Fortnightly Thoughts

April 14, 2014 Issue 72

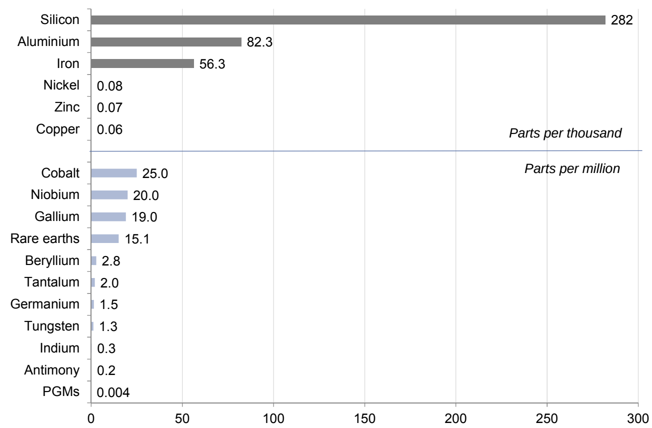
Material changes in the material world

From the editor: In this edition we unearth the substantial shifts in the adoption of new materials and the factors driving the new, different uses of existing elements and materials. We interview two experts from Oxford University and the CEO of graphene-focused company Haydale, while surveying our global analysts for the material shifts in their sectors.

The confluence of structurally higher commodity prices, the evolution of new manufacturing technologies, demand growth for new types of products, particularly consumer electronics, and a rising focus on energy efficiency and pollution is triggering shifts in how and which materials are used. This is ultimately a by-product of two of the strongest investment themes this century; the emerging middle class has grown wealthier and, as a consequence, demands faster, stronger, leaner and cleaner products, much like DM counterparts. At the same time, the commodity super cycle accelerated the need to find alternatives for commodities that have dramatically re-priced over 20 years. Innovation in material science lies at the core of both these challenges. From aircraft to light bulbs and from power plants to passenger cars, there is an important change in how the world makes and consumes things and this matters greatly for the extractors, producers and consumers of materials.

Crusts are good for you

Crustal abundance of materials declared critical by the European commission at the EU level (in blue) and others



Note: Does not include data for magnesium, graphite, fluorspar (also critical)
PGMs: platinum, palladium, iridium, rhodium, ruthenium and osmium
Source: Wikipedia, European Commission.

What's inside

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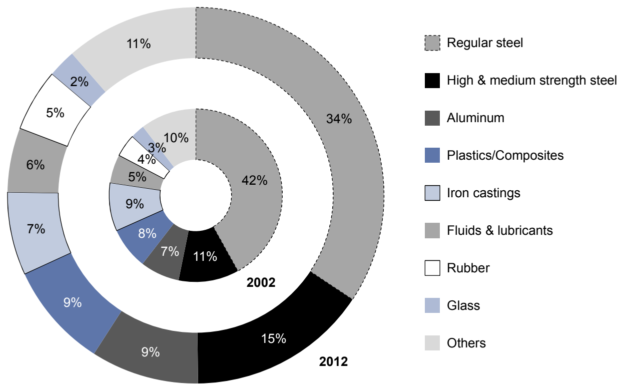
Material changes in the material world

One of the most important and broadest drivers of the shifts in material demand is the rising cost of, and focus on, air pollution. This requires solutions across the energy spectrum, both in terms of production and consumption. The effort to reduce emissions from vehicles has, for instance, driven demand for catalysts made by companies such as Johnson Matthey, Umicore, BASF and Sino-Platinum Metals, that use a combination of palladium, platinum and rhodium to convert carbon and other emissions to less harmful gases. The use of insulation materials (such as stone wool) or paints and materials that keep houses warm or cool, can also reduce energy consumption meaningfully. Reducing the weight of goods is another area of focus. On page 9, Chris Hallam writes about the rising use of lighter composites in aircraft, as the dominant two in the industry, Airbus and Boeing, increasingly compete on weight and energy efficiency. The same is true for cars too. Over the last decade, the amount of plastic and composites in cars has risen at the expensive of regular steel, while the shift towards ‘body-in-white’ or using aluminium (rather than steel) in cars is driving a new leg of demand for speciality aluminium, writes Sal Tharani on page 7 (see chart).

One word: Plastics

Materials content of North American light vehicles



Source: American Chemistry Council.

Materials play a part in solutions to other areas of pollution too. China’s shift to potash and phosphate-based fertilisers, and away from the excessive use of nitrogen, is being driven not just by the need to rebalance crop nutrients and improve yields, but also to limit the pollution in China’s waterways. Of course, there have been other materials and elements that have seen collapses in demand owing to their toxic and damaging effects becoming more widely known and regulated. For example, the use of lead (in the form of tetraethyl lead) as an octane booster in vehicle fuel has declined considerably since the 1970s (90% of the world’s petrol is now lead-free), as countries have increasingly regulated against it. Similarly, the move away from asbestos in construction goods or mercury in batteries required producers to rethink and redesign their products.

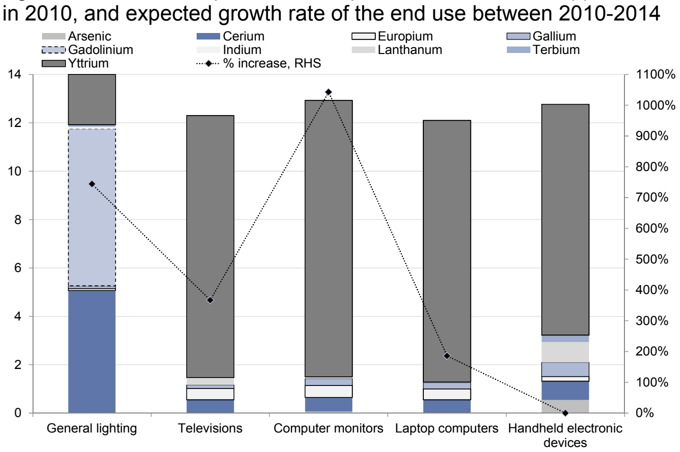
The rise in the cost of fossil fuels and the perceived finite nature of supply has put another constraint on the world. Solving this should result in higher demand for alternative materials, such as uranium for nuclear power. China alone has 28 nuclear reactors under construction, compared to its existing fleet of 19, in its effort to diversify away from coal (c.70% of current primary energy consumption). Given the energy output of uranium and its inherent self-sufficiency from a cost structure perspective (uranium concentrate costs 3% of power generated vs. 80% and 45% for gas and coal in thermal plants in Japan for instance, implying much lower energy price volatility), nuclear energy features in long-term infrastructure plans of many energy importers, including South Korea and India (which accounts for 20% of the world’s known thorium reserves, also used for nuclear energy).

Elementary

Sometimes it is just a case of being in the right place at the right time. Big exogenous shifts in demand can transform the economics of materials. The fifteen elements that reside in the penultimate row of the periodic table are heavily used in many clean energy applications, including catalysts, batteries, wind turbines and consumer electronics such as LED screens for smartphones and TVs. Most of these markets have grown dramatically in size over the last decade, which is why these relatively scarce elements have more than trebled in price since the 1990s. Along with portable electronic devices, the accelerating penetration of electric vehicles should increase demand for batteries, which account for 35% of demand for lithium, another scarce element. On page 14, Neal Sangani writes that Tesla’s new gigafactory should alone account for 16% of today’s global output.

Lighting up

Kgs of materials used per 100 LEDs produced for different applications in 2010, and expected growth rate of the end use between 2010-2014



Source: USGS.

As seen on screen

Greater demand for scarce materials, and the price inflation that accompanies it, is perhaps the strongest incentive for innovation in terms of finding substitutes. For instance, indium tin oxide (ITO) is used in almost every screen you see, thanks to its transparency and conductibility. But based on known reserves and current consumption trends, the world only has about eight years of indium supply left, which is why, as Prof. Peter Edwards highlights on page 16, a lot of research effort and capital is being directed to find a viable alternative.

Scarcity can materialise in many ways. The advent of nickel pig iron (NPI) in response to rising nickel prices and Indonesia’s nickel ore export ban serves as a classic case of price and supply driven constraints catalysing innovation and ultimately providing a ceiling on a commodity price. Nickel remains one of our commodity analysts’ top recommendations for 2014, but they note that as China aggressively builds out NPI capacity within Indonesia over the next two years, significant incremental supply should hit the market in 2015 and 2016, which should weigh on prices. One solution to scarcity, especially for elements that have few alternatives, is recycling. And recycled elements are contributing more and more to overall supply, particularly for expensive elements such as the PGMs and zinc, manganese and niobium (our analysts forecast 30% of palladium and platinum supply to come from recycling, up from 11% in 2005).

Chain reactions

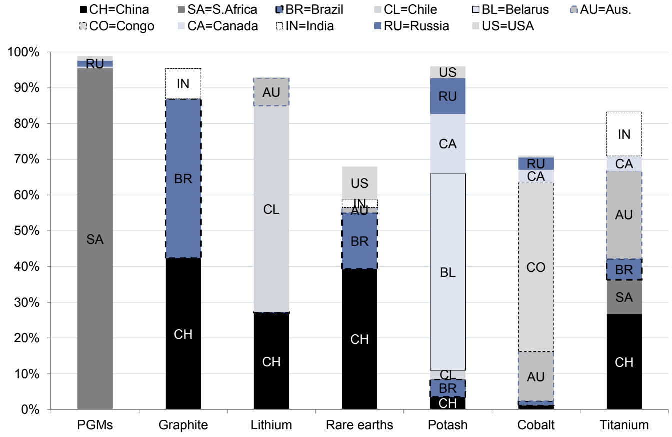
Part of an exogenous shock that shifts demand is new technologies that allow for new and more efficient ways of making things. The poster child here is 3D printing, as it has allowed lighter thermoplastics and polymers to be used in place of heavier metals and alloys in components, and thanks to its additive (rather than subtractive) nature, the technology also leads to less waste, irrespective of the materials being used. It's still early days for what was a prototype technology, but as and when the machines become more capable, particularly in terms of printing a variety of materials with different properties, end demand for these materials can change meaningfully. Nanotechnology, which allows analysis and manipulation of materials at an atomic and molecular level, can significantly enhance material efficiency, dramatically reducing the requirement for expensive elements and reducing the weight of end-products. One of the technologies driving down the weight of smartphones is atomic layer deposition, which lays down elements one atom thick, producing very thin films and making devices stronger and more resilient to, say, moisture, without increasing the weight noticeably.

How to invest in this

The examples and technologies we mention above are by no means exhaustive, but they are consistent in their direction. Given enough time and capital, engineers and scientists will solve problems in the materials world – it isn't smart to bet against them. So, how can we think about investing in this? Firstly, investing around future materials involves the providers and makers, as well as the owners of IP (such as Victrex, Rockwool, Johnson Matthey and Samsung); the flipside to this is who loses out, as new materials invariably replace old ones (see page 26 from Eugene King). Enablers that allow new uses of materials include Oxford Instruments, ASML and HellermanTyton, while innovative users of these materials, such as Tesla, adidas and Airbus, are also well placed to benefit. There are also second-order beneficiaries such as recyclers (Umicore and Sims Metal Management). We have a longer list of stocks exposed on page 6.

In reserve

% of world reserves by country

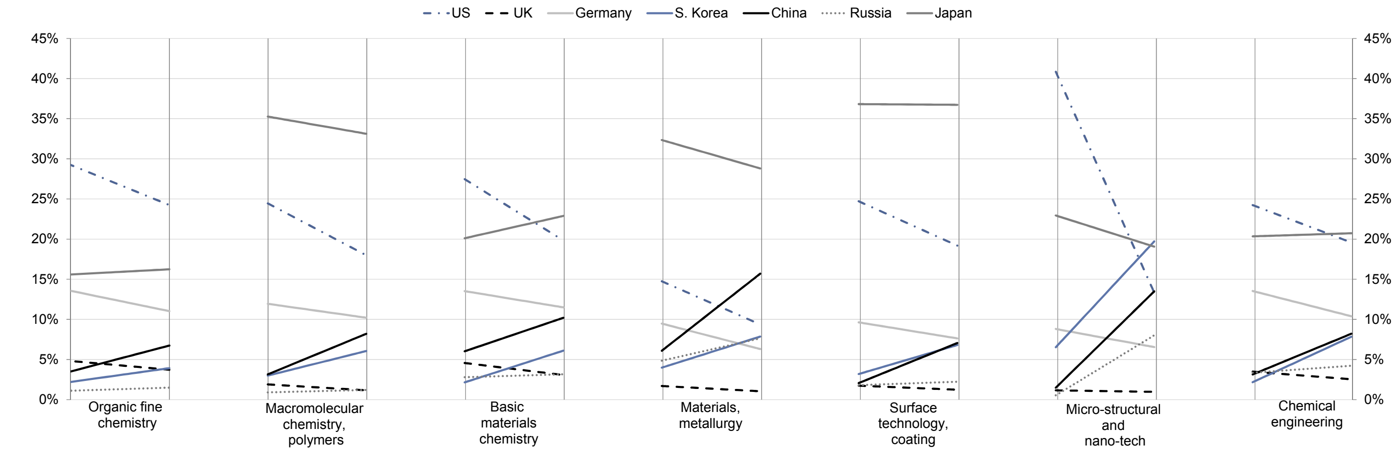


Note: Titanium shown as a sum of ilmenite and rutile minerals.
Source: USGS.

Who is best placed from a country perspective? If we take a broad basket of materials that look set to gain strategic importance then the most favourably exposed countries are China, South Africa, Russia, Chile and Brazil. China in particular is interesting here, given that it is the biggest producer of rare earths and accounts for 23% of known global reserves, as Jefferson Zhang notes on page 24, but has continued to limit exports of these materials. 70% of the graphite from which graphene is isolated is also mined in China, while it has access to lithium and titanium too. But it not just about owning the materials; the technology and IP related to the use of these materials is critical too. And as the chart below shows, competition is heating up.

Potent patents

Country share of global patents in field of material technology, change from 2000-05 to 2006-12



Source: WIPO.

Material information

The periodic table

Is hydrogen the One?
Can **hydrogen** fuel disrupt global energy markets? Yes, but Prof. Edwards argues on page 16 that there are huge challenges in storage and transportation that need to be resolved first

The age of storage
25% of **lithium** is used in batteries for electronics versus 3% in vehicles. If the world drives more electric vehicles, the demand profile could look very different. We would also need more **graphite** (mostly in China and Brazil) and also **cobalt** (c.45% reserves in DR of Congo)

Urban outfitters
Reducing **sulphur** content in fuel in China allows precious metal catalysts (**palladium, platinum, rhodium**) to be used in its cars, key in the effort to deal with air pollution in its cities.

