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Graphite demand growth: the future of lithium-ion batteries in EVs and HEVs

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Summary

- Overview of the graphite market
- Lithium-ion battery trends and applications
- Lithium-ion batteries in EVs and HEVs
- Recent and future trends in the uptake of EVs and HEVs
- Graphite consumption in lithium-ion and other batteries
- What does the future hold for the graphite industry?
- Summary

Overview of the graphite market

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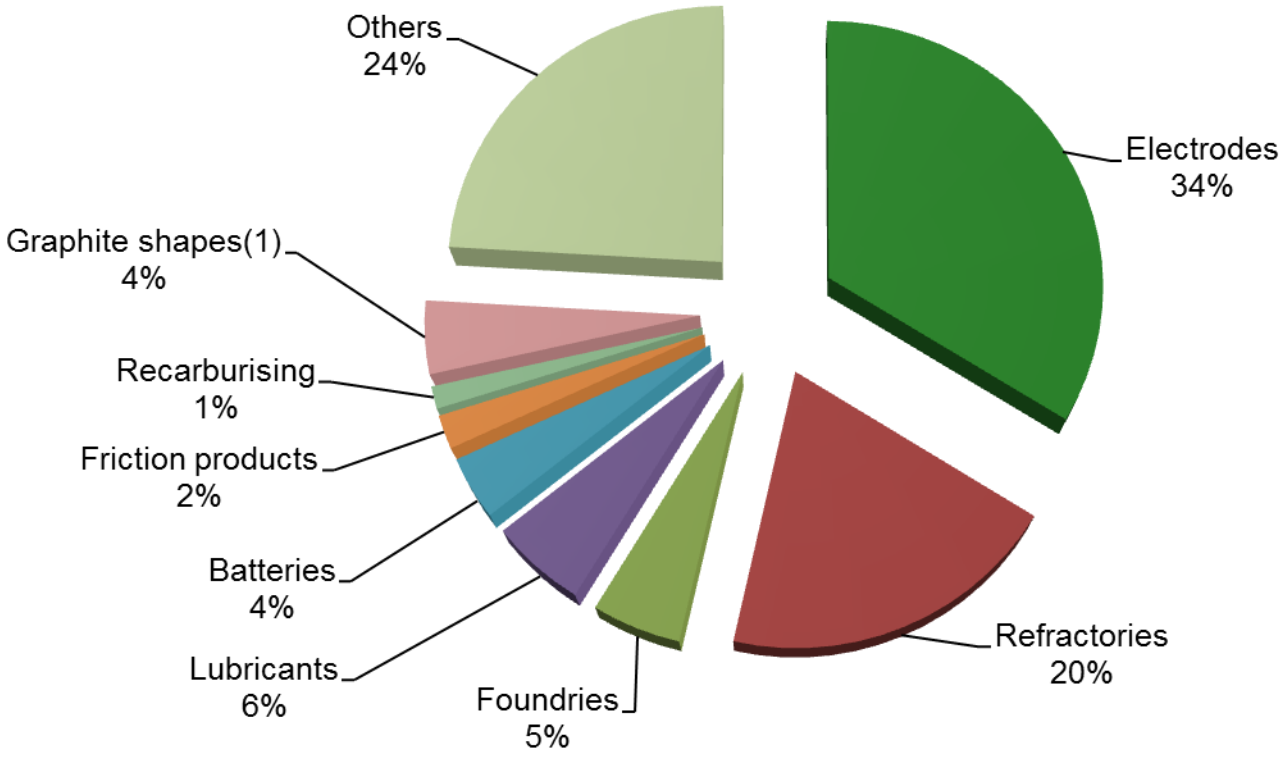
Global graphite demand, 2012



Source: Roskill estimate
Note: 1-Including specialty synthetic products

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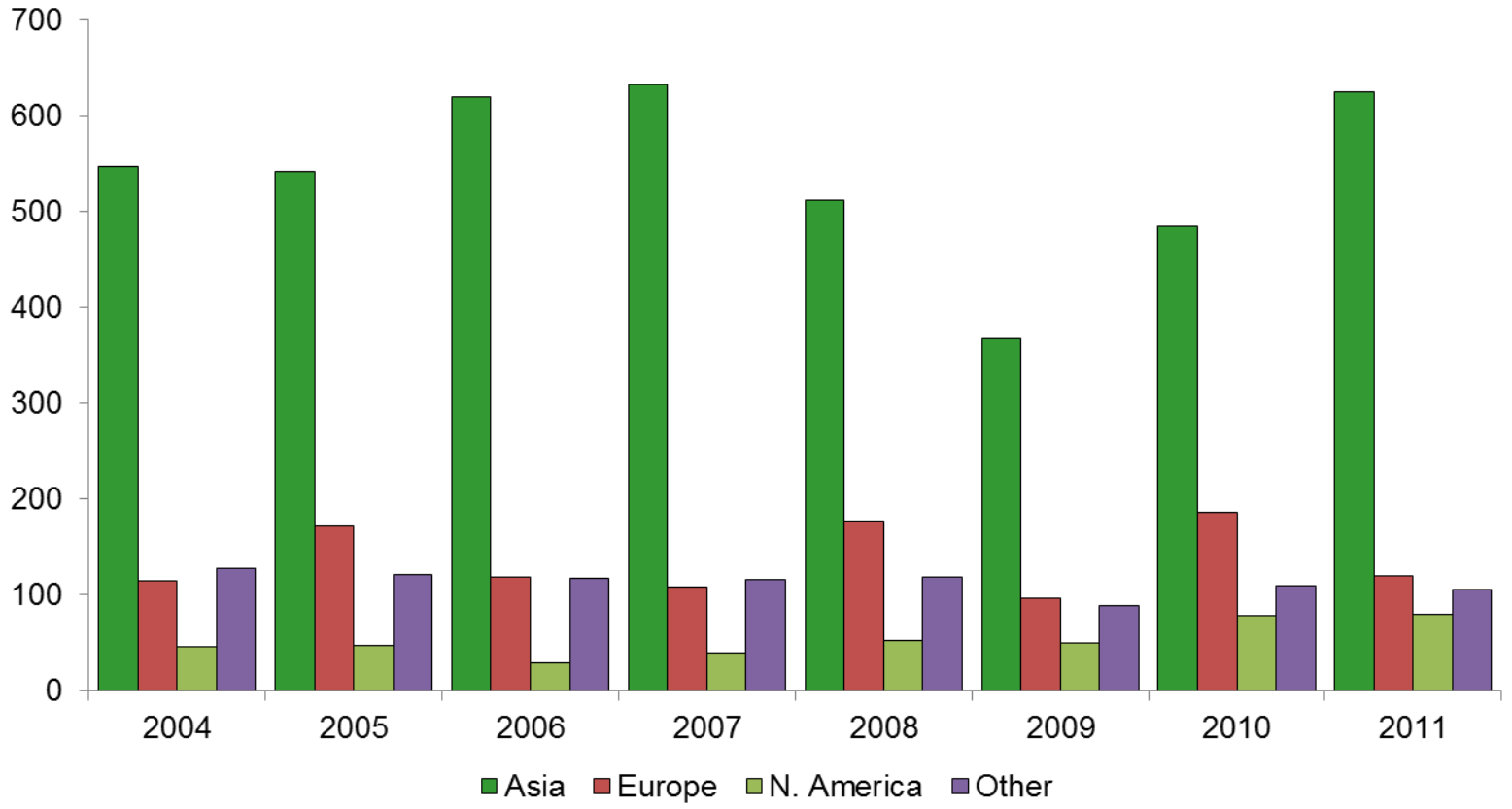
Regional demand for graphite, 2004-2011 (kt)



