voltage
- high power delivery
- longevity
- high cycle stability
- climate tolerance
- low self discharge
- no memory effect
- flat discharge voltage



Market for Li-Ion- Batteries

But: Li-Ion Batteries are not limited to EVs....



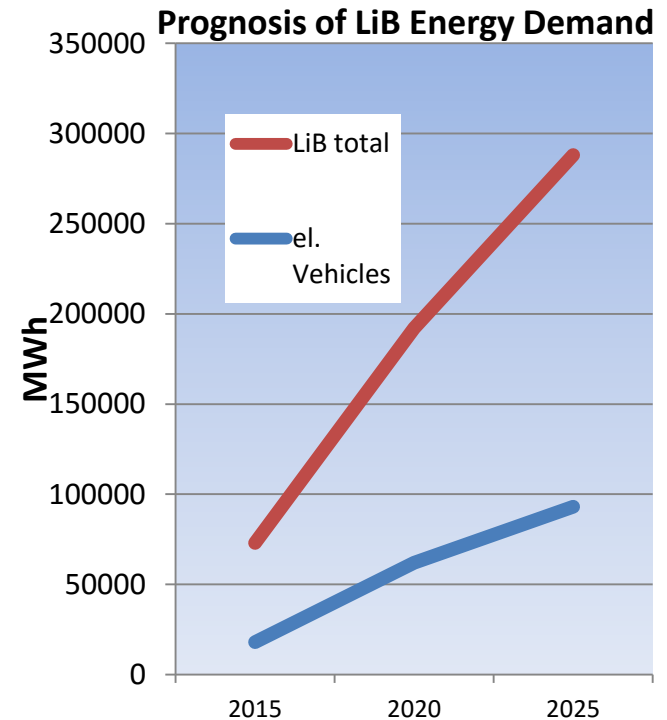
Portables: Laptops, Tablets, Cell Phone, Camcorder, etc.
Others: E-Bikes, Powertools, Telecom, ESS, Medical Devices etc.
el. Vehicles: HEV, PHEV and EV

Data source: Avicenne, own research

Growth rate for value of LiBs

	2020	2025
Portables	5%	3%
el. Vehicles	12%	10%
Others	11%	9%
LiB total	8%	7%

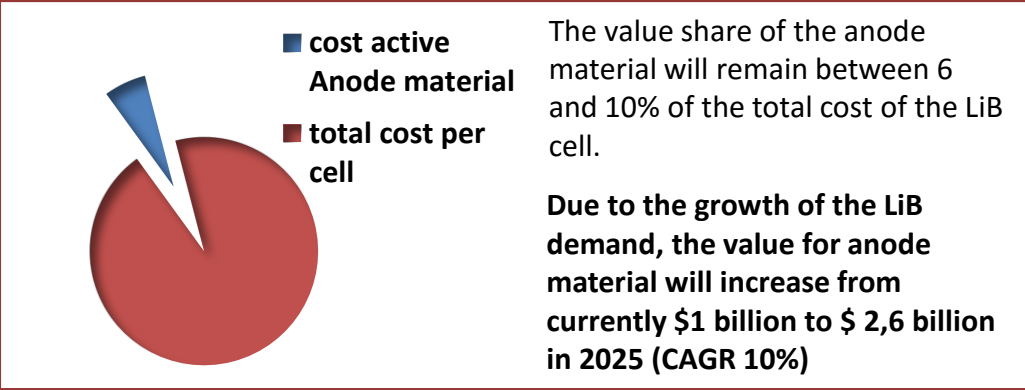
CAGR based on 2015 values



Energy demand: CAGR > 10%

=> US\$/kWh is decreasing from \$300-400 to \$200 in 2020

Graphite in Li-Ion Batteries



Graphite is the dominant Anode Material for LiB

- current market share of graphite above 90%
- thereof: approx. 55% natural, 45% synthetic
- currently oil price low => increase in usage of synthetic graphite, especially for consumer electronics
- other anode materials include LTO, MCMB, hard and soft carbon
- often mixture of different types of graphite / carbon in one cell
- advantages Natural Graphite vs. Synth. Graphite: lower price, higher energy density (EV!)

But: Synth. Graphite more customizable

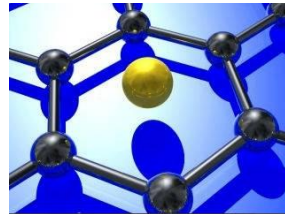
Material	Energy	Life	Power	Safety	Cost
Artificial Graphite	+	+	0	+	0
Natural Graphite *	++	0	0	+	++
Meso Phase Artificial Graphite	0	++	++	++	0
Hard Carbon	0	++	++	++	0
Soft Carbon	0	+	++	++	+