Carbon dating
"It can conduct electricity better than copper, is 200 times stronger than steel atom-for-atom and is very flexible. One gram of **graphene** layered end to end would cover two football fields… Graphene could be the most disruptive material in the 21st century …"
Interview with Ray Gibbs of Haydale on page 20

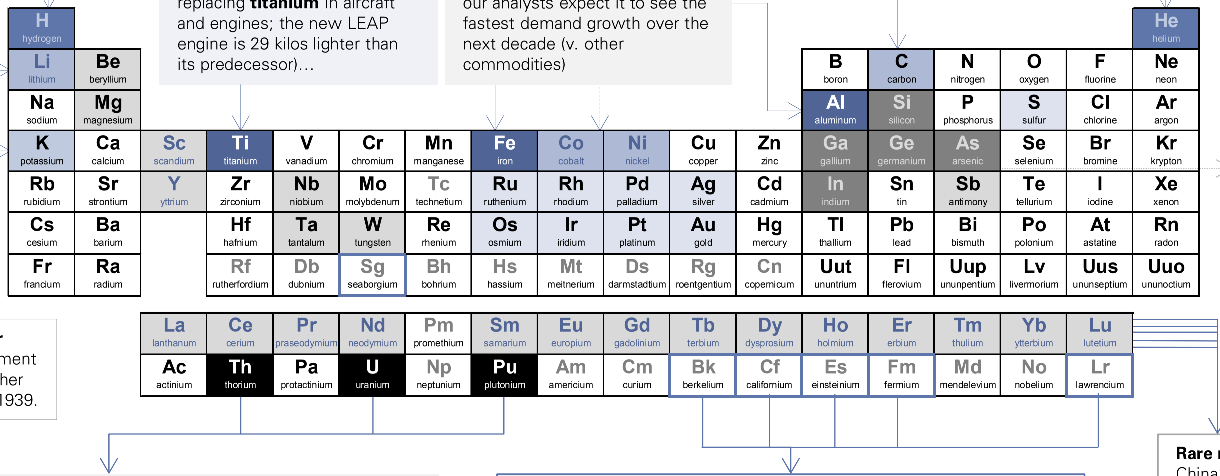
Balloon payments
The US Federal Helium Reserve in Texas accounts for 35% of global **helium** supply (used in high-tech areas - like semiconductors, medtech, aerospace). The US facility has warned that it will continue to ration supply in 2014, as demand continues to overtake supply.

Caution: Concentrated
With c.55% of global reserves in one country, Belarus, (>80% in 3 countries), **Potash** is one of the most concentrated critical resources. But current oversupply leaves our analysts cautious on potash-exposed stocks

The incredible lightness of Boeing
Lighter carbon composites are replacing **titanium** in aircraft and engines; the new LEAP engine is 29 kilos lighter than its predecessor)…

Weight for it
… and steel in cars is being replaced by **aluminium** sheet; our analysts expect it to see the fastest demand growth over the next decade (v. other commodities)

Germanium valley?
Germanium and **indium gallium arsenide** can carry charges 3-6x faster than silicon as semiconductors. But none can match silicon's abundance and economics. Earliest commercial use? Not before 2016-17 (says Donald Lu on page 18) and unlikely even after.



Critical times
14 materials are considered critical for Europe (shaded in grey) and include **antimony, indium, tungsten, graphite, niobium and tantalum**

In the end, it does matter
Francium was the last element to discovered in nature (rather that being synthesised) in 1939.

The new, clear path
38 of the 72 nuclear plants being built today are in China and Russia, while India, is keen on **thorium**, instead of **uranium**, given its relative abundance and safety. Water desalination, which is very energy intensive, could boost demand for nuclear (used already in Japan, Pakistan and more recently in China)

University challenge
The University of California, Berkeley, and its researchers are credited with discovering 6 elements (including **californium** and **berkelium**), while Berkeley Lab (a US Dept. of Energy research facility on campus grounds) has found 16 elements in total, the most by any university.

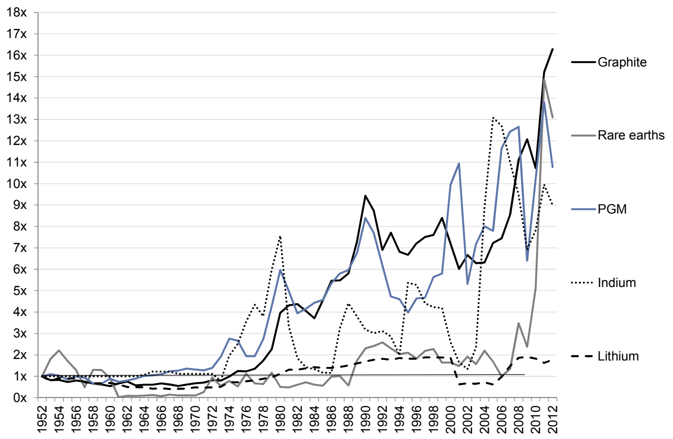
Rare necessities
China's **rare earth** exports quota has fallen from 60kt in 2006 to c.30kt in 2013. Output from the US (the 2nd largest producer) grew 5x yoy in 2013, but still accounted for only 4% of China's output.

Notes: Concentration and reserve estimates are for known reserves only. Kt – thousand tonnes
Sources: Goldman Sachs Global Investment Research, US Geological Survey, European Commission, IAEA-PRIS, Wikipedia

Six charts of substance

Pricing pressure

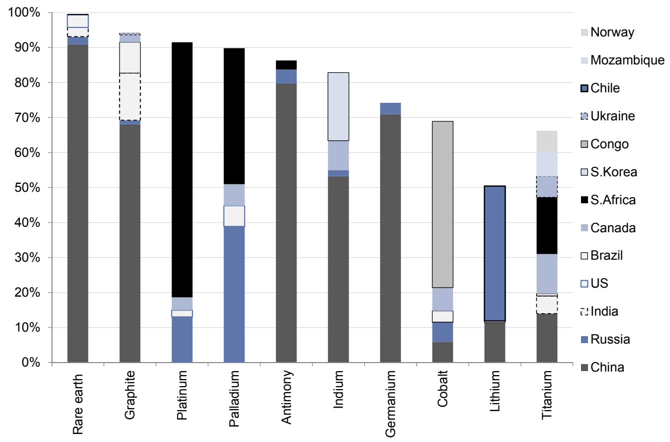
Price in USD per metric ton of apparent consumption in the US, 1952 indexed to 1



Source: USGS.

China's dominance

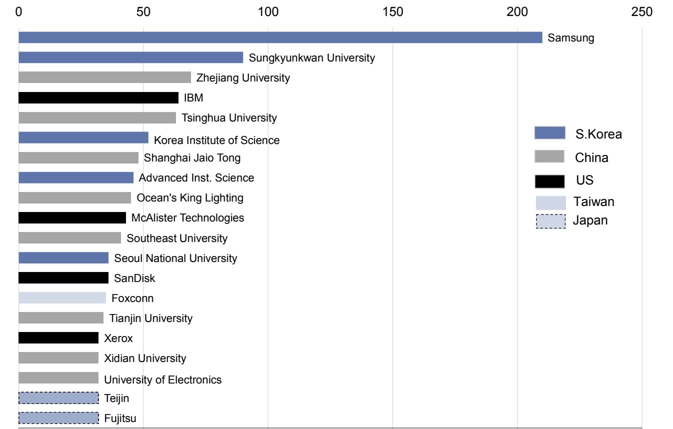
Mine production 2013, breakdown by country



Source: USGS.

Where innovation is happening

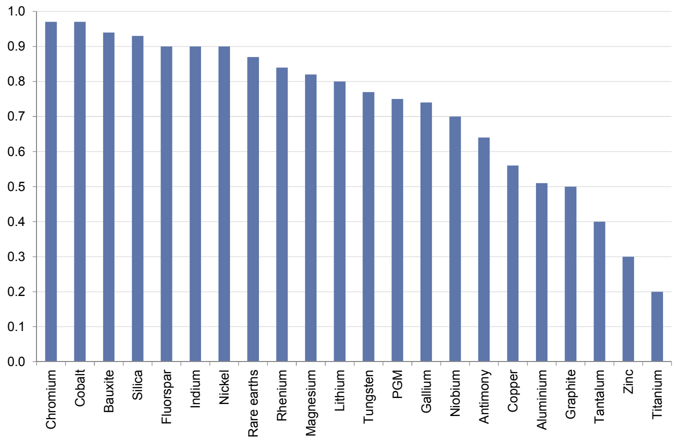
Top holders of graphene inventions (patent families) filed by organisation



Source: Intellectual Property Office.

The super subs

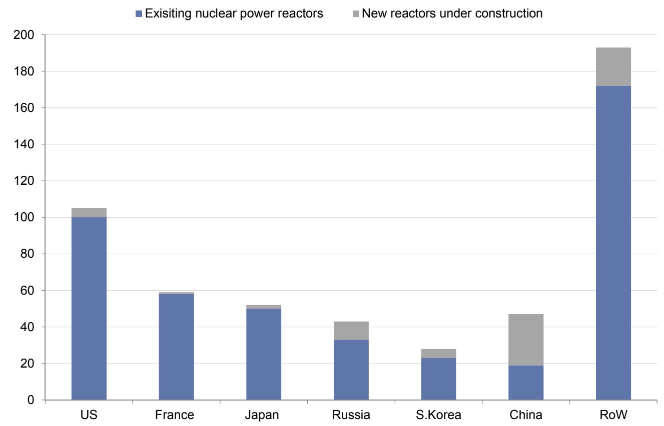
Material substitutability index for E.U region



Note: 0=Easily and completely substitutable at no additional cost, 0.3=Substitutable at low cost, 0.7=Substitutable at high cost and/or loss of performance, 1.0=Not substitutable
Source: European Commission.

Nuclear family

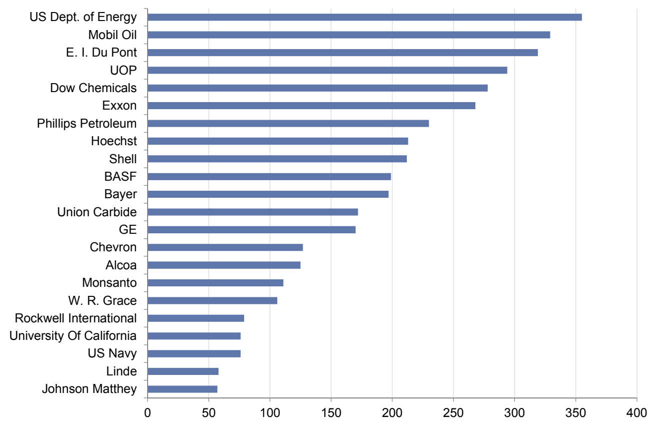
Number of nuclear power reactors by geography



Source: International Atomic Energy Agency.

The chemical brethren

Total utility patent grants in Chemistry of Inorganic Compounds



Source: US PTO.

How to invest in materials

Company	Country/ sector	Rating	Market Cap ($mn)	Last Price	Target Price	Target period	Upside Potential	Exposure to material	Rationale
Producers of new and innovative materials									
Victrex	UK Chemicals	Buy	2,701	1937p	2300p	12 months	19%	PEEK (Specialty polymer)	c.80%+ market share in PEEK, a specialty plastic that can withstand very high temperature and pressure (1 tonne of it is used in each 787 plane); also finding new "emerging business areas" for the use of PEEK in dental applications, trauma, knee and arthroscopy
Sika	Switzerland SmallMidCap	Buy	9,976	SFr3454	SFr4200	6 months	22%	Admixtures, specialty construction	Global leader in specialty construction chemicals; should benefit from increasing usage of admixtures which contribute to <1% of total building cost but allow for upto 40% less cement and water consumption, c.50% less work time, improved durability and longevity
Arkema	France Chemicals	Buy*	6,785	€78.05	€105	12 months	35%	Specialty chemicals	Supplies plastic enclosures for solar cells and lithium-ion batteries; also enables the reduction of harmful toxic releases from paints through its waterborne polymer emulsion offering and should thus benefit from decrease of Volatile Organic Compounds in paints as environmental standards toughen up
Zeon	Japan Chemicals	Buy*	2,172	¥955	¥1280	12 months	34%	High resistance rubber, anti-reflective films	Dominates the hydrogenated nitrile rubber market with over 60% global share (Lanxess is the other big player). Its ZeonorFilms, used as anti-reflectives for mobile devices and as retardation films in LCDs to enable wide viewing angle and contrast optimization, offers further growth potential
PTT Global Chemical	Thailand Chemicals	Buy	9,774	Bt70	Bt86	12 months	23%	Green chemicals, bioplastics	Its increasing focus on higher value downstream businesses like environment friendly bioplastics and other green chemicals (like methyl ester derived from natural raw materials, which is used in biodiesel as an alternative chemical) can drive long term value
James Hardie	Australia Industrials	Buy	5,431	A$13.3	A$14.99	12 months	13%	Fiber cement	World leader in fiber cement cladding (non combustible material used in high bush fire prone areas); should benefit from the increasing penetration of fiber cement, especially in US and Europe, as witnessed in recent results
Polyone Corp.	US Chemicals	Buy	3,554	$36.23	$44	12 months	21%	Engineered polymers, additives	Leader in compounding specialized plastic and polymers that links large commodity polymer producers and more technically driven designers that use these materials in specialized applications (carbon nanotubes and foaming agents for weight reduction)
Cytec Industries	US Chemicals	Buy	3,467	$95.01	$107	12 months	13%	Carbon fiber, composites, additives	Offers a range of carbon fiber products for its aerospace segment (which contribute to c.50% of sales) that deliver superior structural, thermal, electrical and frictional performance for unique applications, including brakes, defense systems and commercial aircraft; also dominant in composites for industrial use
Aksa Akrilik Kimya Sanayi	Turkey Chemicals	Buy	602	YTL6.87	YTL11	12 months	60%	Carbon fiber	World's largest producer of acrylic fibers, a key raw material in the production of carbon fibers, also has a JV with Dow Chemicals focussed on manufacturing and commercializing carbon fibers and derivatives with a specific focus on energy, infrastructure and transportation markets
Beneficiaries of growing demand for existing materials									
Voestalpine	Austria Steel	Buy*	7,751	€32.365	€42	12 months	30%	Specialty steel	One of the best positioned steel companies in our coverage set to benefit from its transition away from conventional commodity steel towards downstream processing and technology activities with new end markets through an €8bn capex program
Alcoa	US Steel	Buy	13,403	$12.54	$15	6 months	20%	Aluminium	Body-in-white (BiW) or greater aluminum content in automotive is a big opportunity as exciting prospects emerge in products for aircraft and cars
Constellium	Metals	Buy*	2,613	$27.48	$35	6 months	27%	Aluminium	Increasing penetration of BiW should contribute to increased demand of aluminium sheet as OEM's reduce the weight in vehicles to comply with stringent emission rules; the expected increase in Airbus's purchase of its AIRWARE (aluminium-lithium) also positive
Zhongke Sanhuan	China Metals and Mining	Buy*	2,307	Rmb13.45	Rmb18.3	12 months	36%	Rare earths	As the world's second-largest NdFeB magnet manufacturer, stands to benefit substantially from the rising demand for high-end NdFeB products used in new energy vehicles and energy saving appliances
Huntsman Corp.	US Chemicals	Buy	5,902	$24.2	$29	12 months	20%	Specialty resins, titanium, MDI polyurethanes	Portfolio shift towards high-performance specialty resins provides exposure to use of lightweight composite materials in aerospace; beneficiary of growing demand of insulation and composite wood products in Asia
GCL-Poly Energy Holdings	China Solar	Buy	5,191	HK$2.6	HK$3.9	12 months	50%	Polysilicon	Low-cost & largest manufacturer of polysilicon and wafers for the solar industry contributing to c.27% of global supply
Xiamen Tungsten Co.	China Metals and Mining	Buy	2,816	Rmb25.65	Rmb27.54	12 months	7%	Tungsten carbide, Ni-Co-Mn, Rare earths	Leader in cemented Tungsten carbide processing technology in China and active in magnetic materials and S.China rare-earth resource consolidation; its ternary Material Ni-Co-Mn (used in Lithium battery cathode) has successfully entered the electric autos market and should benefit from increasing penetration of EVs
HellermannTyton	UK SmallMidCap	Buy	1,100	311p	390p	6 months	25%	Polymer based connecting technologies	One of the largest suppliers of light-weight and resilient polymer-based products that substitute heavier metal components used in autos and industrial applications
Enablers of innovation in the materials domain									
TSMC	Taiwan Technology	Buy*	100,706	NT$117.5	NT$138	12 months	17%	Semiconductor materials	World's largest dedicated independent semiconductor foundry; has confirmed its commitment to introduce EUV (Extreme Ultraviolet lithography) at 10nm at recent industry conference
ASML Holding NV	Netherlands Technology	Buy*	39,113	€66.13	€105	12 months	59%	Semiconductor materials	85% market share in lithography (active in both multi-layer immersion and EUV lithography technologies) which are critical for semi manufacturers to keep pace with Moore's law; improving execution in EUV can lead to further market share gains in an already duopolistic market
Spectris	UK SmallMidCap	Buy*	4,447	2310p	3310p	6 months	43%	Nanomaterials	Recent acquisition of NanoSight Limited, a specialist in particle size measurement instrumentation should further increase group's penetration in its high-growth, early-stage nanotech applications segment
Oxford Instruments	UK SmallMidCap	Buy	1,354	1432p	1990p	6 months	39%	Nanomaterials	Leading supplier of tools and systems used in nanotechnology to analyze or manipulate material at the level of atoms or molecules
Samsung Electronics	South Korea Technology	Buy	224,367	W1365000	W1700000	12 months	25%	Graphene	Holds the maximum number of patents around graphene (one of the lightest, strongest and most conductive materials developed); Samsung recently developed a new method of synthesising graphene without damaging its electric and mechanical properties; should aid its wearable technology push
SK Innovation	South Korea Chemicals	Buy	11,589	W128000	W160000	12 months	25%	Lithium	Has begun to produce xEV batteries by leveraging its separator technology (used in li-ion batteries), attempting to diversify its portfolio to upstream E&P and xEV battery; potential diversification into Energy Storage Systems and the growing EV market remain strong long term drivers
Samsung SDI Co	South Korea Technology	Buy	7,107	W159000	W180000	12 months	13%	Lithium	Competitive lithium battery technology and manufacturing capability makes it a well positioned beneficiary of secular EV/ESS growth
Sims Metal Management Ltd	Australia Industrials	Buy	1,897	A$9.71	A$11.76	12 months	21%	Multiple metals	Operates the world's largest electrical and electronics recovery and recycling business; also the largest metal recycler globally
Users of new materials, innovative applications of existing materials									
Airbus Group NV	Aerospace & Defence	Buy	59,534	€53.32	€57	12 months	7%	Lighter, fuel-efficient planes	Use of composite materials in new wide body aircraft such as the Boeing 787 (50% composites) and Airbus A350 (53% composites) translates into fuel saving (20% and 25% in the two examples respectively) leading to a significant improvement in economics over older aircraft
The Boeing Company		Neutral	93,799	$122.07	$134	12 months	10%		
Ford Motor Company	US Automobiles	Buy	62,867	$15.94	$18	12 months	13%	Body-in-white; lighter cars	Recently unveiled its 2015 F-150 at the Detroit Auto Show with a full aluminum body, making the truck 700 pounds lighter than its predecessor with an expected 30% improvement in fuel efficiency
Toyota Motor	Japan Automobiles	Buy*	168,564	¥5410	¥7300	12 months	35%	EV and hybrid vehicles	Dominant player in electric and hybrid vehicles; has multiple partnerships to source raw materials for vehicles powered by lithium-ion batteries
adidas	Germany Retail	Buy*	22,712	€78.17	€109.1	12 months	40%	Low impact, lighter shoes	The new adidas Boost running shoe is the first to use expanded thermoplastic polyurethane foam to re-direct the impact energy of jogging back to the runner; also uses 3D printing technology to make lighter shoes
Lumenis Ltd.	Israel MedTech	Buy	364	$9.96	$17	12 months	71%	High-end medical equipment	Manufacturer of energy-based therapeutic applications with the surgical segment focused primarily on treatments through holmium and CO2 lasers; FDA filings reveal that the company has recently received clearance for a new 120-watt holmium laser