Source: Roskill estimate

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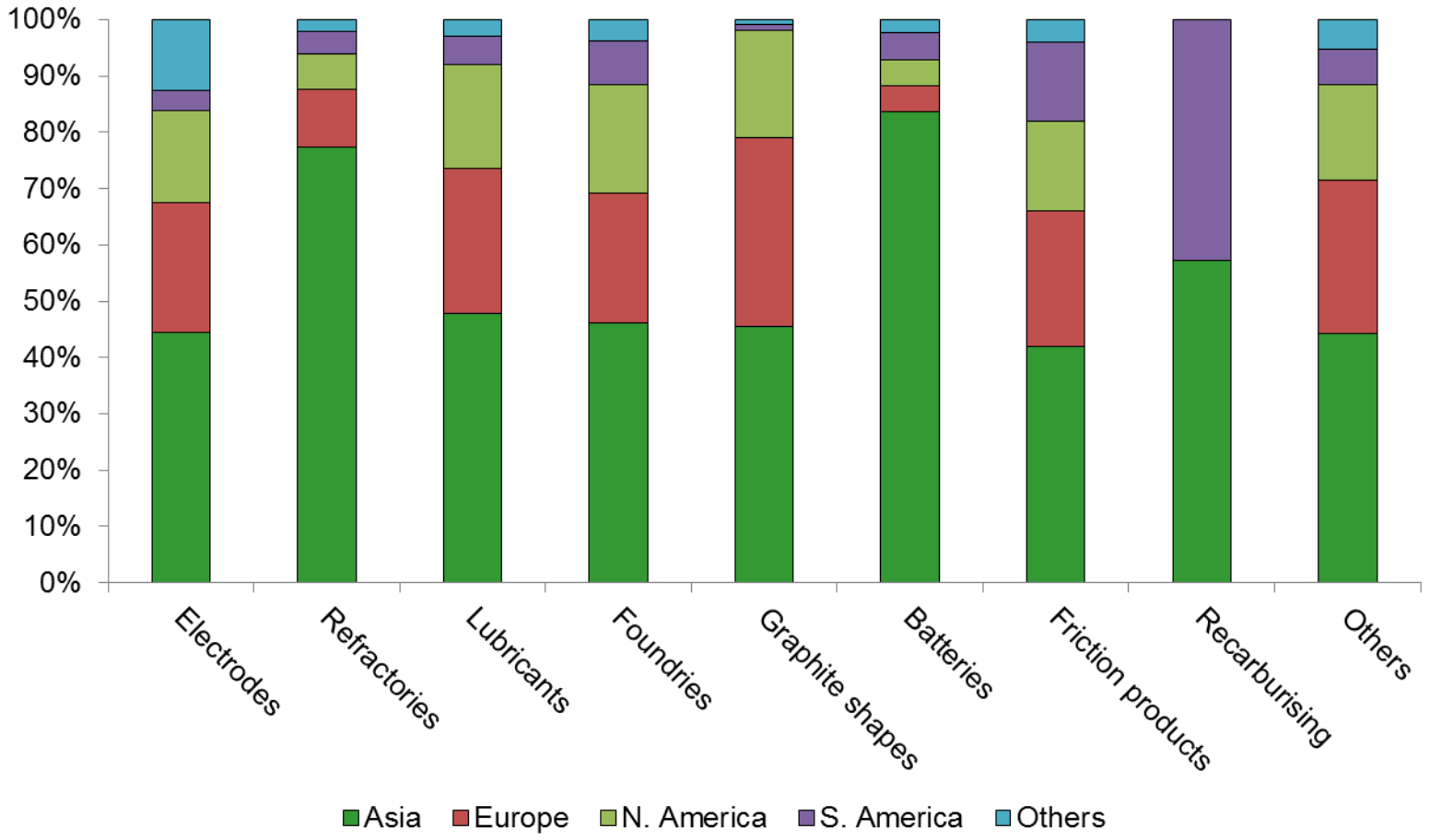
Regional demand for graphite by end-use, 2011



Source: Roskill estimate

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Global graphite market overview, 2012

- Global demand for graphite was 2.50Mt and production 2.26Mt (constrained amorphous production in Hunan)
- Batteries accounted for ~95,000t of graphite demand (68% natural and 32% synthetic)
- By far the largest graphite demand for use in batteries comes from Asia, around 50-55%
- Graphite demand is recovering as we come out of the global economic downturn
- Future demand could increase significantly if EVs and HEVs take off

The role of lithium-ion batteries

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Lithium-ion Vs. NiMH

Typical properties of NiMH and Li-ion battery systems		
	NiMH	**Li-ion**
Nominal voltage (V)	1.2	3.7
Positive electrode	Nickel hydroxide	Lithium-cobalt oxide
Electrolyte solution	Potassium hydroxide	Organic electrolyte
Negative electrode	Hydrogen absorption alloy	Carbon
Energy density		
(Wh/l)	200	370
(Wh/kg)	80	170
Temperature range (ºC)	-20 to 60	-20 to 60
Advantages	heavy duty use	heavy duty use
	no heavy metals	high voltage
	high capacity	no memory effect
	charge cycle of 500	low self-discharge
Applications	portable OA equipment	portable OA equipment
	portable AV equipment	portable AV equipment
	power tools	radiotelegraphic systems
	medical instruments	cameras
	electric cars	electric cars

Source: Roskill estimate

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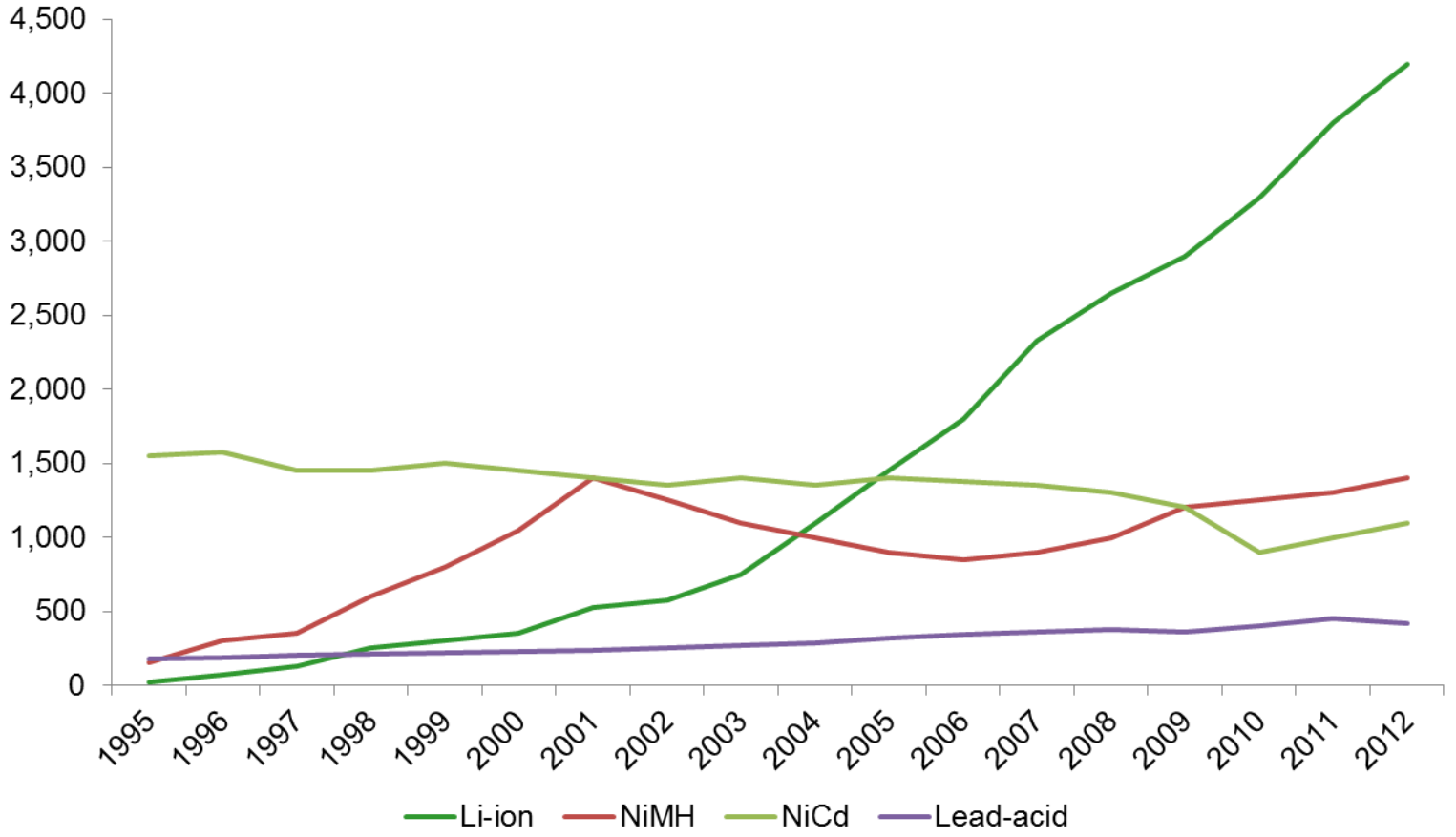
Global secondary battery production (M cells)