Sources: Hitachi Chemical, Sanyo, Porsche, own research

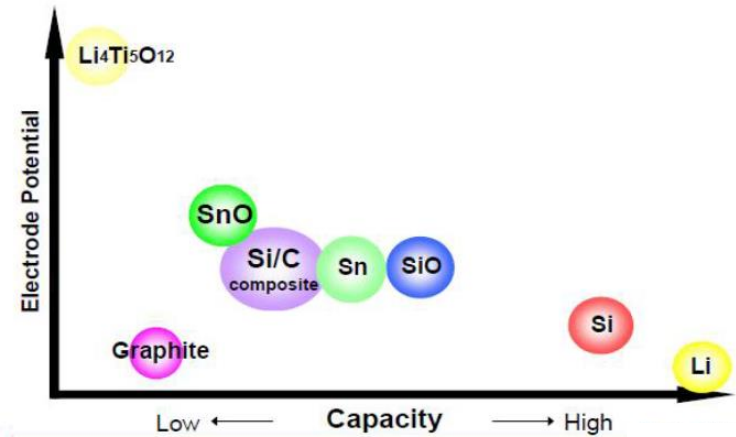
Graphite in Li-Ion Batteries

New Developments for the Anode

- New Developments on the way but it takes years from research -> mass production
- Last 5% of research most challenging!
- New materials: Si (already used as C-compound with 1-5% Si), Sn, Li-Metal, Graphene, Al, Carbon Nanotubes...
- For each new type still massive problems to be solved
- Pressure for new materials:
 - lower cost for batteries
 - higher capacity
 - smaller volume
 - less weight



LIB Anode Materials

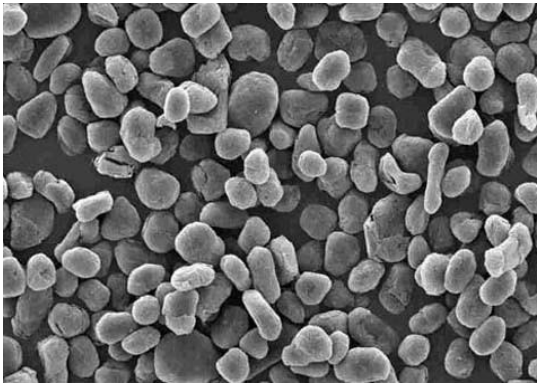
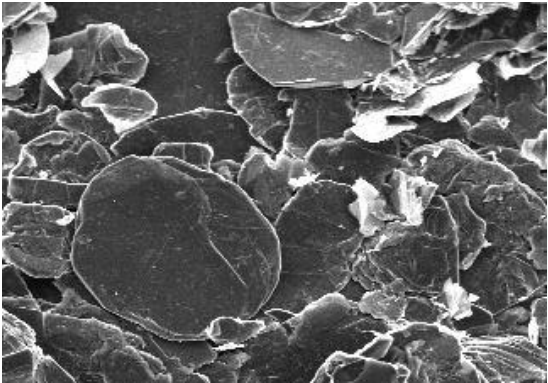
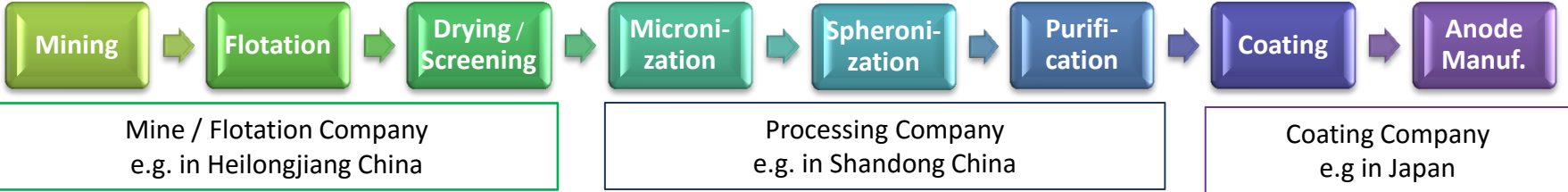


Prototyp of a new LiB with Lithium-Metal as electrode and a solid polymer as electrolyte

Battery-pack in „VW up!“ nowadays: 230 kg for 19 kWh
 With a battery like the Bosch model left, the volume could be reduced by 75%, weight would be half; lower cost, extended range

Natural Graphite for LiB

Process Flow for Production of Spherical Natural Graphite from the Mine to the Anode producer



Flake graphite is converted from a raw material into a sophisticated high tech product