*Source: Datastream, Goldman Sachs Global Investment Research. *On the relevant regional Conviction List. Prices as of the close of April 11, 2014.*

Uptrends for downstream aluminium

Our US metals and mining analyst, Sal Tharani, highlights the new demand growth drivers for aluminium.

Aerospace & automotive; twin engines of demand growth

The downstream aluminium market has been benefitting from long-term secular growth trends in various end markets. In aerospace, a solid back log and strong build rates continue to drive aluminium sheet and plate demand. We believe that this story is well understood by investors. However, very recently another opportunity has surfaced i.e., body-in-white (BiW) or aluminium body for automotive. The sheer size of the automotive market and the OEM's need to reduce the weight in vehicles to comply with stringent emission rules will be the next long-term secular driver of aluminium sheet, in our view. We believe that investors are just beginning to realize the BiW opportunity.

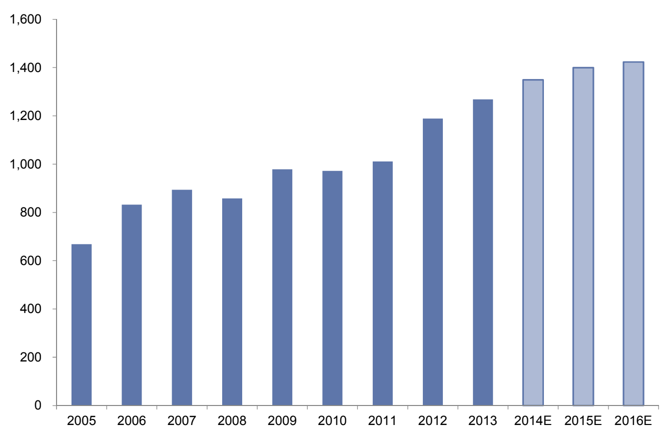
We believe that there is another trend developing which investors have not yet focused on and which could be a significant driver of margin enhancement. The change in the automotive industry could siphon aluminium sheet out of the aluminium can stock to BiW, in turn tightening the can stock market over the next few years. This is a fairly large volume product but is in overcapacity and is very competitive with low margins. We believe that this transition could be a significant source of margin expansion for downstream aluminium producers.

Aerospace; growth continues on historically high build rates

Large commercial aerospace build rates are at historical highs following significant aerospace market growth over the past 10 years. Large commercial build rates have grown at an 8.1% CAGR since 2008, with fast-growing demand for air travel in developing economies driving demand for new aircraft. While we expect build rates to continue to grow, and to remain at historical highs, they should moderate over the next few years. We expect aerospace demand for materials to remain robust, and support high operating rates at aerospace materials producers, though we expect inventory destocking to impact shipments of aluminium plate over the next 12-18 months with growth rising moderately beyond that.

Aerospace build rates at historical highs and growing

Large commercial aerospace deliveries



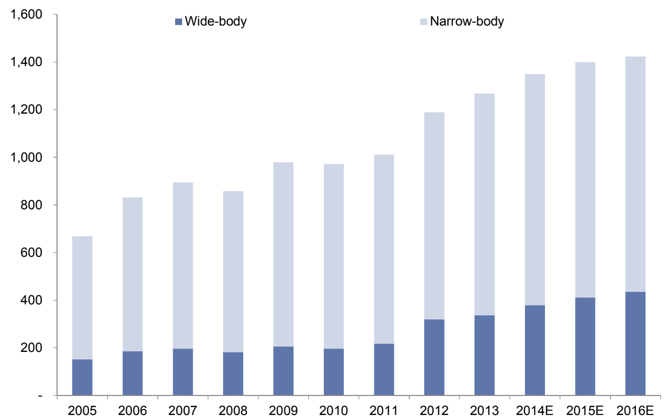
Source: Company data, Goldman Sachs Global Investment Research.

Our global aerospace team expects large commercial build rates to grow at a 3.9% CAGR from 2013 through 2016. However, they expect wide-body build rates to significantly outpace narrow-body build rates, growing at an 8.9% CAGR (compared to a 2.0% CAGR for narrow-bodies). As wide-body aircraft are naturally larger, and require more materials, the shift towards wide-bodies is positive for aerospace materials producers.

Our aerospace team expects the growth in the B-787 and A350 to drive outperformance in wide-bodies over narrow bodies. The B-787 contains relatively little aluminium, but has significant composite and titanium components. The A350 requires aluminium lithium, a very high-margin specialty aluminium product that should drive margin growth for aluminium suppliers that produce this product. Both the B-787 and A350 have seen build rate delays over the past several years, but both appear to be past these delays and our team expects build rate growth to be steep through 2016.

Wide-body aircraft to gain greater market share of all deliveries

Large commercial aerospace deliveries



Source: Company data, Goldman Sachs Global Investment Research.

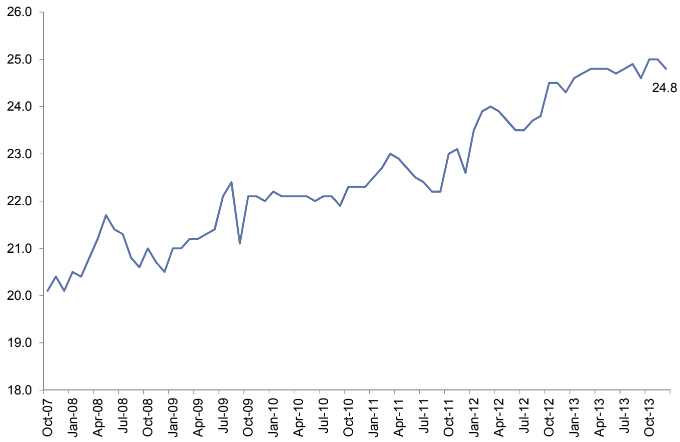
Automotive aluminium sheet (BiW); the fastest-growth product

We expect automotive aluminium sheet to be the fastest-growing commodity in terms of demand over the next several years, as OEMs turn to aluminium from steel to further improve fuel efficiency and meet standards. Some industry sources, including consultant agencies on environmental regulations, expect aluminium auto sheet demand to grow at a 14% CAGR from 2012 through 2025, while Alcoa expects the market to grow at a greater than 50% CAGR from 2012 through 2016.

While aluminium has been used in high-end car bodies for some time, the expense of higher-cost material and retooling manufacturing facilities and other related expenses has not been justifiable for mass-production vehicles. However, with CAFE standards requiring a significant improvement in fuel efficiency over the next several years, and consumers more sensitive about fuel costs, automotive OEMs are beginning to make the transition to greater aluminium use. Ford unveiled its 2015 F-150 at the Detroit Auto Show in January with a full aluminium body, making the truck 700 pounds lighter than its predecessor with an expected 30% improvement in fuel efficiency. Each F-150 is estimated to use about 900 lbs of aluminium sheet and additionally about 40% of aluminium purchased will go to scrap, although most of this scrap will be recycled.

New CAFE rules require average fuel economy to more than double to 54 mpg by 2025

Average sales-weighted fuel-economy rating of purchased new vehicles (mpg)



Source: *University of Michigan Transportation Research Institute, Goldman Sachs Global Investment Research.*

We estimate that the BiW market was about 100K tons in 2013 in North America and we expect it to grow close to 1.0 mn tons by 2017. Almost all of the new capacity (about 900K tons) being put in place by Alcoa, Novelis and Constellium to meet this growing BiW demand is already spoken for; i.e. downstream producers are not building any capacity in anticipation of orders but only when they get commitments from automotive OEMs. In Europe, the BiW market is about 270K tons and is expected to grow to 600K tons by the end of this decade.

The majority of aluminium content growth in automotive over the next 10-15 years is expected to come from automotive aluminium sheet. Automotive OEMs can achieve significant weight reduction by producing Body-in-White from aluminium sheet as opposed to steel, driving strong fuel efficiency improvements. Industry sources, including consultant agencies on environmental regulations, expect aluminium auto sheet to grow at a 14% CAGR from 2012 through 2025. Alternatively, aluminium extrusion content in vehicles is also expected to grow, but industry sources expect content to grow at a 5% CAGR from 2012 through 2025.

2025 fuel efficiency targets imply far to go across models

2025 fuel efficiency target examples by model type (mpg)

Vehicle Type	Example Models	Example Model Footprint (sq. ft.)	2013 Fuel Economy	NHTSA Fuel Economy Target
Example Passenger cars				
Compact Car	Honda Fit	40	33.0	61.1
Mid-size car	Ford Fusion	46	29.0	54.9
Full-size car	Chrysler 300	53	23.0	48.0
Example Light-duty Trucks				
Small SUV	4WD Ford Escape	43	25.0	47.5
Midsize crossover	Nissan Murano	49	20.0	43.4
Minivan	Toyota Sienna	56	21.0	39.2
Large pickup truck	Chevy Silverado	67	17.0	33.0

Source: *US Department of Energy, NHTSA, Goldman Sachs Global Investment Research.*

In North America, the increase in aluminium content per vehicle from 200lb in 1995 to 350lb in 2012 was driven by castings: parts for engines, transmissions, chasses, and suspension systems. Now, as manufacturers seek additional areas in which to reduce vehicle weight to meet fuel efficiency standards, they are focusing on the rolled and extruded parts were aluminium currently has low penetration. We expect aluminium usage in "hang-on parts", including the exterior body of the car and bumper systems, to increase significantly over the next several years. Industry sources, including consultant agencies on environmental regulations and industry participants such as downstream aluminium producers Novelis and Alcoa, expect average aluminium content per vehicle in North America to increase by 200 pounds to 550lb by 2025.

Potential of tightness in aluminium can stock market

The aluminium can stock market has been a tough market for producers of aluminium sheet as a result of overcapacity, particularly in the US where the market has been declining as consumers switch to healthy drinks and away from soda. In our report, "BiW to tighten the aluminium beverage can market", we took a deep dive into the aluminium beverage can stock market and attempted to quantify the impact of metal movement to higher-margin BiW from lower-margin beverage can stock. Our analysis showed that a significant volume of aluminium can sheet could eventually move into BiW, creating a balance to a tight market over the coming years. In North America, we see the biggest potential impact from this transition and believe the can stock market in this region has the potential to become significantly tight as a large number of BiW capacities are completed in the next few years.

Aluminium can stock represents a large volume of the aluminium sheet and plate sold in the US and Europe. We estimate that it constitutes about 45% of total sheet and plate shipments in the US and Canada. We therefore believe that potential tightness in this market, and an eventual increase in pricing, would be a significant contributor to the bottom line of aluminium can stock producers.

None of the new BiW capacity in the US and Europe is adding new sheet capacity; all of these expansions are downstream processing facilities primarily consisting of continuous annealing and heat treating lines. There is no new rolling capacity being added at this time for any of these expansions. The substrate (aluminium hot rolled sheet) is being diverted from other low-margin products to BiW, mainly from the beverage can stock market. We estimate that in North American, more than 60% of this new BiW substrate would come from aluminium sheet from beverage can stock, amounting to more than 550K tons by 2017-2018E. This could create a tighter aluminium can stock market by 2017 and put some upward pricing pressure on this product, enhancing margins for the producers.