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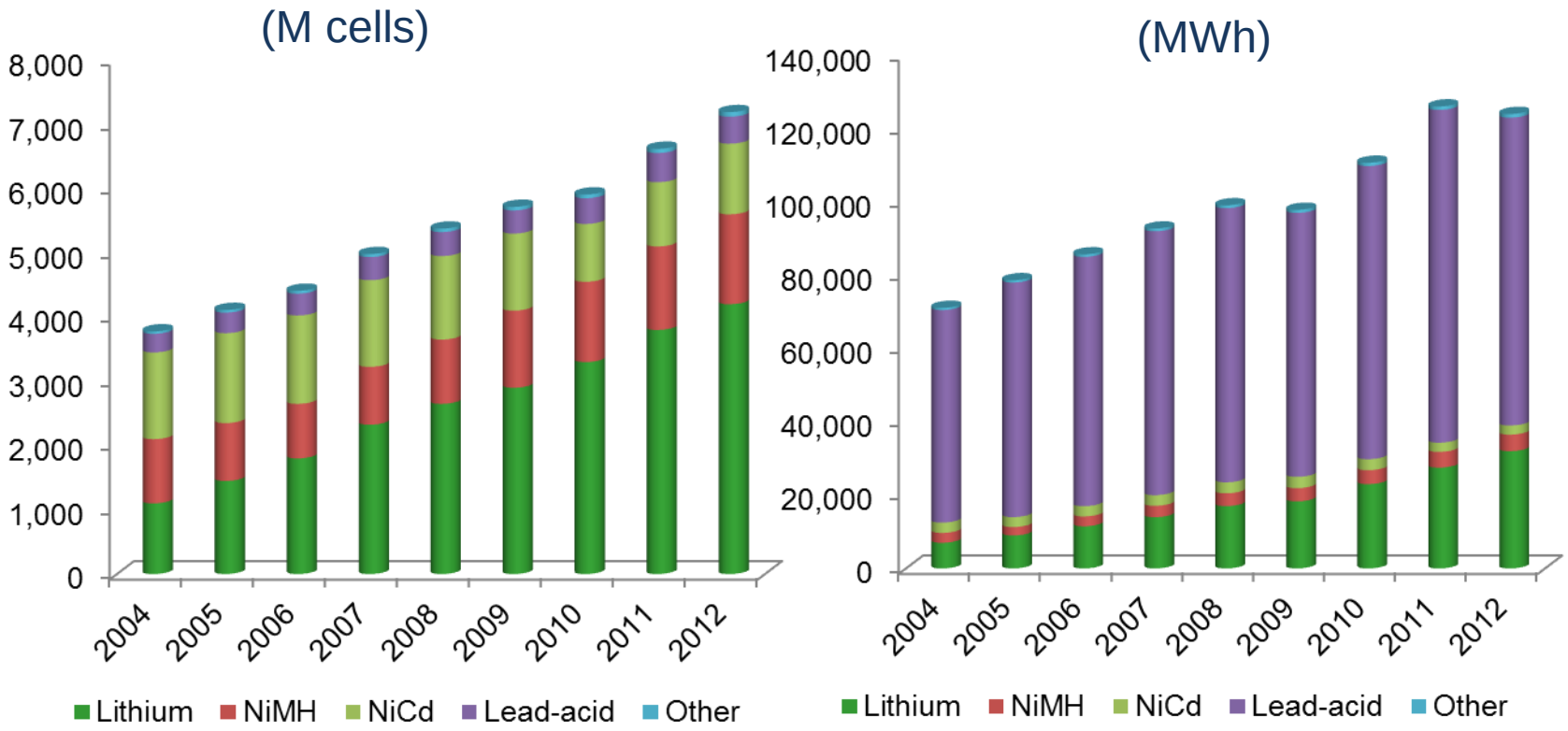
Global secondary battery production



Source: Roskill estimate

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Regional secondary battery production (M cells)

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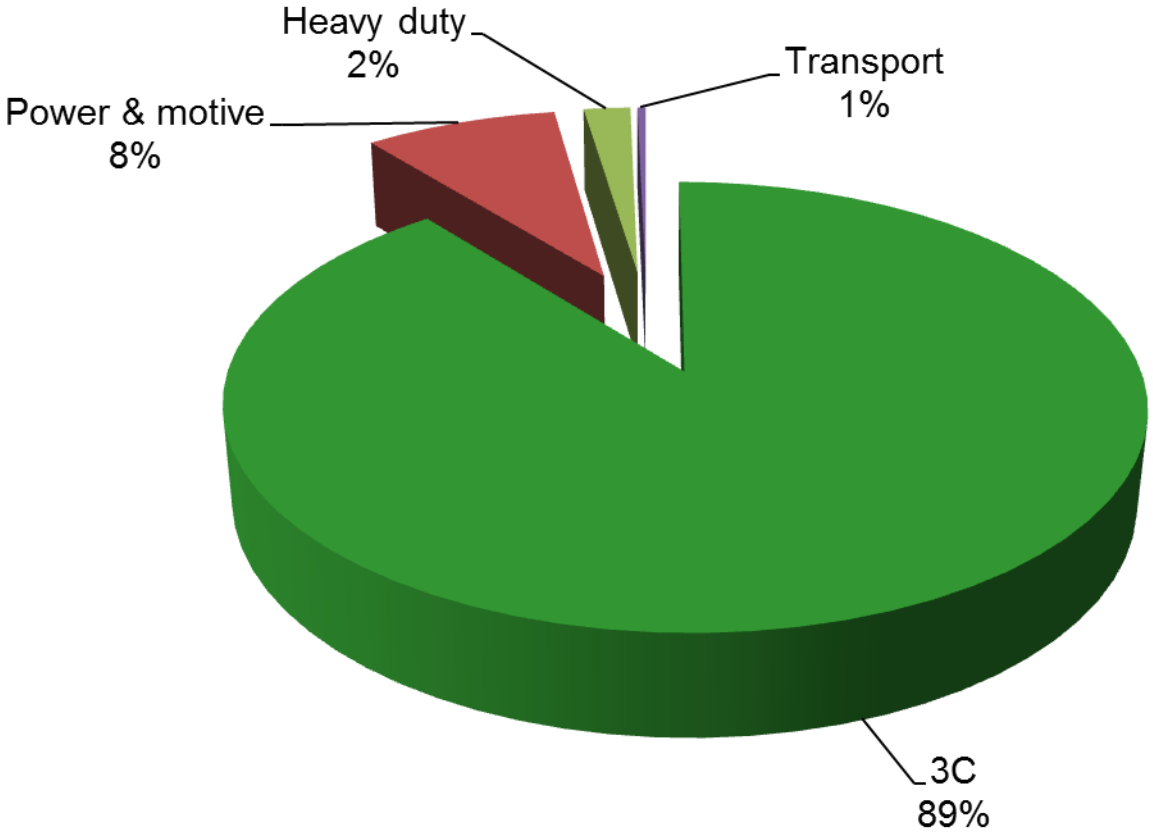
Global secondary battery consumption, 2012



Source: Roskill estimate

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EV and HEV applications for lithium-ions

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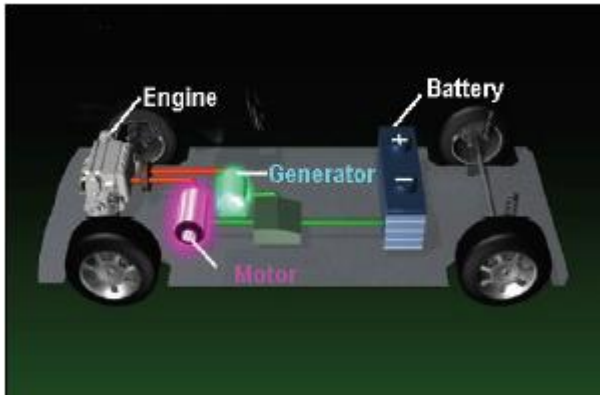
Different HEV and EV technologies

- HEV – hybrid electric vehicle:
  - battery supplements engine
  - recharge using excess energy from vehicle
  - several types: full, power assist, mild/micro



http://www.pro-zev.com

- PHEV – plug-in hybrid electric vehicle:
  - recharge from external source
  - small engine to charge battery during use

- EV – electric vehicle:
  - powered only by battery
  - recharge from external source
  - limited distance

Source: Magna international

Why use batteries in cars?