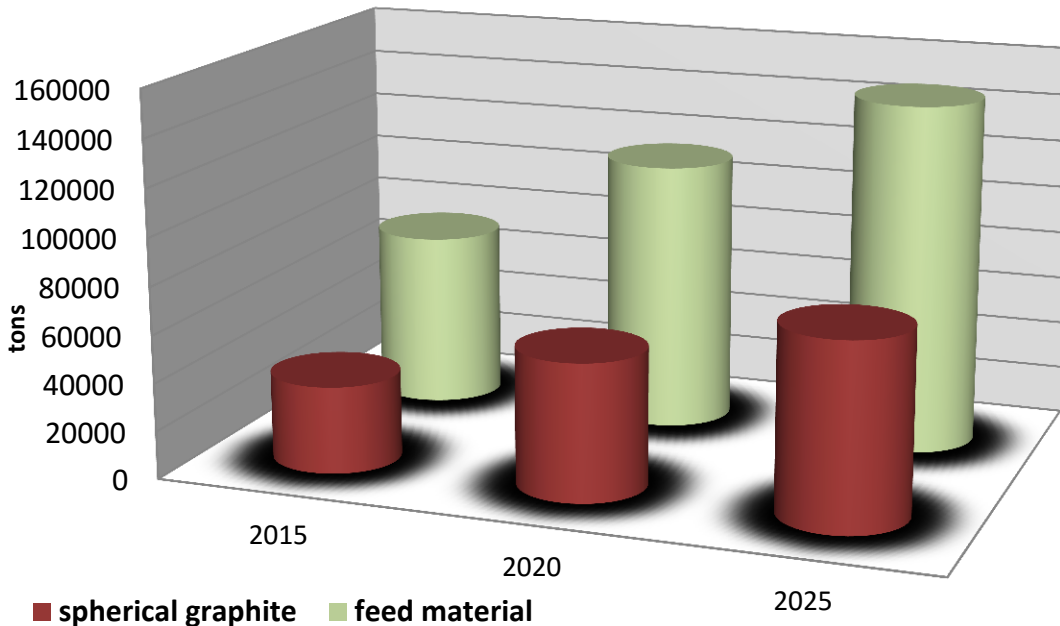
- Very strict quality requirements for spherical graphite

- Graphite needs to be suitable, like high bulk density, good purification behavior

- Infrastructure needs to be suitable: cheap consumables, electricity, skilled labor....

Forecast of the graphite demand for production of LiB

		2015	2020	2025
Anode material needed for LiB	k tons	70	160	270
market share graphite as anode material		95%	91%	88%
spherical graphite needed	k tons	67	146	238
thereof share of natural graphite		55%	50%	50%
spherical natural graphite needed	k tons	37	73	119
yield spherical graphite from feed		50%	51%	53%
natural graphite needed as feed	k tons	73	143	224
additional demand of nat. graphite vs. 2015	k tons		70	151
CAGR based on 2015			14%	12%



Demand of natural spherical graphite and necessary quantity of feed material (flake graphite) 2015-2025

data: ProGraphite GmbH

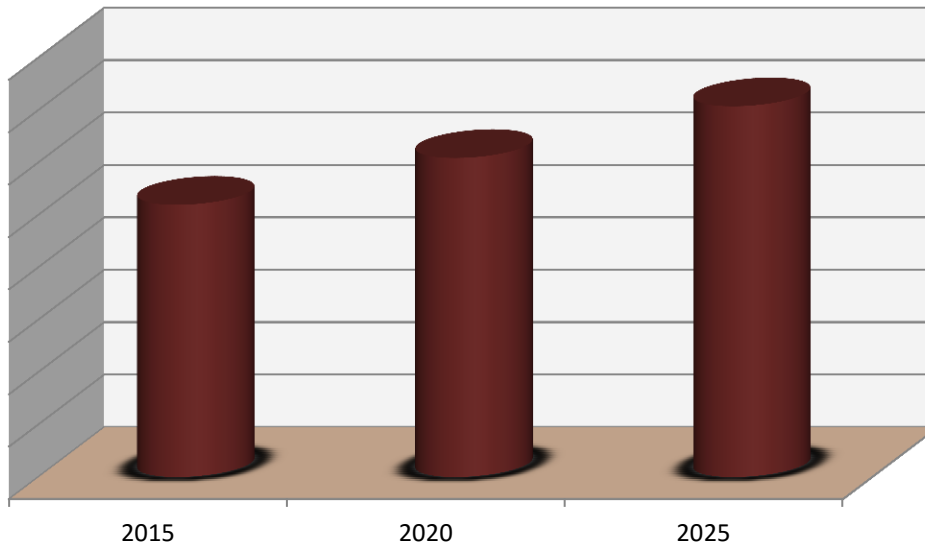
Future potential demand for natural graphite

Outlook for Natural Flake Graphite

- Flake Graphite demand will increase, because of
 - Lithium-Ion-Batteries
 - successful other grades (like expandable graphite)
 - special applications (like building insulation)
- In 2020 approx. 90 k tons additional production could be required
- Until 2025 another 100 k tons additional production could be required
- It is unclear, how much will be covered by China (current market share of China = 70%)
- Customers would like to source spherical graphite but also traditional graphite grades from outside China.
- China also could reduce its output of commodity grades which would lead to further demand for production outside China.



Flake Graphite Demand



There is good opportunity for new graphite mine developers like Kibaran Resources to find a good market, provided quality and price are competitive.

data: ProGraphite GmbH

**Thank you!
Questions?**

Pro**Graphite** 

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