We forecast the North American beverage can stock market will shift to deficit from surplus as BiW capacity grows

Thousand metric tons

2013 Shipment volume	1,550
Utilization rate	77%
Implied capacity	2,010
Implied excess capacity (Kt)	460
Estimated capacity to move to BiW by 2017	**550**

Source: *The Aluminium Association, Goldman Sachs Global Investment Research.*

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A lighter touch

Our global Aerospace & Defence analysts, Chris Hallam and Noah Poponak, see a take-off in the use of composite material in aircraft and aircraft engines.

Aerospace has pioneered the use of new materials

The Aerospace industry has long pioneered the use of new materials, first using composite technology in aircraft in the 1950s. Recently, the pace of adoption by aircraft manufacturers such as Airbus and Boeing has accelerated; in the 1990s composite materials accounted for 10%-12% of new wide body aircraft (A340 and 777), and this number has now surged to 50% in the case of the 787 and 53% in the case of the A350.

This change has been mirrored in the engine industry, where the new generation of engines has made use of carbon and ceramic composites to reduce weight and lower maintenance requirements. This shift to composite materials has had, and will continue to have, important implications for the entire aerospace value chain; improving industry fuel efficiency, improving airline profitability, supporting new aircraft demand, lowering aircraft production costs and improving engine OEM profitability and returns.

US and European OEMs are ahead of their global competition on the development and implementation of these new material technologies. This edge should afford the US and European manufacturers a degree of technical advantage and insulate them from EM competition through the decade.

Boeing and Airbus at the vanguard

The impact of new materials has been felt most keenly by the two largest aircraft manufacturers, Airbus and Boeing. The use of composite materials in new wide body aircraft such as the 787, A350 and 777X has led to a significant improvement in economics in comparison to older aircraft and provides a compelling product cycle through the decade.

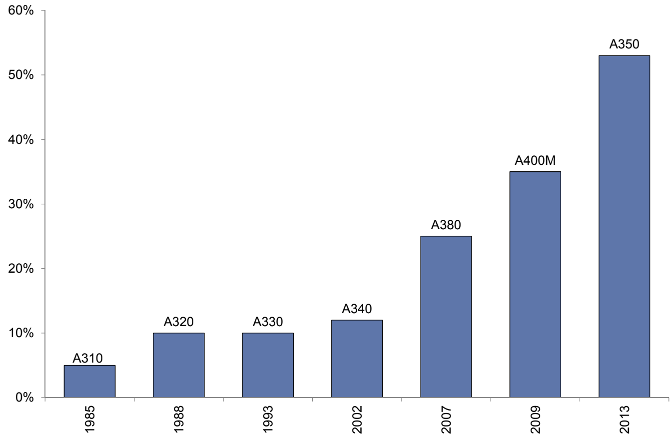
The Boeing 787 was the first aircraft to reach the 50% composite mark, which equates to a 20% weight saving and contributes to the 20% fuel saving afforded by the aircraft. The Airbus A350 is 53% composite and is expected to deliver a 25% fuel saving over its competition. Finally the proposed Boeing 777X will retain an aluminium fuselage but will have the largest composite wing in the sky and offer a 12% saving over competing aircraft.

Customer demand and production efficiency are the drivers

This push to increase the use of composite materials is driven by two factors; customer demand and production efficiency. Fuel costs represent roughly 35% of an airline's operating costs and hence there is a significant incentive for Boeing and Airbus to offer more fuel-efficient aircraft to the industry.

Our global airlines team recently published its analysis of the key drivers of competitive advantage within the industry. Key to their assessment is the operating cost advantage enjoyed by airlines with younger fleets. The fuel efficiency gains afforded by new composite-based aircraft are a key element in this lower operating cost position and hence replacement demand should remain high for Boeing and Airbus as airlines are required to maintain a young fleet or replace their ageing fleet in order to sustain their relative competitive position within the industry.

% of composite content (by weight) in an aircraft



Source: Airbus.

The second factor driving the adoption of composite materials is the potential production efficiency gains and lower maintenance costs. Both Airbus and Boeing are very asset-light businesses and so the emphasis on returns progression has been on reducing costs and improving margins.

Airbus believe that incorporation of composite materials has reduced development times and will enable higher production rates on the final assembly line. For the 787, the composite fuselage reduces the number of fasteners required in production by 80% and results in fewer than 10,000 holes needing to be drilled during the production process vs. more than one million for the 747.

This improvement in production efficiency is coupled with lower after-sale costs as maintenance and replacement costs are lower and composite materials are more durable and experience less fatigue than older metallic components. This reduces the amount of unscheduled maintenance required saving both the airline and the airframers money on maintenance.

Commercial imperative balanced by new product risk

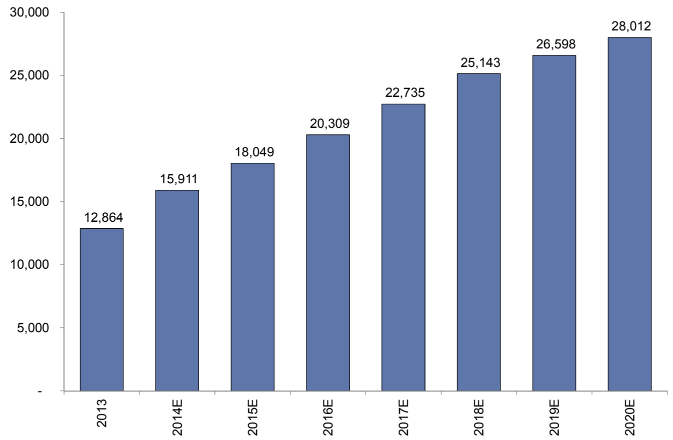
From a financial perspective, this commercial imperative is balanced by the financial risks of developing and marketing new products. While both the 787 and A350 were offered as more fuel-efficient 'clean sheet' designs to the airlines, the 777X, A320-NEO and 737-Max are all derivatives of pre-existing platforms where the incremental efficiency gain is principally driven by updated engines. This derivative approach to improving efficiency reduces both the costs and the risks to the aircraft manufacturer.

Boeing and Airbus lead the competition in the use of composite materials in aircraft manufacturing. Other manufacturers have plans to develop composite planes but to a lesser extent than the 787 or A350. Crucially, the technical barriers to adoption remain high, with Comac recently reducing the amount of composites it plans to use in its new C919 programme, citing difficulties with development.

The following exhibit highlights the expected progression of deliveries of composite-based aircraft through the decade. We expect both Airbus's and Boeing's new aircraft programmes (such as 787 or A350) to be margin-dilutive in the early stages of deliveries, but over time the improvement in manufacturing efficiencies, coupled with lower after-market cost, should drive margin progression.

This margin progression should be supported by continued top-line momentum as newer, composite-based, more efficient aircraft increase the benefit to customers of renewing their fleet.

Composites delivered by Airbus and Boeing (tonnes)



Source: Company data, Goldman Sachs Research Estimates.

Engines have also driven demand for advanced materials

Aside from the aircraft themselves, the engines used to power the new generation have also increased the use of advanced materials in an effort to save weight and reduce the cost of maintenance. Both the 'LEAP' and 'GE9X' engines (powering the 737/A320 and 777X respectively) will use carbon composite fan blades in place of the current titanium option. The LEAP engine is the successor to the highly successful 'CFM56' engine, whereas CFM56 engines have 24 titanium blades the LEAP engines will have 18 3D woven composite blades. The move to carbon composite blades has led to a 39kg weight saving despite the fan increasing in diameter by 8 inches. These lighter blades improve the fuel efficiency of the engine. In addition, because of the lower spinning mass from the lighter blades the engine casing, bearings and fasteners can all be lighter, enabling further weight savings.

The use of ceramic matrix composites (CMCs) has also increased in the new generation of engines. CMCs are able to withstand higher temperatures than the current metallic alloys being used. Increasing the use of CMCs therefore reduces the requirement for cooling of metallic components, reducing the weight associated with cooling systems. For the GE9X engine the use of CMCs reduces the cooling requirement by 20% and the weight of the heat-exposed components by two-thirds.

While the use of new material technologies and the improved fuel efficiency of new engines is a boon to the airlines, the development and implementation of these materials also benefits the engine makers themselves.

Increased use of carbon composites and CMCs results in a lower maintenance requirement. Carbon composites are more durable and suffer from less fatigue than metallic components, while using CMCs means engines require less cooling. Less cooling equates to fewer parts to service which in turn drives down the cost of maintenance. Lowering the cost of maintenance is crucial for engine manufacturers as they transition from 'time & materials' (T&M) contracts to 'rate per hour' (RPH) service contracts.

Under T&M contracts, services revenues were made by selling spare parts and the focus was therefore on achieving the highest price per part. For RPH contracts, the engine OEM and the operator agree a rate for every hour the engine is flying, with the engine overhaul being carried out by the OEM for free. With RPH the OEM is therefore incentivised to reduce the cost of overhauls as a path to improving profitability and returns. The investment in new materials by the engine companies therefore satisfies several criteria; the commercial impact to customers of fuel savings, the environmental/regulatory requirement for lower emissions and the OEM's own profitability and returns outlook.

Everyone's a winner

Overall therefore, the development and widespread adoption of new composite materials throughout aircraft will benefits airlines, aircraft manufacturers and engines makers. For aircraft manufacturers, the shift to significantly more fuel-efficient aircraft should support replacement demand in a market environment where new aircraft demand continues to be high.

For engine makers, the maintenance savings afforded by new material technologies is well timed, given the shift to RPH contracts from old-style T&M contracts. This shift should increase the barriers to entry and improve the value capture of the engine aftermarket by OEMs (as discussed in, '*Help me to help you' – Fortnightly Thoughts*, January 21, 2014).

R&D is vital in the aerospace industry and the development and implementation of composite materials serves as an excellent case study in how successful R&D can drive higher growth, profitability and shareholder returns.

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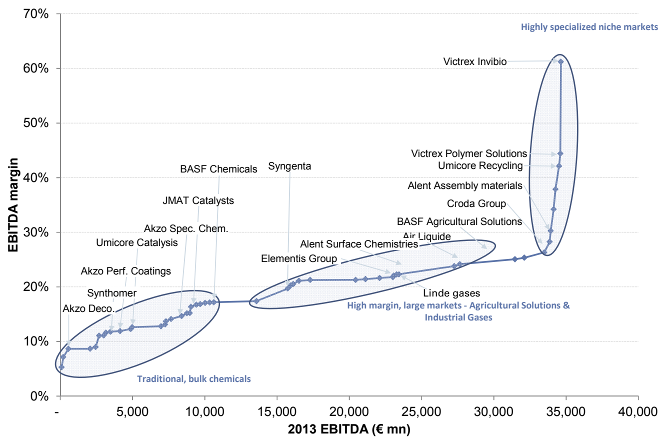
Testing tubes and melting pots

Our European Chemicals analysts, Rakesh Patel and Michael Rae, peer into the science lab to discover the new materials and technologies making products lighter, cleaner and stronger.

Little has changed in the chemists' philosophy over the past few centuries. Researchers continue to hunt, albeit with more advanced instrumentation, a more multi-disciplinary perspective and a more commercial acumen, for the elusive temptress: alchemy! While historically the focus has been on turning base metals into precious metals, chemists are working to find new materials with high performance while avoiding scarce elements, and to drive more efficient processes that can just be as lucrative. We showcase a very small range of new materials/processes which are starting to work their way from the lab into the commercial domain of "specialty chemicals" which could be a strong driver of margins and returns for the companies that can get this right.

There is a wide spread of margins across the sector depending on specialisation

Selected divisional EBITDA across the sector, arranged by margin



Source: Goldman Sachs Global Investment Research

Across the European chemicals space, the archetypal specialty plastic is PEEK, manufactured by Victrex (c. 80%+ market share), Solvay and Evonik. Spun out of ICI by way of an MBO in 1993, revenues at Victrex have grown from £59 mn in 2000 to £222mn in 2013 while the company has been able to protect its industry positioning. PEEK is seen as a polymer of last resort (priced at c.£76,000/tonne vs. PVC at c.£820/tonne) and seen as a replacement for metal with one tonne being used in each 787 plane for a variety of applications. The plastic can withstand high temperatures (melting point of 320°C) and pressures (Young's Modulus 3.6GPa) and burns with a clear flame.

The name of the game has been to find new applications for PEEK and there appears to be no shortage with uses being found in speakers for mobile applications but also in the body. Victrex is finding new "emerging business areas" for the use of PEEK in dental applications, trauma, knee and arthroscopy. The danger, of course, with finding a new wonder material is being able to protect IP: Victrex's near 50% EBITDA margin is attractive for any would-be competitor and the polymer itself is not patented (though Victrex's process which allows for a higher grade/quality of PEEK to be manufactured is). All of Victrex's manufacturing facilities are based in England to withstand any IP leakage and in addition Victrex is backward integrated, allowing production of a purer form of PEEK which competitors cannot replicate. While the lack of polymer patent remains a bear point, to date no new wonder material such as PEEK has been developed, nor has IP infringement occurred, allowing profitability to be protected.

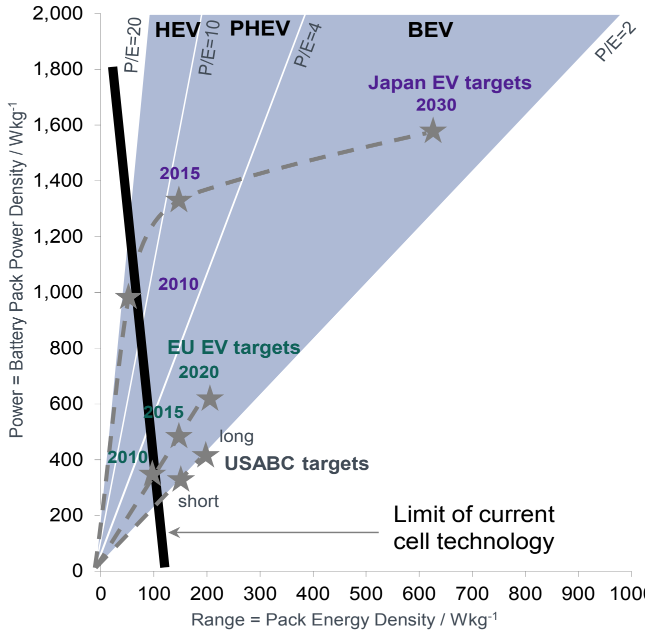
While the use of PEEK helps in part to drive efficient fuel use (e.g. in cars/aeroplanes), there is a broader question to be answered on fuel efficiency/clean air. The latter gained recent prominence after the City of Paris implemented a temporary motoring ban to control dangerously high pollution levels. This led to the City's Vélib (JCDecaux) bike sharing scheme and the Autolib' (electric car equivalent-Bolloré) being free of charge alongside public transport. In our minds, longer term, this opens up a new avenue leading to both the electrification of the car (and indeed bikes) and the potential use of hydrogen as a fuel. Hydrogen could potentially provide a revolutionary way to power electric cars through fuel cells (fuel cells combine oxygen and hydrogen to produce electricity). The advantages of hydrogen are well known (light weight, abundant and when used as an energy carrier it generates no emissions at the point-of-use other than water). The consequences could be far reaching – if 10% of cars were powered by fuel cells this could amount to €100 bn in sales for the industrial gas market (double the size of the industry today).