- HEVs/EVs offer better fuel efficiency
- Operating costs are also lower for HEVs/EVs (although initial purchase cost is higher)
- Increasing environmental legislation on a global scale
- Consumers choosing to be green
- Battery systems are smaller and lighter than a traditional engine

Energy density of vehicle fuels and batteries

Energy source	Nominal energy density (Wh/kg)
Hydrogen	28,000
Gasoline	12,300
Natural gas	9,350
Coal (bituminous)	8,200
Methanol	6,200
Lithium-ion battery (various types)	110-160
Nickel-metal hydride battery	60-120
Lead-acid battery (sealed)	30-50

Source: Electric Vehicle Technology and Cadex Electronics

EU Emission standards for passenger vehicles (g/km)

Directive	Date	CO	THC	NMHC	NOx	HC+NOx	PM
Diesel vehicles							
Euro 1	Jul 1992	2.72	…	…	…	0.97	0.14
Euro 2	Jan 1996	1.0	…	…	…	0.7	0.08
Euro 3	Jan 2000	0.64	…	…	0.50	0.56	0.05
Euro 4	Jan 2005	0.50	…	…	0.25	0.30	0.025
Euro 5	Sep 2009	0.500	…	…	0.180	0.230	0.005
Euro 6	Sep 2014	0.500	…	…	0.080	0.170	0.005
Petrol vehicles							
Euro 1	Jul 1992	2.72	…	…	…	0.97 (1.13)	…
Euro 2	Jan 1996	2.2	…	…	…	0.5	…
Euro 3	Jan 2000	2.3	0.20	…	0.15	…	…
Euro 4	Jan 2005	1.0	0.10	…	0.08	…	…
Euro 5	Sep 2009	1.000	0.100	0.068	0.060	…	0.005[2]
Euro 6	Sep 2014	1.000	0.100	0.068	0.060	…	0.005[2]

Source: DieselNet

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Trends in vehicle production

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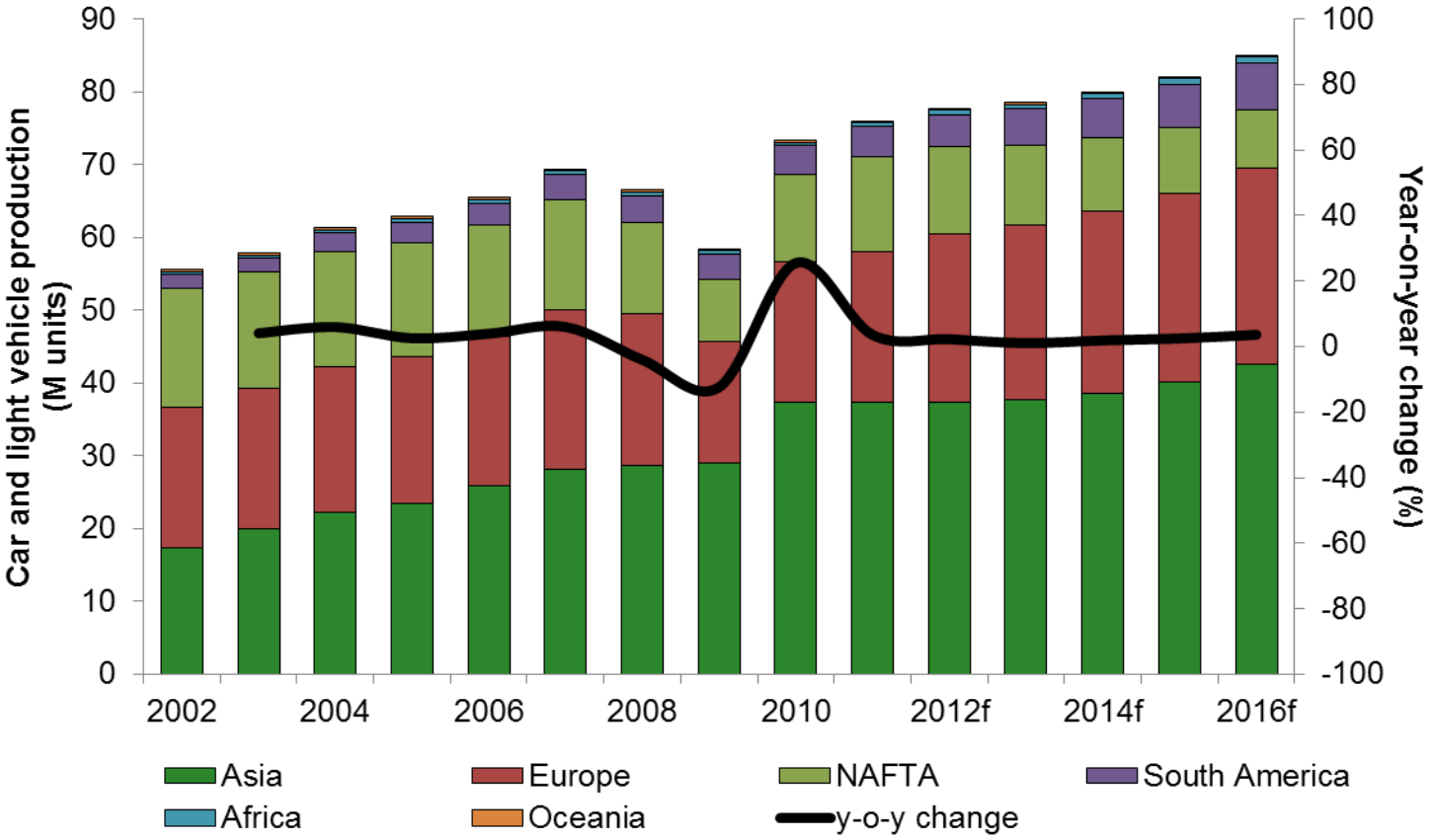
World: Production of cars and light vehicles (M units)



Source: Roskill estimate

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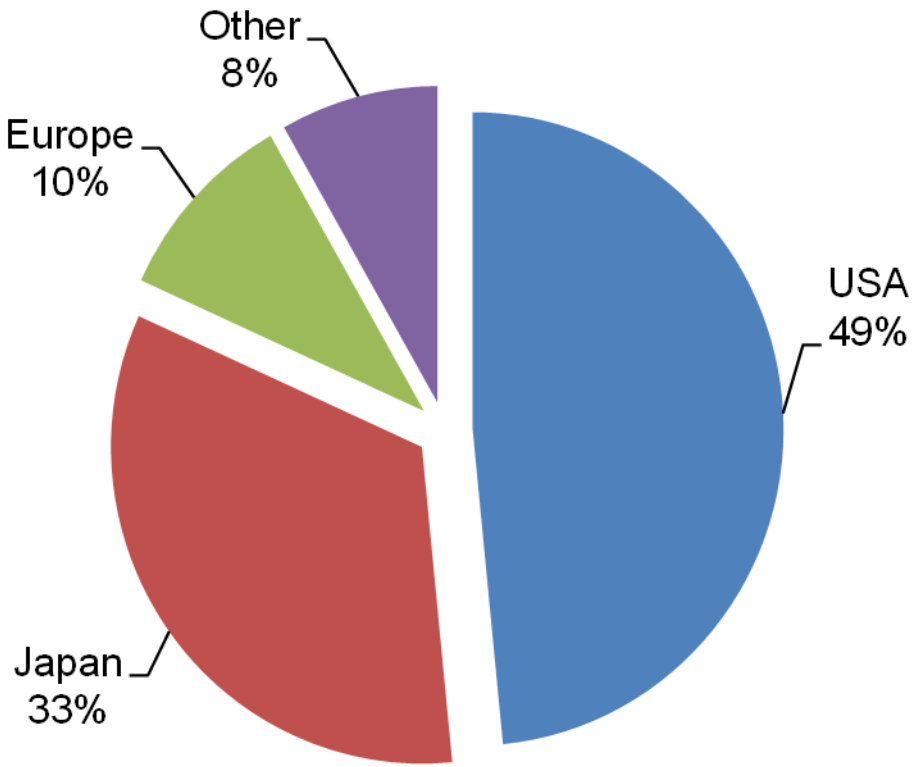
Regional estimated cumulative HEV sales, 2011