This is not just science fiction, progress is being made. Currently less than 1% of cars are pure "battery electric" with c.2.5% being hybrid (require a catalyst). This Is amplified with the LMC expecting the proportion of battery vehicles being c.1% in 2020 and hybrids moving close to 5%. In the UK, there are 10 electric car models (e.g. BMW i3) with an additional 40 due to be released soon. This year, Hyundai has delivered an assembly-line production car that can run for 600km before refuelling (vs. 480km for the Tesla electric car). Nevertheless, the road is still rocky and a number of basic, operational problems must be overcome. For instance, fuelling stations cost €1 mn each and the cars are not mass produced (the average electric car costs more than its gasoline counterpart before any government rebates - the BMW i3 costs US$42k before government incentives). However, we believe that as the technology develops costs will fall. We expect the IEA battery price to keep falling through to 2020, to about half what it is now. To improve infrastructure, a consortium of industrial gas companies has built more than 60 fuelling stations and has agreed to expand Germany's network by 100 in 2017 and 400 by 2023. Elsewhere, globally the US, Canada, Japan, South Korea and China have all implemented a refuelling station infrastructure programme.

In revolutionising the car through electrification, new demands are placed on the vehicle (e.g. energy efficiency, heat utilisation and safe and effective on-board energy storage). The latter is an important hurdle in driving EVs, as substantial improvements to current battery technology are required. As Prof. Edwards notes in his interview, great strides are being made. In Europe, both Johnson Matthey and Umicore are investing in battery materials. JMAT is targeting £300 mn in revenues from battery technologies in 2020 from c.£65 mn currently. In addition, we believe Umicore is a supplier of cathode materials (market leader with 32% share) to Tesla. Indeed, Umicore expects demand for cathode materials to rise to 170k tonnes in 2020 from 45,000 in 2011. Through our 2020 Vision framework we forecast the market for battery materials to grow to c.€11 bn in 2020 (from €1 bn in 2011). Other end uses of battery materials should also be important drivers of demand, such as notebooks (10% CAGR to 2020E), mobile phones (15% CAGR to 2020E) and tablets (25% CAGR to 2020E), among others.

Battery material technology is still not sufficient to meet some electric vehicle requirements

Electric Vehicle Battery Requirements



Source: BMW, AABC2010, Johnson Matthey.

Efficient exhaust systems are increasingly important in helping to solve the near-term carbon footprint problem of cars. Increasingly stringent emission standards in developed markets are well documented and solutions are served to OEMs by BASF, JMAT and Umicore (combined c.90% global market share). However, China still has a major problem with air quality in cities and legislation is in place to drive cleaner exhaust emissions from trucks (notably diesel trucks) and cars now that sulphur content in fuel has been reduced (which was previously an impediment as it poisons the precious metal catalyst).

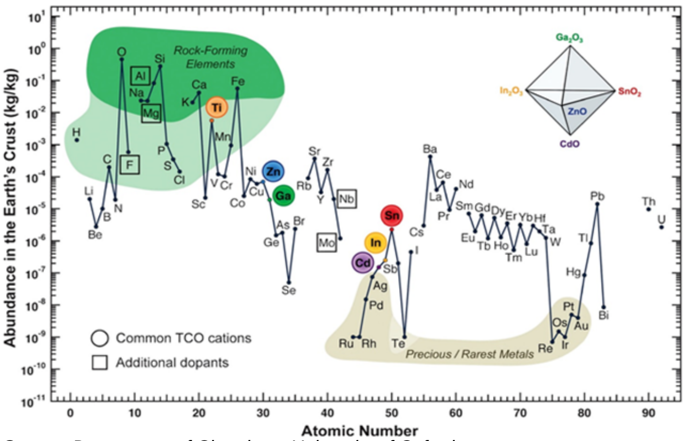
Consumer care is an area of innovation which continues to see good growth for chemical companies, in particular premium cosmetics, driven by urbanisation in emerging markets and aesthetics in developed markets. The specialty ingredients provided by chemical companies 'tends to be the magic powder' in the formulation (e.g. allowing shinier hair from shampoos). Prices of the chemical tend to be c.0.5% of the final selling price. At first glance, profitability is attractive, with a number of companies competing in the space (albeit in different niches) including Arkema, BASF, Clariant, Croda, DSM, Elementis, Evonik, Symrise and Givaudan among others.

Beyond this, we would highlight the continuing development in everyday items such as running shoes. Recently, BASF and adidas reported on their new adidas Boost running shoe where "the impact energy of jogging is no longer wasted – but sent back to the runner." This is driven by the foam (the world's first expanded thermoplastic polyurethane) of the shoe's midsole which springs back into shape upon compression leaving energy expended returned back to the athlete. Even paint finds new innovation. Nano Labs in Detroit has recently invented self-cleaning paint that uses nanoparticle technology to degrade dirt. These particles break down dirt using natural light.

Long term, a number of European chemical companies have pointed towards electronic chemicals as being a strong avenue for growth over the next decade, despite near-term volatility. To drive further progress in the never-ending quest for the miniaturisation of the electronic device, a number of problems have to be solved (e.g. lithography which is being pursued by ASML). However, we would note that there is also a move to drive costs down in electronics. For instance, indium doped tin oxide (ITO) is used in the front end of nearly every computer, touch, and display screen owing to its remarkable combination of high electrical conductivity and good optical transparency. However, owing to the high cost and limited supply of indium and the lack of flexibility of ITO layers (for flexible screens) alternatives are being sort. More earth abundant substitutes are being pursued with comparable optoelectronic properties. These include carbon nanotubes, graphene, and ZnO doped with SiO_2 (SiZO™) to improve substitute materials performance as compared to ITO.

Focus of chemists is on replacing scarce metals with those which are more abundant

Abundance of elements in the earth's crust (logarithmic scale)



Source: Department of Chemistry, University of Oxford

Finally, the ability to recycle materials in a resource-constrained world remains important. In our view, planning is key. Previously, recycling was mainly considered the domain of precious group metals, pgms, silver and gold given their importance in manufacturing products from denim to fertiliser and their use in chemical/auto catalysts and jewellery. Given technology developments, the status quo has changed. For instance, the price of cobalt was changed overnight by the launch of the iPad and iPhones where the element is used in flat batteries. Electronic scrap if collected and recycled in an environmentally-friendly manner could potentially help towards solving some element scarcity issues. According to Frost & Sullivan, the European e-waste recycling market was sized at US$1.3 bn in 2012 and is forecast to reach US$1.8 bn in 2020. We would note that to realise the opportunity more efficient collection methods are required. Umicore is in the process of piloting ultra high temperature (UHT) smelting technology which can purify cobalt (and other metals) from spent cathode metals, which has been difficult in the past. However, the present cost of metal recovery will likely be more than the value of the recovered metal at current prices.

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Interview with...Chris Grovenor

Professor Chris Grovenor is the Head of Department for Materials at Oxford University. His areas of interest include application of advanced analytical techniques to understand the relationship between chemistry, microstructure and the properties of functional materials, as well as nuclear materials and synthesis of new superconducting compounds.

Hugo Scott-Gall: What material science developments excite you?

Chris Grovenor: Despite the excitement around new materials discoveries, people often disregard the traditional metallurgical and materials industries as 'old hat' and not offering opportunities for generating value. In reality, conventional materials drive the development of novel engineering products; 90% of everything that we make is still made from plastic, metals or concrete, and exciting developments are happening in these traditional materials. New alloys are being developed from nickel, aluminium, steel and titanium for instance, allowing cars to be lighter and jet engines to run quieter, leaner and at higher temperatures. Companies that can develop these alloys cost-effectively and commercialise them first will definitely be able to generate good returns. In new materials, the area that excites me most is energy storage, the progress of which is almost completely based on materials technology. For renewable energy to make any sense, it's critical that we develop storage devices which can cope with intermittent yield and it's impossible to make any kind of grid scale energy storage device without solving the materials bottlenecks that everyone is struggling with currently.

Hugo Scott-Gall: Who's most committed to investing in developing storage technologies?

Chris Grovenor: There's good work being done all over the world. It's important to remember that the lithium ion battery was invented in Oxford in the 1980s, but the protection and exploitation of university intellectual property was not as sophisticated then as it is now, and the batteries were commercialised mostly in Japan. As demand for lithium ion batteries exploded, the technology made Japan a tremendous amount of money over the past 30 years. The UK and Europe can't afford to repeat the mistake. The West is still lagging in terms of investment in the storage domain, particularly compared to countries like China and Korea. As Asia is now a much more potent research enterprise than 30 years ago competition is far more severe, making it essential for Western governments commit investment to energy storage technologies. Despite making enormous progress in engineering equipment for renewable power generation, we won't be able to use renewable energy to its maximum potential unless storage is resolved. During the recent winter weather for instance, when we had a lot of wind power available, much of the UK's wind generation plants were not generating any power as the grid did not need the input and we could not store the energy. That is simply inefficient.

Hugo Scott-Gall: Can nuclear solve the world's energy issues?

Chris Grovenor: At present, less than half the uranium entering a nuclear reactor is burned to generate electricity. Better-engineered Gen-3-plus reactors planned for some UK sites are safer, but they will still only burn a similar fraction of the material. That said, the energy output of a ton of uranium is so significant that even without building the more efficient Gen-4 reactors, nuclear can provide baseload electricity output to the UK for many years and help us to meet our carbon reduction commitments. Elsewhere, China and India are developing and building high temperature Gen-4 reactors. In Europe, some research is being done on the new generation of reactors, but no manufacturer is willing to commit the capital needed to design and test new reactor technologies. Instead, Europe's capex is mostly leapfrogging Gen-4 technology and is being directed towards energy generation from fusion.

Hugo Scott-Gall: Is the scarcity of some elements an issue?

Chris Grovenor: There are a few elements including cobalt, tantalum and indium that everyone worries about, but I don't think scarcity is a major problem. The US is now re-opening mines closed 20-30 years ago because they were uneconomical then, but prices have changed so much recently that these mines are now profitable. It has become economically worthwhile to extract these scarce materials from dilute ores. Then there is recycling. If we simply scavenged the trace elements of all the mobile phones that are thrown away, we wouldn't have a problem of scarcity for many elements. Currently, the UK either exports our discarded products for recycling elsewhere or doesn't recycle at all. Broken or disused consumer electrical products that lie at the back of drawers at home contain valuable amounts of gold, indium, platinum and ruthenium among other elements.

Hugo Scott-Gall: Can new technologies such as 3-D printing change the way materials are used?

Chris Grovenor: There's a lot of enthusiasm for 3-D printing and manufacturing of complex objects from starter materials by self-assembly, but the technology is still in its early stages. We need to develop the technology to use as many materials as possible with different conducting, structural and mechanical properties, which can then be printed arbitrarily in three-dimensional space to build genuine functional engineering devices. We're a long way from achieving this, but it is an area I find very exciting. To begin with, the properties of some polymers need to be tweaked so they can be used in a 3-D printer: PEEK is an interesting polymer with some unique properties, but its molecular structure makes it difficult to use it in a conventional 3-D printer which only works with a narrow range of viscosities, temperatures and delivery parameters. So scientists need to marry the right functionality of the polymer with 'processability', something the polymer industry is very good at.

Hugo Scott-Gall: How do universities work with the private sector to bring innovation to the market? Is capital a constraint?

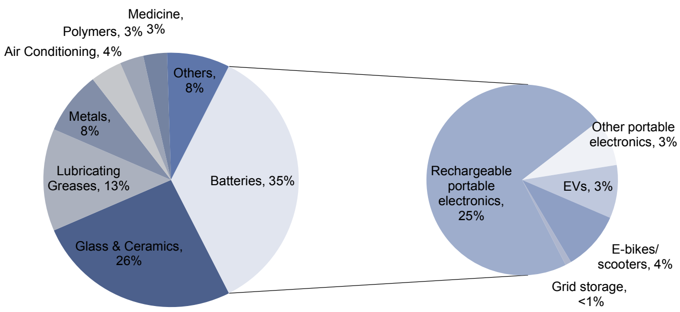
Chris Grovenor: Many UK universities are very active at turning good science into market value, though attracting second and third-stage funding for spinouts has been more difficult in the last five years, though not impossible. The market value of companies that have originated from Oxford is estimated at about €3 bn, but the value they contribute to the university varies hugely, depending on the dilution factor of the equity when the companies go through the various stages of fundraising. Most universities are getting much more savvy about this now, and are more professional about holding onto a larger share of equity and protecting IP better. There are huge differences in the willingness of companies to invest in blue-sky projects and research. From my experience, companies from the US, the UK, Thailand and Korea are more understanding about the need to share IP with the institute so there is a genuine sharing of the benefits of scientific development between the two.

Lithium: Storing up potential

Our US Chemicals analysts, Robert Koort and Neal Sangani, highlight the future demand growth for lithium as electric vehicles take off.

Commercially introduced in the early 1990s, the lithium-ion battery has become essential to modern life with near-universal adoption in rechargeable portable electronic devices (smartphones, tablets, etc.). Key to this proliferation has been lithium, a versatile but scarce element whose compounds (lithium carbonate and lithium hydroxide) provide the lithium-ion battery higher energy density, lower discharge and lower maintenance than alternative materials. Once almost entirely used for its heat-resistant properties in glass and ceramics, lubricating greases, and other low-value applications, lithium-ion batteries now represent the largest share (35%) of lithium demand.

Lithium demand by applications



Source: SignumBox, Goldman Sachs Global Investment Research.

After a decade with a c.10% CAGR in lithium consumption, driven by rechargeable portable electronic devices, the potential growth of lithium-ion batteries in electric vehicles and utility-scale energy storage may offer lithium another robust growth channel for the next decade. These expectations have gained momentum in recent weeks as Tesla has unveiled its plans to build the world's largest lithium-ion battery plant in support of its plans to launch its next-generation electric vehicle at mass market scale (approximately 500k vehicles).

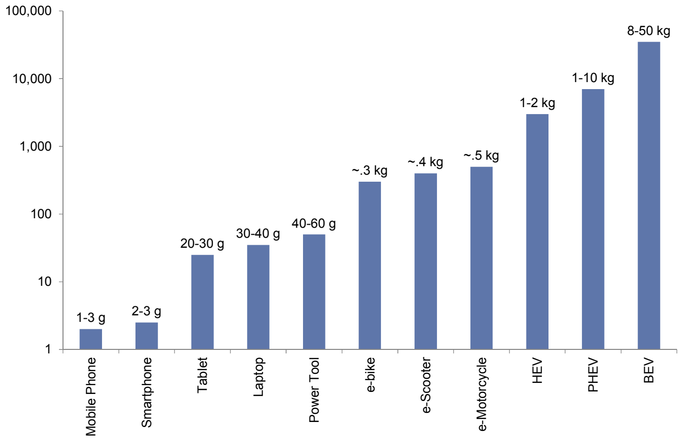
At full annual lithium-ion battery cell capacity of 35 GWh, we estimate that Tesla's "gigafactory" alone could consume 24kt of lithium carbonate equivalent (LCE), or about 16% of current LCE output of 150kt. In addition to the 35 GWh of lithium-ion battery cell capacity we presume will be mostly dedicated for its own EVs, we note Tesla has also planned total battery pack capacity of 50 GWh, which would allow Tesla to serve competitor EV programmes or the grid storage market while acquiring the necessary battery cells from a third party.

Tesla's emergence in electric vehicles is significantly positive for the overall lithium demand outlook as lithium content varies dramatically across applications (following exhibit). Lithium content in hybrid electric vehicles (HEVs) ranges between: 1-2 kg LCE in standard HEVs and 1-10 kg LCE in plug-in HEVs (PHEVs), well below the 10-50kg LCE in pure BEVs.