Source: Roskill estimate

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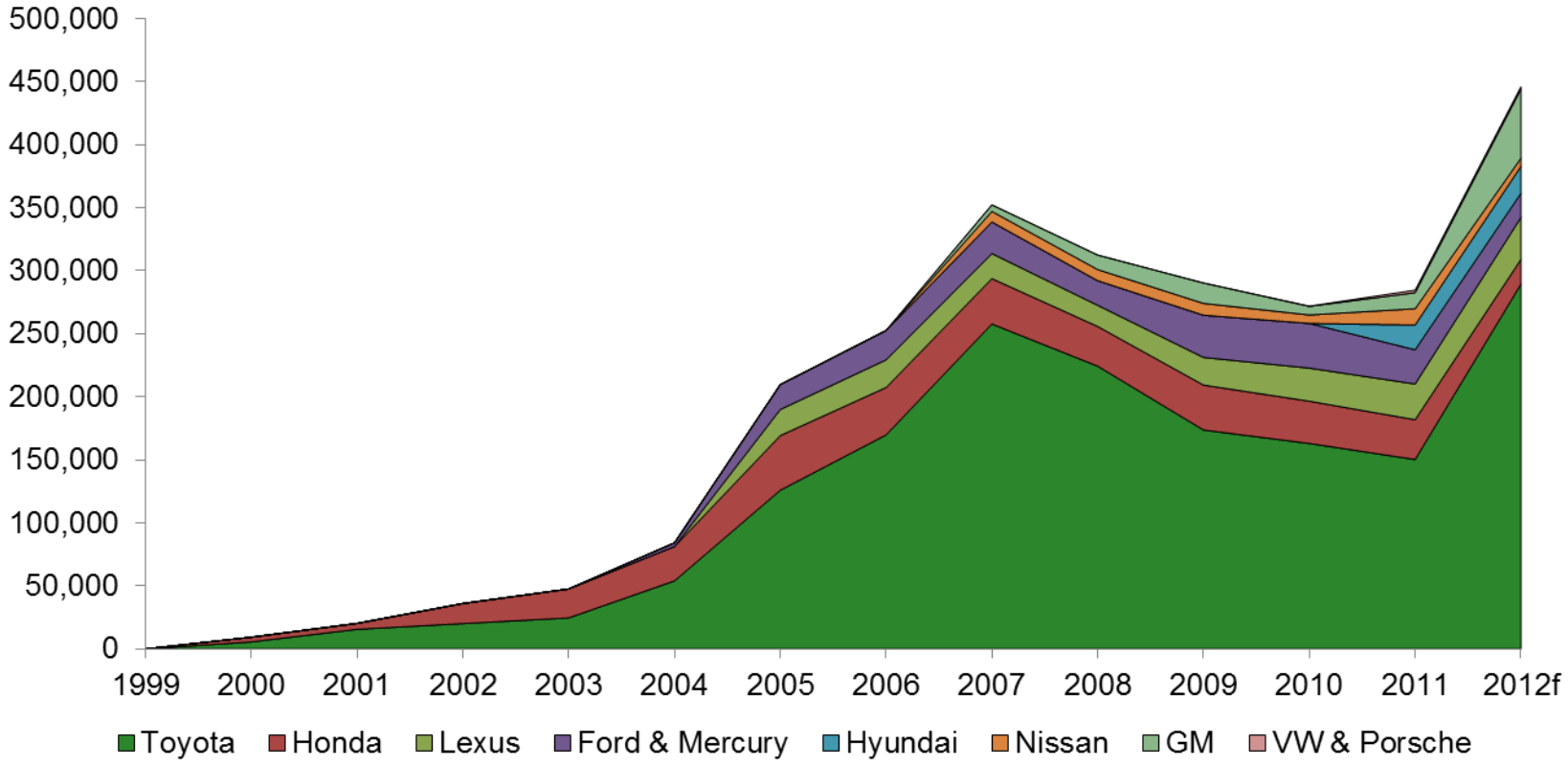
USA: Sales of HEVs and PHEVs by major manufacturer



Source: Arnold Magnetic Technologies

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Overview of the current EV/HEV market

- HEV/EVs account for just 1-2% of total vehicle production
- The USA is home to the largest number of alternative energy vehicles, followed by Japan and Europe
- China was seen as the future, but growth has been slower than expected
- Only 1 Prius was sold in China in 2010, while sales of high-status sports utility vehicles increase (of 13.8M vehicle sales in China in 2010, 6% were SUVs – a 24% growth in SUV sales on 2009)
- Global sales recovered in 2011 following the global economic downturn and increased through 2012

Future growth of EVs and HEVs

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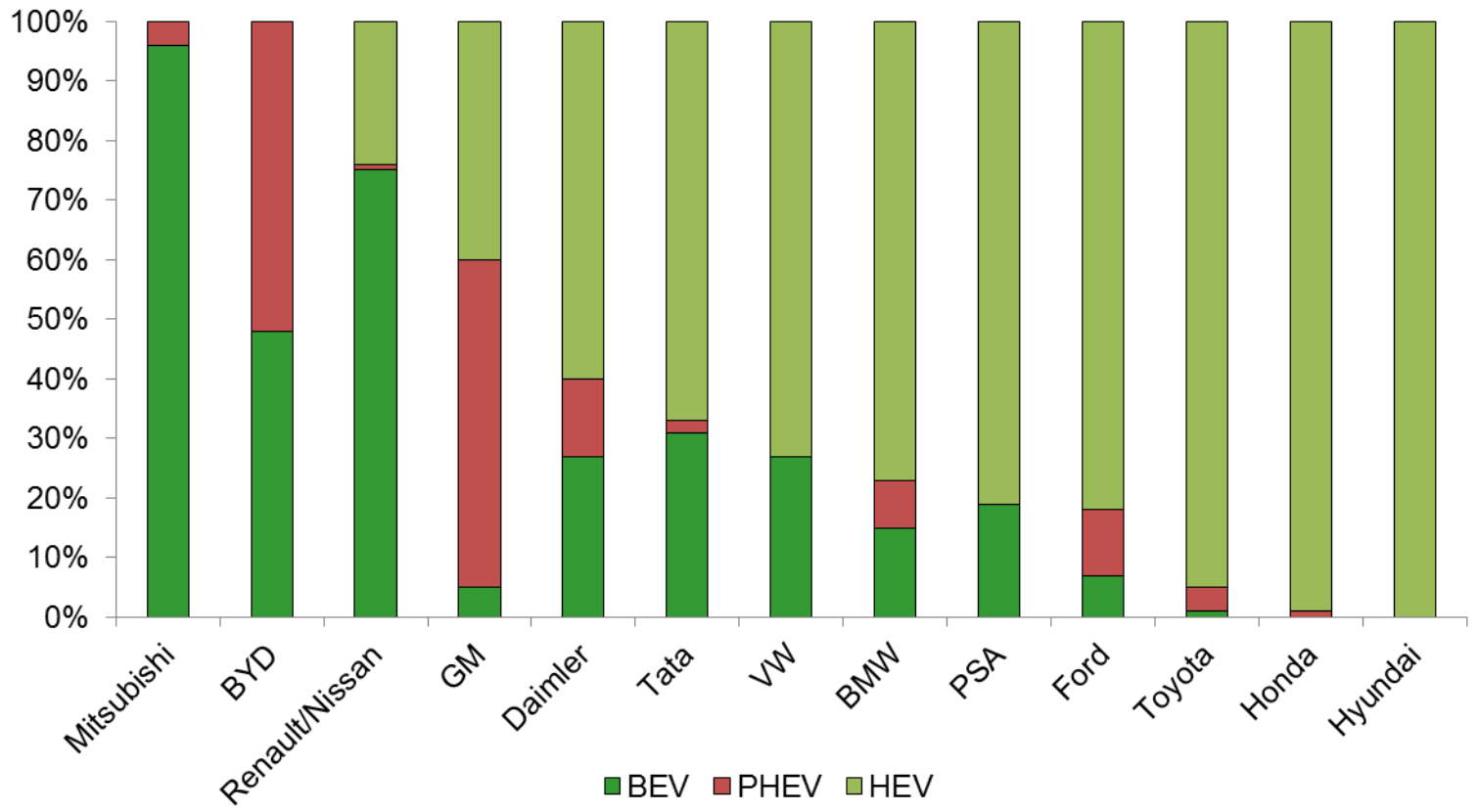
Factors affecting future growth of EVs/HEVs