With a relatively large 85 KWh battery pack in a Tesla Model S versus other BEVs, such as the 24 KWh battery in a Nissan Leaf, Tesla represents the high end of the BEV unit content at about 50kg. By comparison, the Toyota Prius PHEV, which represented about 25% of US plug-in EV (PHEV and EV) sales in 2012, requires only about 4 kg LCE per vehicle.

Per unit lithium demand by application, log scale

LCE/Unit (Grams)

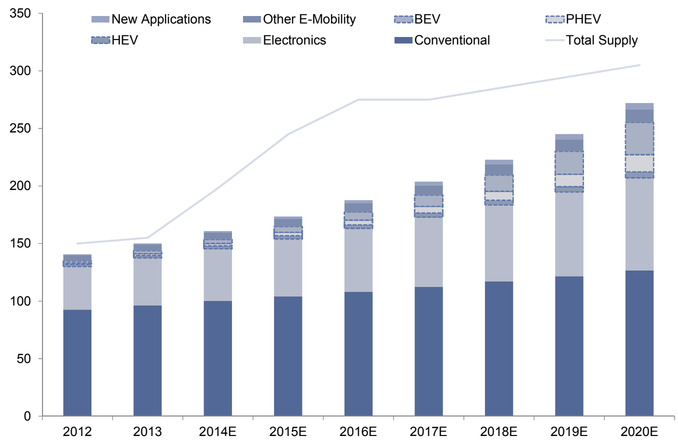


Source: SignumBox, Goldman Sachs Global Investment Research.

As a result, while our demand forecast assumes BEVs have about 15% share of the total EV market in 2020 (forecast at 6 mn vehicles), we expect these higher lithium-content BEVs like the next-generation Tesla to represent 28kt of LCE demand in 2020. By comparison, current total global lithium demand of around 150kt LCE includes a relatively small 5kt LCE contribution from the nascent EV market. Layering these estimates with GDP-linked growth of lithium in low-value conventional applications and ongoing fast 10% demand growth from portable electronics, our supply/demand analysis projects inflection in electric vehicles may help ease oversupply of lithium (discussed in detail below) around 2020.

Our lithium supply/demand forecast

K tonne LCE



Source: Goldman Sachs Global Investment Research.

We believe that it is still early to forecast a large demand boost from the grid storage opportunity for lithium-ion batteries, as these applications remain in their infancy (less than 1% of demand). However, several industry analysts see a sizable opportunity for an even more dramatic inflection in lithium demand towards the end of the decade. Currently, grid-scale battery pilot projects have targeted 10-40 MWh of capacity and Rockwood echoed this sentiment on its most recent conference call, noting "the grid storage potential could actually be bigger than cars" as large solar and wind projects being planned need an efficient means of energy storage in the absence of water. Pumped hydro, which involves sending water to a reservoir and releasing it later to run generators, is still the oldest, most common, and most economical approach to storing grid energy.

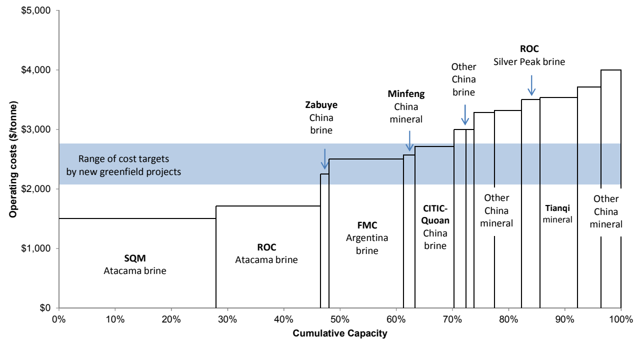
This significant potential inflection in lithium demand has spurred both current producers and new entrants to aggressively invest in new sources of lithium supply. While abundant in trace quantities in the Earth's crust and sea water, commercially producing sources of lithium are predominantly limited to lithium chloride-rich brines in South America (produced by Rockwood, SQM in Chile and FMC in Argentina) and lithium oxide spodumene rock deposits in Australia (produced by Talison). Together, these four producers currently represent about 95% of lithium output.

Planned capacity expansions from each of these existing producers generally require less investment than greenfield investments and should be online in the next few years. Most notably, Australian producer Talison, which holds the most cost-advantaged spodumene-based lithium assets, has nearly doubled its capacity but remains underutilized at roughly 55% of 100kt LCE capacity. This is largely because Talison does not currently produce lithium carbonate or higher-value downstream lithium compounds, instead exporting its lithium concentrate volume to China. On the brine side, Rockwood and SQM both have plans to pursue additional capacity in their assets in Atacama, Chile, 18kt LCE and 12kt LCE, respectively. FMC, hampered with process and operational issues while pursuing its 7kt LCE expansion in Hombre Muerto, Argentina, should also normalize to 26kt LCE this year.

Greenfield entrants to the lithium industry are looking to exploit a large number of untapped sources of lithium. While one producer aims to innovate a new technological processes aimed at recovering lithium from geothermal brines, most other new projects are also limited to brine or rock sources. Potential new brine projects largely include new deposits in Chile and Argentina and deposits in Bolivia and China. Potential new rock projects largely include new deposits in Australia and deposits in Canada, China and Africa. In total these new projects offer potentially vast reserves in total about three times greater than reserves of currently producing lithium sources.

However the production costs associated with these reserves are substantially higher than existing sources as they hold significantly lower concentration and grades of lithium. Given this steep lithium industry cost curve (following exhibit), we expect few greenfield entrants to reach commercial production, as these more economical expansions by Rockwood, SQM, and Talison are sufficient to absorb incremental demand.

Global lithium cost curve



Note: Cost curve based on end producers of LCE. Talison supplies a large share of China's lithium mineral but does not produce LCE.
Source: Roskill, Goldman Sachs Global Investment Research.

For brines, Rockwood and SQM hold the most cost-advantaged assets in the Atacama, Chile, as the high concentration of lithium chloride at 0.16%, generally 2x-4x higher than untapped resources, aids the 12-18 month evaporation process needed to concentrate the lithium content in the brines to usable levels (about 6% lithium chloride). The concentrated brine can then be treated with soda ash to produce lithium carbonate. Other favourable factors for the Atacama reserve also include the dry climate (greater rain in Argentina can dilute the brine pools) and lower impurity levels (magnesium content is a sizable hurdle for lithium production in Bolivia). Illustrative of this advantage, FMC, the sole current Argentinean producer, has halted further capacity expansions in favour of upgrading existing volumes to value-added products.

In addition to heavy rains in early 2012 diluting the brine pools and contributing to other operational difficulties, FMC has cited high inflation, taxes, regulation and unfavourable exchange rates in Argentina as key headwinds to its lithium business. Lower potash co-product economics following the significant recent decline in prices may have also worsened economic assumptions for planned Argentinean brine development projects. While potential developments in Chile are seen as more economical, Chile's mining code generally prohibits mining concessions for lithium, therefore only allowing Rockwood and SQM to operate under pre-1979 concessions.

We view economic feasibility of rock-based deposits as also primarily correlated with the lithium concentration within the reserve. The Greenbushes deposit in Australia where Talison produces at 1.5% lithium oxide generally holds 2x-3x higher concentration than untapped deposits. This aids the milling process to produce a spodumene concentrate of about 5%-7% lithium oxide that can be sold directly to for low-value applications or processed chemically to lithium carbonate or lithium hydroxide by an energy intensive heating and extraction process. Illustrative of this advantage, lithium converter Galaxy decided to abandon its 20kt LCE restart of its spodumene reserve in Mt. Catlin, Australia, instead contracting Talison to supply its Chinese carbonate plant.

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Interview with...Peter Edwards

Peter P. Edwards is Professor of Inorganic Chemistry at the University of Oxford and Fellow of St Catherine's College. He was elected a Fellow of the Royal Society (FRS) in 1996 and Einstein Professor of the Chinese Academy of Sciences in 2012. His areas of interest include sustainable and renewable chemistry for energy, particularly hydrogen storage in solids and turning carbon dioxide into fuel as well as metal-insulator transitions.

Hugo Scott-Gall: What are the key problems that researchers in your field are trying to resolve?

Peter Edwards: There are three key problems that need solving. First, we clearly need to meet future energy demands in a sustainable way, using energy sources that are ultimately carbon-free, or, at least carbon-neutral, such as renewable energy. I strongly believe that hydrogen will be the ultimate fuel of the future and in the medium to long term, it could be the element that the economy and transportation system are based upon. However, developments need to be made in both production and storage before it can become a viable solution. In the meantime, we must obtain maximum energy from the current, highly-effective fossil hydrocarbon fuels, efficiently extracted from their sources with minimum energy , while minimising the harm from CO_2 emissions. Second, we need to find substitutes for scarce elements and materials, many of which are used in a whole host of consumer products. For example, indium, which is an excellent conductor of electricity, is used in almost all touch screen displays in the form of the transparent conducting material, indium tin oxide. But indium is known as an earth-scarce element and perhaps there is also an overreliance on China (90% of production), which is why we need to find effective earth-abundant substitutes in form of other transparent conducting oxides, or find a way to make or use ITO more efficiently. Third, global healthcare problems are demanding attention: a considerable effort is going into using nano-materials as targeted solutions for specific problems and drug delivery.

“I strongly believe that hydrogen will be the ultimate fuel of the future and in the medium to long term, it could be the element that the economy and transportation system are based upon.

Hugo Scott-Gall: What are the bottlenecks in terms of energy?

Peter Edwards: At present, hydrogen is produced by decomposing natural gas, methane (CH_4), and this carries an enormous carbon footprint and thereby doesn’t make much environmental sense; using renewable energy instead to decompose water, for example, with the right photo-catalyst is a viable solution and a formidable materials challenge for scientists.

Developing a method to store hydrogen in solid, liquid or gas form and making it effectively transportable is the second major obstacle. Hydrogen stored in gas form has been highly effectively employed by companies such as Toyota; however, unlike petrol, hydrogen’s natural state is gaseous and as such it requires storage at high-pressure in large, pressure-safe containers. Hydrogen liquefied at low temperatures has also been developed, but it also carries a whole host of infrastructure issues.

So, the most desirable form of storage from a scientific perspective is in the form of a solid-state material that can store hydrogen. There has been some progress here; submarines for instance use a material such as lanthanum nickel hydride to effectively store hydrogen, which is then used in a fuel cell at sea by simply heating the material. Although, this technology is relatively advanced, the weight of the hydrogen storage material is a major problem, particularly for mobile transportation uses, given lanthanum is a very heavy element. Another area of materials research is using catalysts to convert CO_2 emissions back into a fuel. This was in fact number six on the World Economic Forum’s top 10 emerging technologies for 2012. One area of research is to use catalytic materials (differently from catalytic converters in cars) and combine the CO_2 from emissions with hydrogen to produce hydrocarbon fuels. i.e. instead of, for example, using hydrogen in a fuel cell, it can be combined with CO_2 to produce a liquid, easily transportable fuel that uses the existing infrastructure. Nevertheless, this would only be an environmentally friendly process if hydrogen was produced using renewable sources.

“There is a real, rapidly growing demand for this new “earth-abundant electronic materials” technology, as rare earth and other metals are used in the manufacturing of a wide range electronic goods, but use up large amounts of energy in extraction and subsequent processing, and can be highly challenging to recycle.

Hugo Scott-Gall: What developments you see excite you most?

Peter Edwards: Some of the most exciting developments are taking place in an effort to replace earth-scarce materials with earth-abundant oxides. Remarkably, oxide materials are good insulators and good semiconductors , as well as the very best conductors and superconductors – materials that when cooled have no electrical resistance whatsoever.

However, to “tune” such materials properties requires clever physics and chemistry to first make them electronically active. There is a real, rapidly growing demand for this new “earth-abundant electronic materials” technology, as rare earth and other metals are used in the manufacturing of a wide range electronic goods, but use up large amounts of energy in extraction and subsequent processing, and can be highly challenging to recycle.

Another exciting area is the world-wide trend of research and development into thin film materials and thin-film based electronic devices. Typically, such films are presently made by high-temperature evaporation routes (usually in vacuum machines). A major advance is a technique known as spray pyrolysis, which involves depositing a chemical solution of the target. Material is spray-deposited at lower temperatures, usually under atmospheric conditions, which can improve the energy needed to produce the films while maintaining the material's performance. It also uses far less of the material for the same end application.

Most of our work is based around developing such new solution routes that use significantly less energy and have less environmental impact.

> “Superconductivity, particularly the tantalising prospect of superconductivity at room temperature, must surely be the most important, unsolved problem in the science of materials.

The other area of interest which has excited me for many decades centres on the magic (almost alchemy!) of turning insulators into metals; a simpler way to say that is “turning wood into copper”. If we change a certain material's chemical composition or temperature, we can, say, change its electrical conductivity by ten orders of magnitude and selectively transform and control its electronic properties. If we achieve that, we have electronic control for a whole variety of applications.

This ultimate transformation one finds in dense, black ceramic oxides, that become superconductors at low temperatures. Remarkably, there is presently no universally-accepted theory on why these “perfect conductors” behave in this way. But if we can understand the fundamental science of this phenomena better, these materials can have huge implications for our future; for example, in energy and the environment (electrical power transmission lines having no resistance) and health care (MRI machines currently use energy-consuming low temperature superconductors).

Superconductivity, particularly the tantalising prospect of superconductivity at room temperature, must surely be the most important, unsolved problem in the science of materials. Scientific American in 2010 noted that room-temperature superconductivity is one of “twelve events that will change everything”. I agree.

Hugo Scott-Gall: How do you collaborate globally, particularly with researchers in emerging countries?

Peter Edwards: The biggest gating factor for new materials is the pathway to manufacturing i.e. the transition from research labs to pilot plants. However, the UK government have been good at thinking about strategic materials that need substitutes, while we are also receiving increased funding and research interest from emerging countries.

For example, our strong partnership with the King Abdulaziz City of Science and Technology in Saudi Arabia have focused on investigating the possibilities for new technologies, including microwaves and new generation “super catalysts” in its petrochemical plants to reduce their environmental and carbon footprint while at the same time improving performance.

There are clear targets to develop model refineries that incorporate new, clean technologies, such as solar into energy plants, in the next three years or so. There has been both a continuous evolutionary approach in this industry to petrochemical production and a longer-term revolutionary or “repowering” approach.

China has also been very active in sending some of its brightest students to my group to help improve the performance of key energy materials. Tackling the country's air pollution challenge has been at the top of the government's agenda. And they have been very clear that they need to solve the problem in the next 3-5 years. This includes solutions such as removing sulphur from fuels, improving catalysts or reducing dangerous particulate emissions by making fuels cleaner.

> “The biggest gating factor for new materials is the pathway to manufacturing i.e. the transition from research labs to pilot plants.

Overall, emerging countries are catching up very quickly and in some areas, such as catalytic science and semiconductors, they may overtake the West by the middle of the century.

Hugo Scott-Gall: What in your view is the next big material?

Peter Edwards: In the semiconductor industry, I believe that silicon will remain supreme. Remarkably, it is still the basis of almost all of the consumer electronics and of course photovoltaics. But after that, I would focus on oxide (and possibly organic) electronics, particularly for large-scale applications with a real target of high-performance, earth-abundant oxide electronics.