- Growth rates not as high as some suggest – China is not the future once predicted
- Withdrawal of incentives has already occurred in the USA and new incentives are unlikely in the current economic climate
- However, total vehicle production is increasing
- Continued concern over environmental issues both from consumers and stricter government legislation
- Higher uptake of EVs/HEVs likely from 2015/16 once the global economy recovers. Already seeing increased diversity of models available from manufacturers
- Production of EVs/HEVs could reach 5-8M vehicles by 2020

Forecast sales of BEV, PHEV and HEVs by major manufacturer, 2016



Source: JL Mag

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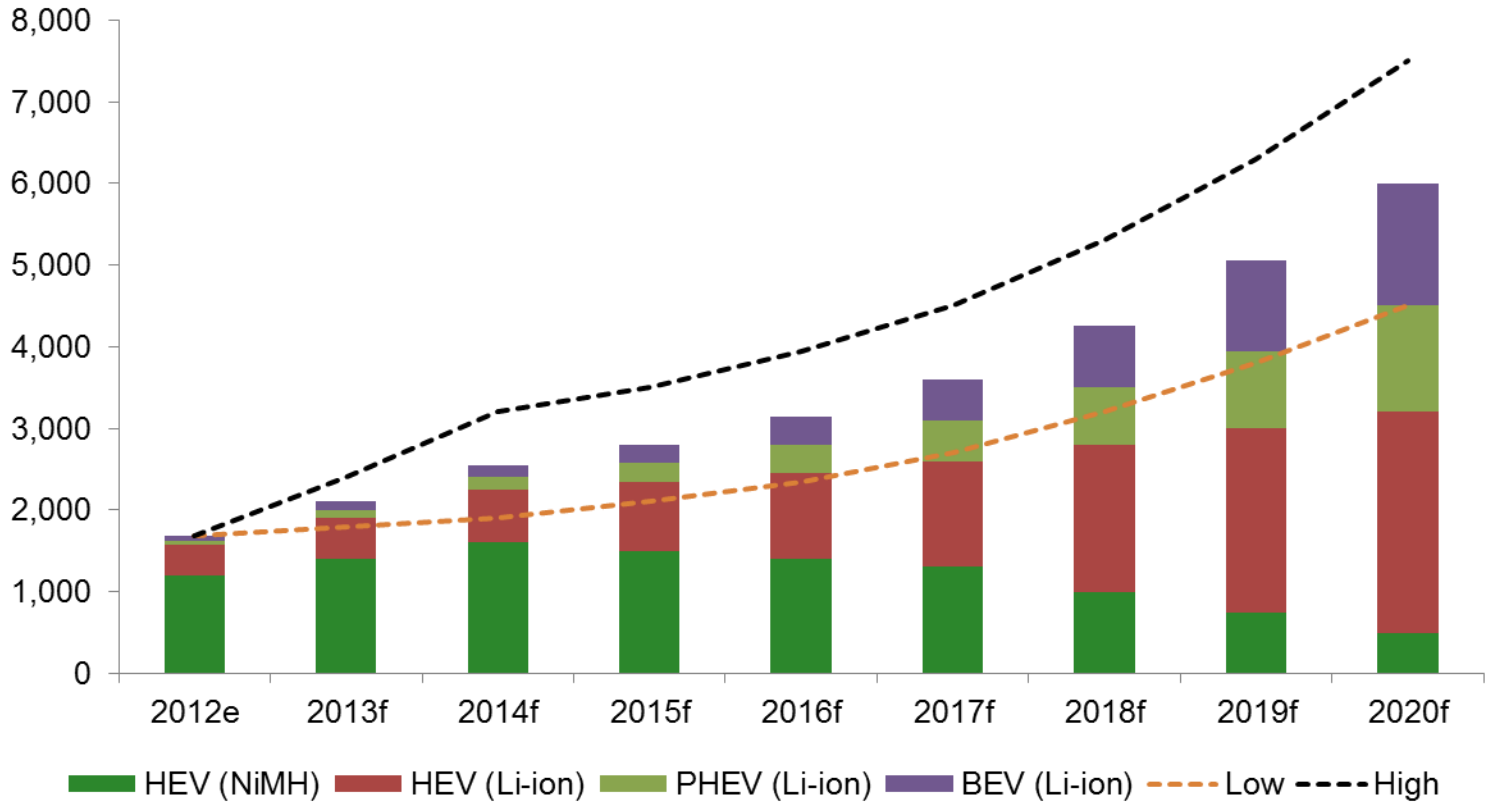
Global forecast production of EVs/HEVs (000’ units)



Source: Roskill estimate

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What does this mean for graphite consumption?

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Major uses of graphite in batteries and fuel cells

Battery type	Use of graphite	Types of graphite
Lithium-ion	Anode - main host material	Primary synthetic, spheroidal flake
Primary alkaline	Cathode - additive	Primary synthetic, purified flake and purified expanded flake
Lead-acid	Anode/cathode - additive	
Fuel cell	Bi-polar plates - main filler material	

Source: Roskill estimate

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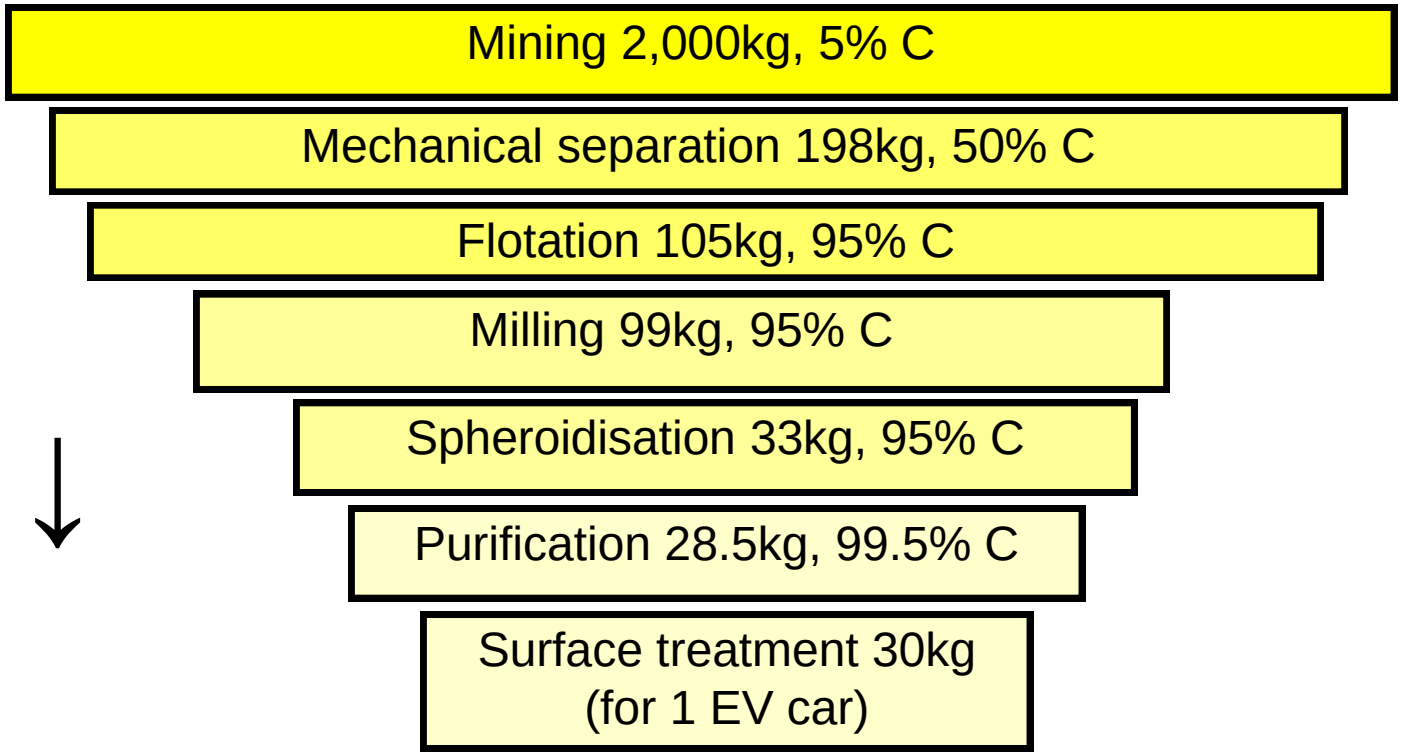
Graphite in Lithium-ion batteries

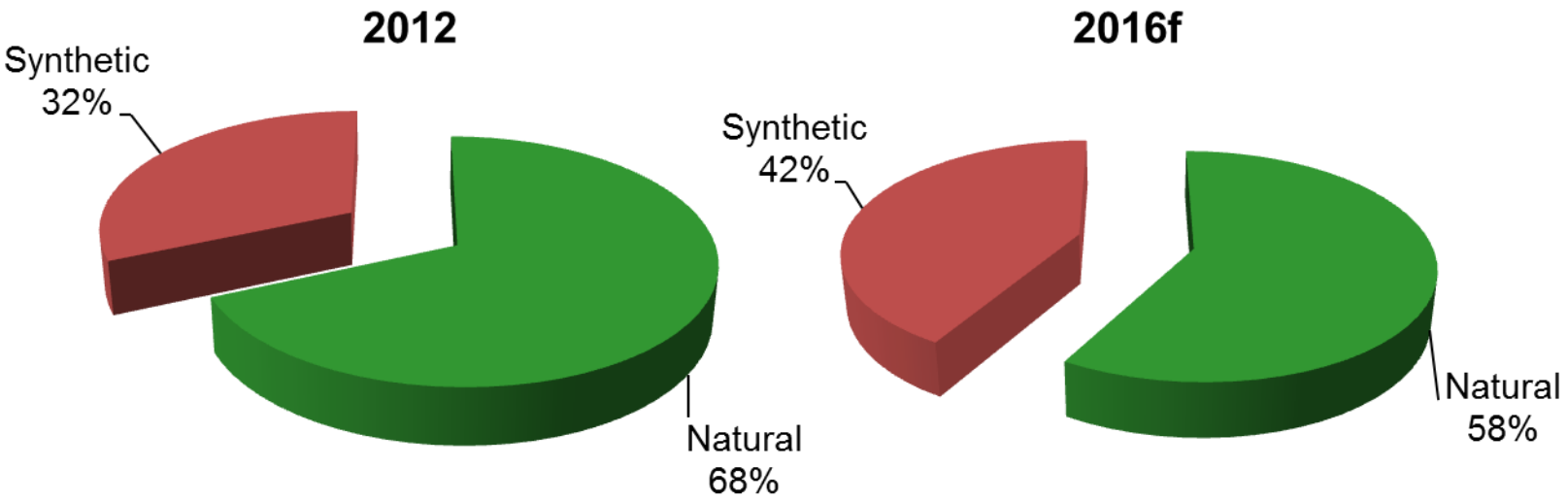
- Both high purity synthetic and natural graphite can be used
- Natural flake must undergo a high level of expensive processing to change it into spherical-shaped, high-purity graphite
- High performing spherical graphites are increasingly produced at a price similar to those of synthetic graphite and so competition is increasing between the two materials
- Lithium-ion batteries are one of the few industries where natural and synthetic graphite compete
- The final often comes down to choice come down to price and availability, which may depend on the location of the lithium-ion anode manufacturer – i.e. are you closer to a mine or a synthetic plant

Production of spherical graphite



Source: Superior Graphite

Global graphite consumption in batteries, 2012 and 2016f



Source: Roskill estimate

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What does the future hold for the graphite industry?

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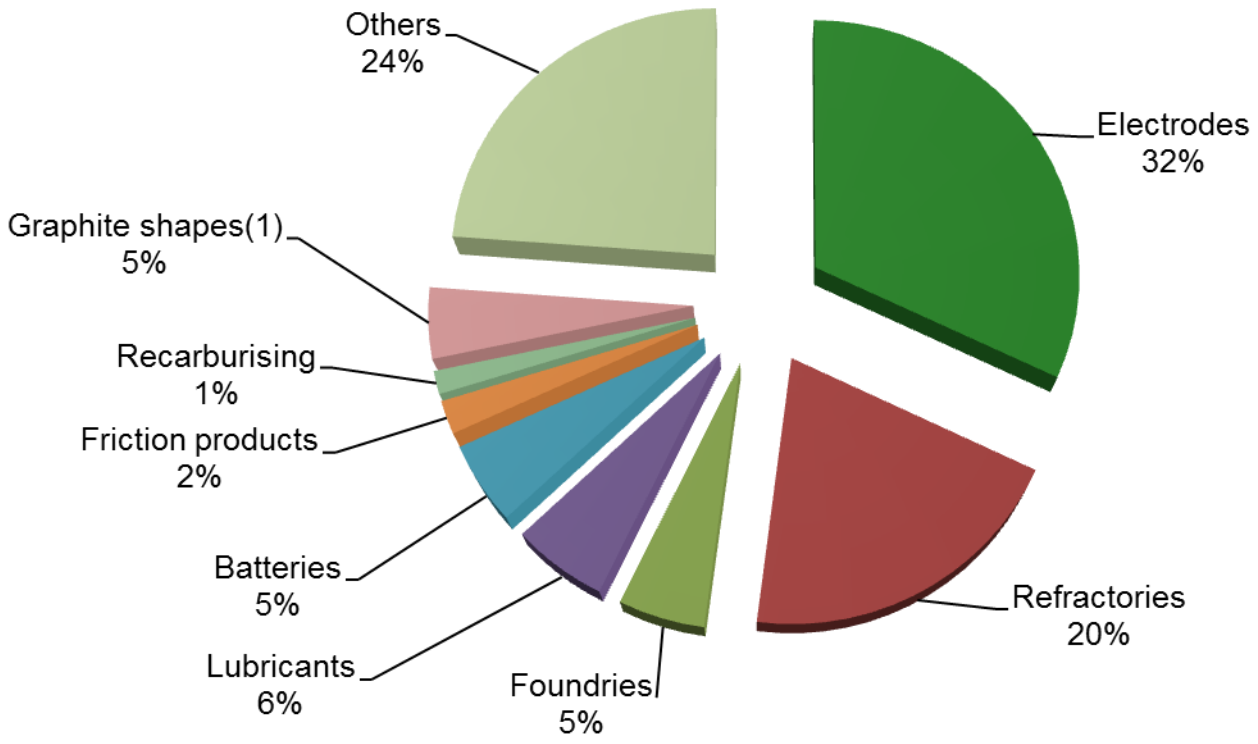
Global graphite demand, 2016