Across the vast areas encompassing fossil fuel and renewable energies, the need is for high-performance, earth-abundant catalysts. Finally, if we can solve the bottlenecks of sustainable production, effective solid-state storage and carbon-neutral liquid fuels then hydrogen will become really exciting.

Wafer thin wonders

Donald Lu, our Asia Technology & Telecoms analyst, discusses new technologies and materials in semiconductor manufacturing

Semiconductor manufacturing has followed Moore's Law for the last 40 years, shrinking the size of transistors on integrated circuits by half every two years. The current state-of-the-art is 14nm in feature size, or1000th the thickness of a copy paper. 10nm should be available in early 2016, followed by 7nm in 2018. According to Mike Mayberry of Intel, "Moore's Law is not a law of nature, it is an expectation of continued innovation" to achieve faster transistors, lower power consumption, and decreasing cost per transistor (at least to 10nm according to Intel). Beyond 10nm, it is not yet clear if the cost per transistor can continue to decline. The semiconductor industry has continued to employ new material and technology to overcome technical challenges, which should escalate in the next few years as feature size approaches the physical size of a few atoms. We highlight the status of a few potential new materials and technologies in logic semiconductor manufacturing and explore their stock implications here.

EUV (extreme ultraviolet lithography) is the next-generation lithography technology that determines the smallest feature size of a transistor.

Lithography is an optical technology and the wavelength of light will limit the feature size. After migrating from ultraviolet (365nm wavelength) to deep violet (193nm wavelength) light, lithography is slated to adopt EUV with a wavelength of 13.5nm. Without EUV, 20nm requires double patterning lithography that is very costly. But, EUV still has significant technology challenges; EUV is produced by laser, but current laser power is insufficient for the desired throughput and therefore cost of ownership; cleaning and defect inspection of the EUV mask are challenging; and the focus of EUV requires an extremely flat mirror with less than a 1mm bump if blown up to the size of Germany.

ASML is the global leader of EUV lithography. According to ASML, its R&D investment in EUV is already similar to that of the previous two generations of lithography technologies. Despite multi-billion dollar investment, the progress of EUV in high volume manufacturing has been slow. Intel is considering EUV for critical layers at 7nm if the cost of ownership improves significantly by 2017. TSMC has reconfirmed its commitment to introducing EUV at 10nm at a recent industry conference, but our checks indicate that few of TSMC's major customers have started to use EUV reference design in their early 10nm R&D.

A 450mm wafer is 2.25x larger than a 300mm wafer and can potentially reduce the chip cost by 8%-30% according to SEMI and Future Horizon, respectively.

In the past, the transition from 200mm to 300mm has lowered chip cost by 26%-29%. 450mm could help to prolong the cost curve of Moore's Law in theory, but requires heavy investments at both equipment vendors and semiconductor makers. In addition, each 450mm fab would cost over US$10 bn in capex, and as such only the top semiconductor makers (e.g. Intel, TSMC, Samsung Electronics, and probably government backed GlobalFoundries) could likely afford a 450mm fab.

For equipment vendors, the return on 450mm investment is questionable, adding on the cannibalisation effect on 300mm tools. Intel has been the main proponent of 450mm technology, but has recently pushed out the launch date of 450mm production from 2016 to potentially 2020 or beyond, according to Times Union. Accordingly, ASML has reduced its R&D effort on 450mm. We attribute the delay of 450mm development to the increasing bargaining power of Applied Materials and Tokyo Electron after their merger, an improving outlook for 10nm chip costs at Intel, and reluctance at TSMC and Samsung.

Germanium (Ge) and indium gallium arsenide (InGaAs) are also semiconductors like silicon but can carry charges 3x to 6x faster than silicon.

Intel, IMEC, IBM, and others have proposed replacing silicon with Ge and InGaAs in channels that carry current at the heart of a transistor. Ge and InGaAs can potentially improve performance (speed) or reduce voltage (power consumption) by leveraging their high mobility. In high-volume manufacturing, the key technical challenge is the defect caused by different crystal constants between silicon and the new material. In addition, additional processing steps and material should also increase manufacturing costs. We estimate that the earliest commercial use of Ge and InGsAs would be at 7nm, potentially in 2017-2018 if ever.

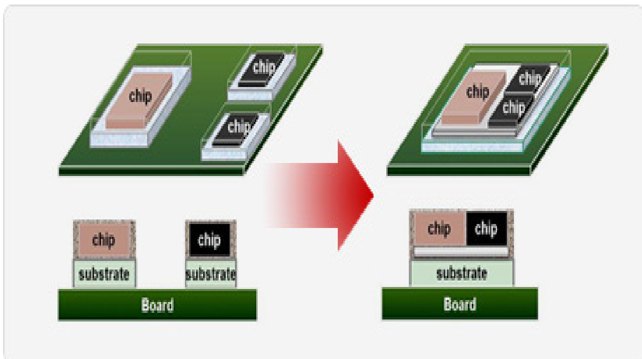
3D wafer level packaging uses through-silicon via to connect multiple wafers on top of each other or side-by-side on an interposer wafer.

Compared to traditional packaging that wraps individual chips, 3D packaging reduces the length of interconnect between chips therefore improving speed, improving power consumption, and reducing form factor. In addition, 3D packaging allows the partitioning of a large die into smaller ones that fit different process technologies to optimise cost. For example, one can use advanced and mainstream technology for processor and RF, respectively.

The most likely early adopters of 3D packaging are server, GPU, FPGA, and high-end processor for mobile device. 3D packaging is already mature enough for mass production. On October 23, 2013, TSMC and Xilinx announced the volume production of a 28nm CoWoS (chip-on-wafer-on-substrate) 3D FPGA.

TSMC's CoWoS integrates multiple chips into a single device on a substrate

Migration from traditional packaging to CoWoS

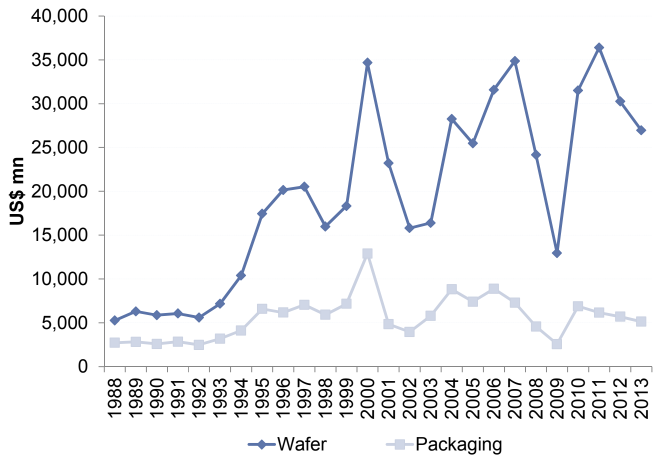


Source: TSMC.

This indicates that TSMC's CoWoS technology has already achieved a mature yield and reasonable cost level. 3D packaging technology of logic and memory is also ready, but the commercial application is still a work in progress as a result of cost and the lack of communication protocol among different chips (logic, memory, passive, etc.). To that end, we are pleased to note that ASE and Micron have recently set up an alliance to develop 3D packaging, following that between TSMC and Hynix. Intel and Altera have also recently revealed their collaboration to develop 3D FPGA product. Packaging has been the back water of semiconductor R&D and capex investments as a result of a lack of innovation and could potentially be a low-hanging-fruit for innovation. We expect 3D packaging to become a disruptive technology in semiconductor manufacturing.

Semiconductor wafer and packaging capex have diverged as wafer manufacturing has followed Moore's Law, but packaging has lacked innovation

Comparison of global total foundry and packaging capex, US$ mn



Source: SEMI, SIA, Gartner, Goldman Sachs Global Investment Research.

We believe that the stock implications of EUV, 450mm, and Ge/InGaAs are similar to previous innovations such as 300mm, high-K/metal gate and FinFET in recent years.

These innovations increased the capex and R&D intensity of the industry and strengthened the competitive stance of the industry leaders, namely Intel, TSMC, and Samsung at the expense of second-tier foundries and IDMs.

On the other hand, the industry's consolidation has been incrementally negative to semiconductor equipment vendors. Among the equipment vendors, ASML, KLA Tencor, and Hermes Microvision have fared relatively well because lithography and wafer level inspection are two areas that enjoyed a higher growth CAGR than the overall market as Moore's Law continues. On the other hand, Moore's Law has become increasingly difficult to follow as shown by the delay of EUV and 450mm commercial deployments. The eventual and unavoidable stoppage of Moore's Law should impact the industry leaders more than second-tier vendors, in our view.

3D wafer level packaging could potentially shift some of the traditional packaging businesses from pure packaging service suppliers such ASE and SPIL to foundries such as TSMC as:

1) TSMC leads in 3D packaging technology such as CoWoS today; and,

2) as an integrated supplier from wafer to packaging, TSMC is better positioned to take on the yield responsibilities of multiple wafers.

In addition, 3D packaging also has a few unique technical challenges which are interesting opportunities for some suppliers:

1) Because the through-silicon-via is a very small hole and works on only very thin wafers (5 micron wide and 100 micron deep), 3D packaging requires the grinding away of over 90% of wafers. Disco has 90% of semiconductor grinder market share and should benefit from the incremental demand for grinders, in our view;

2) We need innovation or special carrier and carrier substrates to handle the extremely thin wafers during and after grinding. Several companies have announced products and projects in 3D thin wafer handling.

3) Wafer-level testing is extremely important in 3D packaging because any defective die would damage the entire stack of dies in the 3D packaging. We expect the wafer-level testing time to increase in 3D packaging. Teradyne and Advantest are two leading semiconductor tester makers.

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Interview with...Ray Gibbs

Ray Gibbs is the CEO of Haydale, a company based in South Wales developing commercial applications for graphene. Previously, Mr Gibbs was a finance director at the FTSE 250 defence company Chemring (1996 -1999), and partner at Deloitte and Touche (1987-1996).

Hugo Scott-Gall: What is graphene and what are its potential applications?

Ray Gibbs: Graphene, which is a single-carbon lattice layer one atom thick, has outstanding thermal, mechanical and electrical properties. It is stated to have potential applications in significant markets such as battery and energy storage, electronic devices including bio-medical sensors, conductive inks and films plus polymer composite fillers and resins.

Although it has always existed, it was first isolated by Prof. Geim and Prof. Novoselov of the University of Manchester in 2004. They were subsequently awarded the Nobel Prize in Physics in 2010 for their discovery. Graphene has a whole host of properties that make it an incredibly exciting material for the future. It can conduct electricity better than copper, is 200 times stronger than steel atom-for-atom and is very flexible. One gram of graphene layered end to end would cover two football fields, and stacking three million sheets on top of each other would only make it one millimetre thick. Graphene could be the most disruptive material in the 21st century making products potentially faster, better and/or cheaper.

For these reasons, graphene has attracted a lot of attention from researchers and companies which have scrambled to file patent applications. In particular, Far Eastern countries have been very active because of its potential use in the electronics industry. A single layer of graphene could be used to make screens for a whole host of appliances as it is virtually transparent (it blocks only 2.3% of light) while being conductive, bendable and strong enough that as a touch screen it will not shatter. The Holy Grail for many electronics companies including, Samsung, Sony, Hitachi and LG has been to develop reel-to-reel sheets of graphene that can be used in appliances from TVs to smartphones. However, as a single layer sheet of graphene is approximately 64 angstroms thick (an angstrom is one ten-billionth of a metre), it has been a difficult challenge for manufacturers.

In addition, there is significant potential for the use of graphene in energy harvesting, ranging from super capacitors to batteries for cars. The opportunity to develop batteries that take less time to charge, and hold that charge for longer periods is appealing as it also reduces emissions. Less high-tech, but equally impactful uses include applications in the food industry, which suffers from high levels of waste. The average film used for food packaging does not keep out oxygen for an indefinite period of time, using graphene films instead as a barrier should increase the chances of lengthening the shelf life of food.

Hugo Scott-Gall: Given graphene's unique properties, there has obviously been a lot of interest from the manufacturers' side. How have they co-ordinated with producers to bring this innovation to the market?

Ray Gibbs: Many companies are investing large sums of money to produce graphene either from mined organic graphite or synthetically. Many see the opportunity to sell vast quantities of the material and make strong financial returns in the process. However, the commercial picture is complicated by the fact that there exists many different types of "graphene" and many target markets. Each type of "graphene" offers a different set of properties depending on the form in which it arrives, which can vary from less than 10 to over 100 layers of graphene sheets laid on top of each other. The picture is further complicated by the fact that there are a number of production techniques, and each one delivers a different material, cost structure and scalability.

As companies look to integrate the material into applications, they face challenges in mixing and then bonding the graphene with the material to give the desired properties. The problem is compounded by the large price differentials between the various graphene materials on the market today. So from a production perspective, there needs to be a standardised definition for graphene, so that there is clarity of meaning, making technical comparison and price comparability easier. That way there will be a level playing field in the industry.

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Hugo Scott-Gall: In terms of the timeline, when can graphene really begin to change the nature of every-day products?

Ray Gibbs: It is very difficult to say when the first commercially available single-layer sheet of reel-to-reel graphene will be created, which is something that the Far East is desperately trying to develop. However, I believe there could be early adoption in some areas in the next 12 months.

Graphene faces a number of serious challenges that have to be overcome before it becomes a commercially viable substitute. To successfully commercialise graphene, we need to develop the ability to combine it with other materials. For example, dispersing graphene into a paint substance as a barrier film (impervious to gas) would stop the ingress of oxygen and reduce the oxidisation of steel (rusting) in ships and other structures, potentially increasing their useful life. However, because graphene is a carbon-based structure, it is inherently inert which means that it does not naturally mix with other materials and makes it hard for producers to bring all its properties to the end-product.

We believe that functionalisation is the key to commercialising new discovered materials such as graphene. Functionalisation would generally involve the addition of chemical groups or radicals to enhance the dispersion into another material, to promote bonding. In other words, the industry and the scientific community needs to work to improve the functionalisation of graphene. i.e. ensuring that there is chemical compatibility between graphene and what it is being combined with, whether that is paint, a polymer or a resin. Some manufacturers also employ methods for functionalisation that involve processing graphene in an acid, resulting in a chemical group coating of the surface. Outside the environmental issues, there are drawbacks to this and in many cases acid treatments can have the opposite to intended effect on the final product.

> "the industry and the scientific community needs to work to improve the functionalisation of graphene. i.e. ensuring that there is chemical compatibility between graphene and what it is being combined with, whether that is paint, a polymer or a resin.

Although Haydale is not a manufacturer of the raw material, it sees a whole variety of graphene products and acts as an enabling technology. Using a plasma-based process in functionalisation ensures that the molecular structure is not destroyed and can combine with a range of standard and exotic chemical groups which gives an infinite variety and possibility of uses. The technology is also a low-energy user and, more importantly, environmentally friendly. So having access to a range of materials, allows the Haydale technology to provide value-added solutions to both raw material producers (looking to enhance their offering) and industrial corporations seeking the right material and functionalisation to make a difference to their product.

Our aim is for Haydale technology to play a key role in the development and commercialisation of graphene and other nanomaterials. Enabling solutions in partnerships that make a difference.

Hugo Scott-Gall: As the prices of traditional commodities have risen significantly over the past decade, can graphene become an economically viable substitute for them eventually?