Source: Roskill estimate
Note: 1-Including specialty synthetic products

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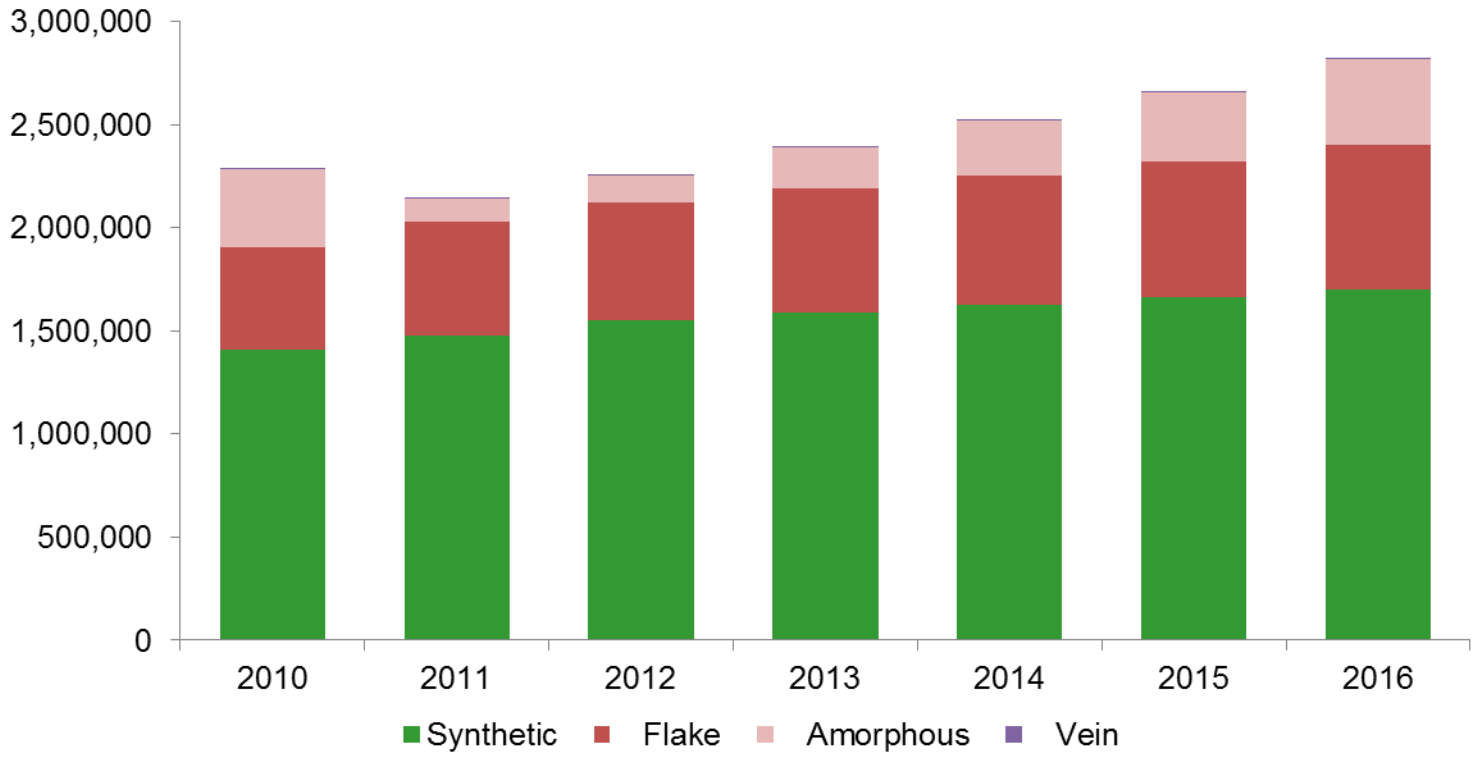
Global graphite production by type (t)



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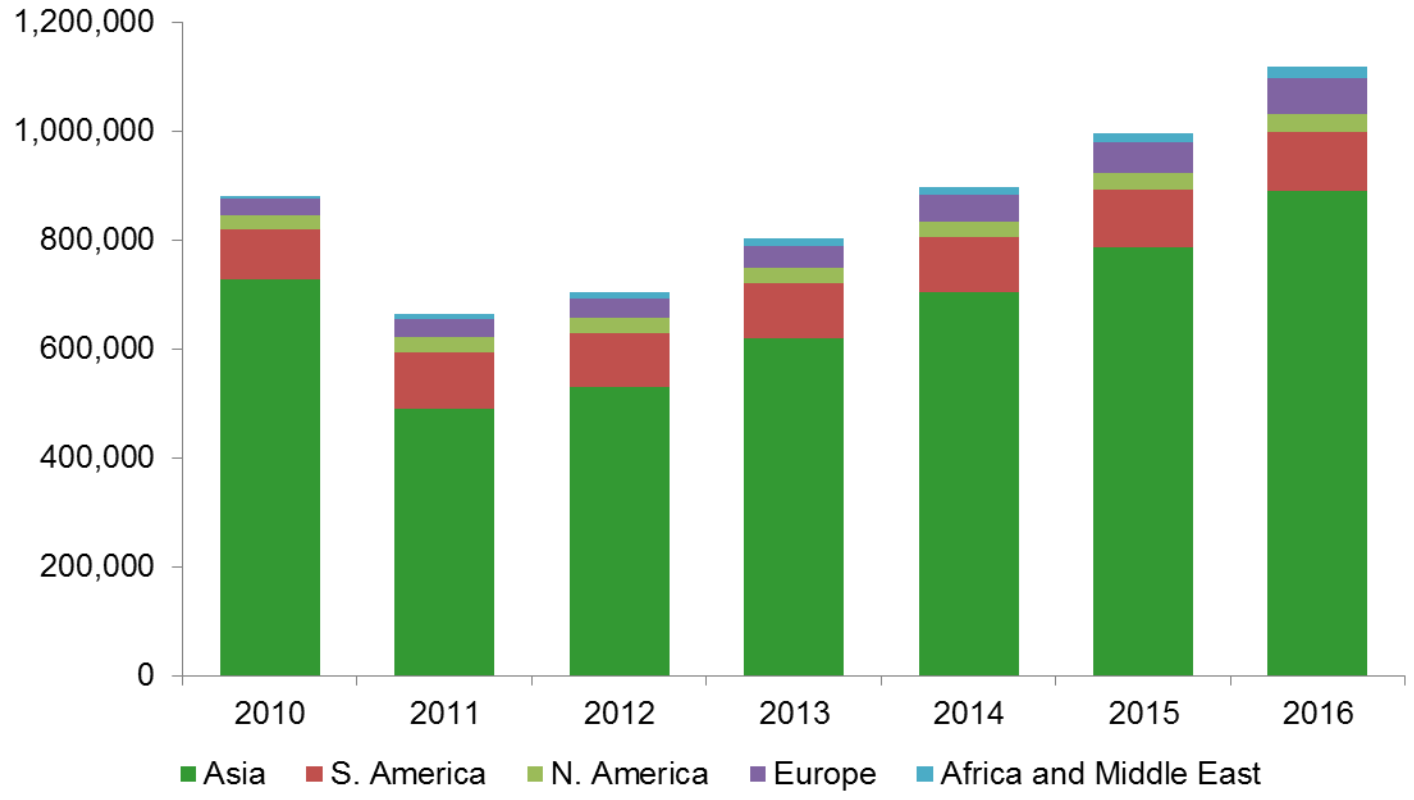
Natural graphite production by region



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Summary

- In 2012, around 80% of the graphite used in batteries was consumed in lithium-ion batteries
- Graphite consumption in batteries to increase to 114,000t by 2016 mainly due to lithium-ion batteries in consumer products, but to some extent from EV/HEV production
- Accelerated growth after 2015/16 as lithium-ion batteries take an increasing market share from NiMH batteries in HEVs
- Growth in EVs/HEVs underpinned by the desire to increase efficiency and decrease emissions, both from the consumer and from governments
- Demand will increase both for synthetic and for natural graphite and is already encouraging the development new flake deposits and synthetic capacity

Natural & Synthetic Graphite: Global Industry Markets & Outlook

8th Edition, 2012

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