Ray Gibbs: The industry has made positive strides through its investment in driving the price of graphene down. This has been great for users of the material, but more is required before it can start becoming a cost-effective substitute. At present, five to six layers can cost US$1,000-2,000 per kilo, and often much more, and sometimes it may or may not work in its intended application. Although lower-quality forms do exist (priced at US$100-150 per kilo), the key questions for users is whether the end-product performance is enhanced enough by using low levels of graphene compared to the material it is displacing. For example, using 1% graphene in a product to achieve the same performance as using an existing material that currently requires a 10% loading makes economic sense as long as graphene is not more than 10 times as expensive as the original material. I believe this requires the price of graphene, in a form I would call workman-like (up to 100 layers thick) to come down to around US$100 per kilo. Given the focus of the producers around the world on increasing volumes for economies of scale, I am confident that the price will come down eventually: it is a simple case of economic principles surrounding supply and demand.

Hugo Scott-Gall: What are the bottlenecks in accessing the graphite?

Ray Gibbs: At present, the annual supply of graphite is 1,100kt, of which almost 70% comes from China. Graphite is used in a wide range of applications such as brake pads, crucibles, lubricants and batteries. It is also used as a pre-cursor in producing graphene layers known as graphene nano platelets (GNPs). The industry has been working hard to find alternative mines around the world since there is very little reliability or stability expected in future production from the major producer, where efforts to control activity in this area have increased uncertainties. The interest in graphene and the GNPs has offered the graphite mine owners a possible increased value option for their commodity and consequently, alternative sources for graphite are being explored by the mining industry in countries such as Sri Lanka, Canada, Africa and Brazil.

There is also the technology to make graphene synthetically. This can range from using CO_2 to placing hydrocarbons such as palm oil in a furnace. Graphene NanoChem , a company listed on AIM, uses palm oil and operates out of Malaysia. Nevertheless, synthetically produced graphene is almost certainly going to have to overcome the same issues of functionalisation as the mined organic graphite-based material.

Hugo Scott-Gall: What role have governments played in the development of the product?

Ray Gibbs: There has been significant support from European governments to provide help and aid to the graphene industry. In the UK, the National Graphene Institute was set up at the University of Manchester (where graphene was first isolated) and is dedicated to developing commercial uses. There is the hope that it could provide a boost to the economy by providing graphene-related goods and services. The European Union in 2013 also committed €1 bn over the course of the next 10 years to be used in further graphene research. The Technology Strategy Board in the UK offers funding support for projects and has a specific graphene initiative to enable ongoing research and commercial development to occur.

However, in a world that is moving rapidly, often the waiting time to access grant funding from the EU initiative for example is too long for some companies. Many early adopters of graphene, such as the printing world, which is looking to benefit from first mover advantage, are looking at alternative sources of capital. For example, developing a resin that can be used to provide a stronger, stiffer composite or fast-tracking a conductive ink for use in flexible printed electronics will be pursued aggressively by companies seeking competitive advantage.

A lightweight material with some graphene loading that could replace existing products has great attractions for the auto industry, while having a flexible conductive, recyclable product that does not use precious metals will cause market leaders to aggressively pursue these new materials. Not waiting for grant funded opportunities is, I believe, very indicative on how fast the industry is progressing.

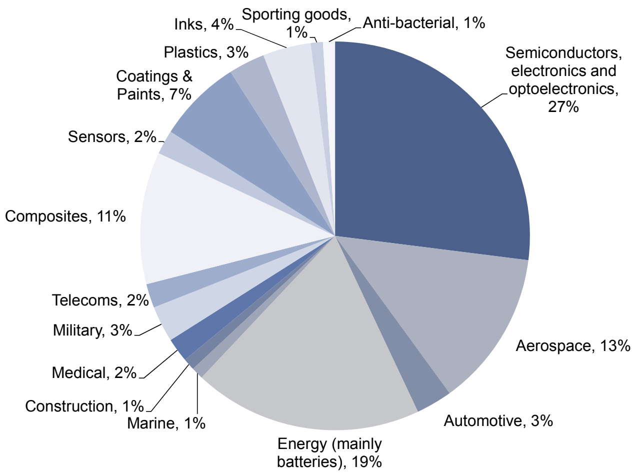
Niche exposures to material trends

Our European Mid-cap analysts highlight new material innovators and winners across different end markets

We highlight here opportunities among small and mid-cap stocks that offer concentrated exposure to trends and developments in materials. We focus on four areas: (1) invention of material technologies, such as graphene for applications in electronics and engineering; (2) substitution between materials as a source of cost savings, such as the displacement of metal products by plastic; (3) innovation of materials to boost performance and productivity, such as specialty materials used in construction and autos; and (4) environmental materials, such as biofuels and other derivatives of sustainable materials.

Pervasive impact of graphene development

Graphene target end-markets by %



Source: Future Markets

Invention: New materials to leapfrog engineering challenges

New materials can bring a step change in manufacturing and promise to leapfrog binding engineering constraints. Elsewhere in this issue, our aerospace analysts have described the development and use of composite materials in aircraft. Here, we look briefly at graphene, another form of carbon that could have transformative applications in electronics.

Samsung recently reported the development of a new transistor structure based on graphene that promises to overcome the limits of silicon-based technology. Today's silicon-based devices consist of billions of silicon transistors. In order to realise Moore's Law and increase the speed of devices, the industry has succeeded in constantly reducing the size of individual transistors to shorten the travelling distance of electrons. However, the advances achieved by scaling down become harder and harder to achieve. Further advances therefore become more dependent on alternative technology road maps, including developing new material technologies that can help overcome the constraints of silicon. Especially interesting are materials that have higher electron mobility and that allow for faster electron velocity. Graphene is potentially a promising alternative to silicon since it possesses electron mobility about 200 times greater than that of silicon, although the material also brings additional complex engineering challenges (source: Samsung).

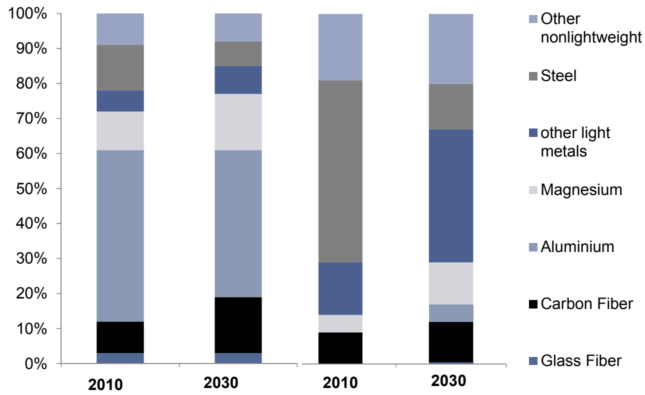
Oxford Instruments (Buy; 1,380p) offers tools that are crucial in the research and development of graphene. These tools include cryogenic systems that enable environments near absolute zero and tools that create specific magnetic fields. As large electronics and engineering groups compete to stay at the forefront of graphene research, we believe that Oxford Instruments is well placed to address a growing R&D opportunity.

Substitution: Swapping materials for cost and efficiency gains

For any industry dependent on scarce raw materials, substitution by cheaper or more plentiful alternatives can be a key source of efficiency gains. In autos and aerospace, lighter materials in particular contribute to lower fuel consumption in vehicles.

Aviation and autos leading way in substitution of traditional materials by more lightweight alternatives

Material split by percentage across aerospace & autos



Source: McKinsey

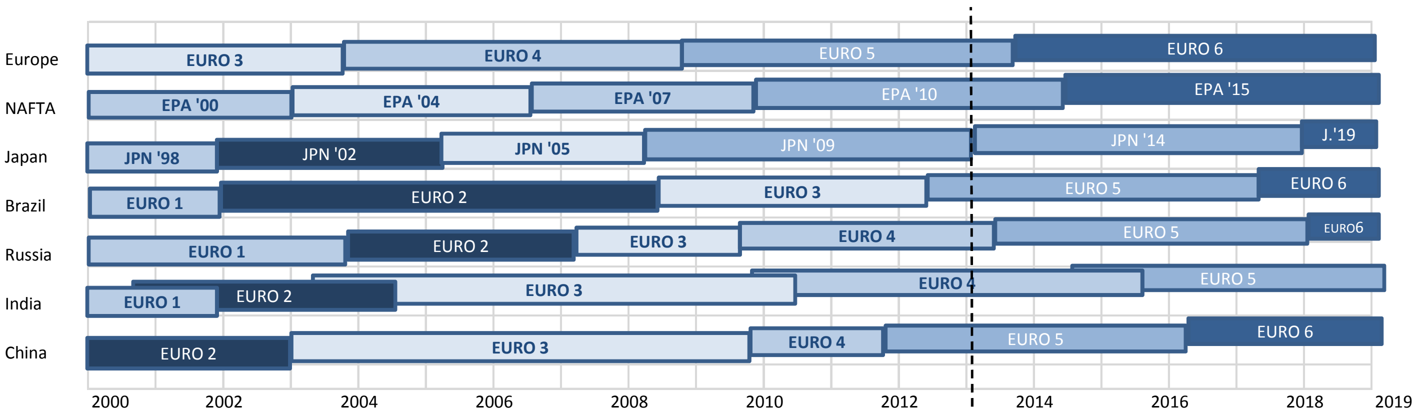
Besides composite materials, high performance engineering plastics are increasingly displacing metals in multiple components. These ongoing changes enable manufacturers to meet increasingly demanding emissions regulations, as shown in the following exhibit.

Other agreements undertaken by autos producers include the corporate average fuel economy (CAFE) standards, which specify a target of 54.5 miles per gallon by 2025. On average a 10% reduction in the curb weight of a vehicle can reduce fuel consumption by approximately 6.5%. The new Cadillac ATS, for example, is due to target a 15% weight reduction compared to the current production model in order to overcome these regulatory hurdles (source: GM Chairman and CEO Dan Akerson).

HellermannTyton (Buy; 320p) is one of the largest suppliers of connecting technologies used in autos and industrial applications. The group supplies light-weight and resilient polymer-based products that often substitute heavier components made out of metals. The group is one of the world's largest consumers of the chemical PA66, which is an engineering nylon employed as a result of its high mechanical strength, rigidity and heat resistance properties. The increasing electrical and electronic content per vehicle, driving the use of plastics, can also be both safety and comfort-related. Examples include mandatory airbags in Brazil (safety) and electrically operated seats (comfort).

Emissions regulations drive increasing cabling content

Evolution of global truck emission standards



Source: ACEA

Innovation: Specialty materials for higher performance

Speciality chemicals can significantly enhance the specific application niche that they serve. The construction, transportation and engineering sectors all rely on specific engineered chemicals to enhance performance characteristics. Concrete admixtures, for example, can halve work times, reduce cement and water consumption by up to 40%, and significantly improve durability and longevity. Since concrete pillars were first used in buildings, the required diameter of a concrete pillar supporting 100 tonnes has been reduced by more than 90% from 100 cm to less than10 cm. Admixtures confer material benefits and savings therefore, but typically represent a small cost, often less than 1% of overall building costs. Sika (Buy; SFr3,575) is a global leader in specialty construction chemicals and ranks in the top three players in each of its product verticals. We believe that the group is well positioned to benefit from increasing penetration of admixtures in construction activities and from industry consolidation. We expect penetration growth above all in emerging markets. For example, four concrete manufacturers for China's Nanjing Metro adopted a Sika admixture after unsatisfactory results and thereby helped to improve productivity by a third.

Elsewhere in the building materials sector, Kingspan (Neutral; €13.4) supplies insulation products manufactured from advanced polymers that have attractive thermal efficiency properties at lower weight and volume. We similarly see a long-term opportunity to benefit from growing penetration, both of insulating materials in the building stock and particularly of speciality high-performance materials within the insulation category. Specialty chemicals are also used in the autos industry. Fuchs Petrolub (Neutral; €72.5) supplies lubricants that improve engine longevity.

Environmental: Green alternatives to established materials

Materials scarcity and the increasing awareness of external environmental costs have long driven the development of more sustainable alternatives. In Europe, the energy-intensive forest products industry is developing products based on by-products and residues of its key raw material, wood. Waste was traditionally left to decompose or burnt in cogeneration plants to create energy. Now the industry is turning waste into transportable wood-based biodiesels that offer a low-cost and clean source of renewable energy. Wood-based biofuels also (unlike first-generation biofuels typically based on vegetable oils and animal fats) do not significantly impact food commodity markets or land resources and require less water in production. UPM estimates that wood-based biofuel can deliver up to 80% lower CO_2 emissions than fossil fuels for a given amount of power generation, materially lower than the 40% reduction offered by conventional forms of biofuels. The fuel is also compatible with existing engines for road transport.

Wood-based diesel offers material advantages

Comparison of key diesel grades

	Fossil diesel	Traditional biodiesel	UPM renewable diesel
Raw material	Crude	Vegetable oils and animal fats	Residues from forest industry
Renewable supply	Non-renewable	Part of food chain, causes indirect land use change	Renewable
End product	Hydrocarbon	Fatty acid methyl ester	Hydrocarbon
Stability	High	Low	High
Engine compatibility	All	Limited	All
Energy content	High; good fuel efficiency, power output	Low; reduction in fuel efficiency, power output	High; good fuel efficiency, power output

Source: UPM.

In addition to biofuels, other key derivative materials or biochemicals include microcellulose (used as a texturizer and fat substitute), lignin (used in diverse applications including cement, water treatment, and textile dyes) and other specialty chemicals.

Within our coverage, UPM (Neutral; €11.9), Stora Enso (Neutral; €7.86) and Holmen (Neutral; Skr227) own forest assets and offer potential exposure to derivative materials. UPM has recently built the world's first biorefinery producing 100k tonnes of wood-based renewable diesel per annum, and is expecting the mill to start production by mid-2014 (generating c.1% of FY15E revenues). Stora Enso has also committed to expanding its product offering within its larger Biomaterials segment (c.10% of sales) including biodegradable carbon fibres, bio-chemicals and lignin based polymers.

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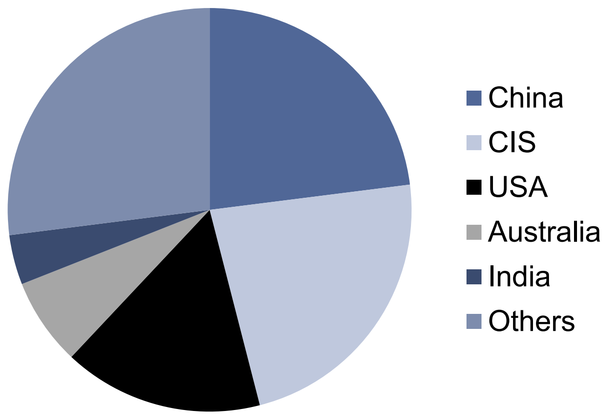
Rare treasures

Our Asia Commodities analyst, Jefferson Zhang, highlights the demand and supply dynamics of rare earths.

Rare earth elements are the 15 elements of the lanthanide series plus two closely related elements, scandium (Sc) and ytterbium (Yb). Based on atomic mass and chemical properties, the rare earth elements can be divided into light rare earths (LRE), medium rare earths (MRE) and heavy rare earths (HRE). According to statistics from the Chinese Society of Rare Earths (CSRE), global rare earth resources (measured by the amount of rare earth oxides (REO)) totalled 81.09 mn tons as of 2009, with 18.59 mn tons (23% of global resources) located in China. Other countries and organizations with significant rare earth resources include the CIS (23%), the USA (16%), Australia (7%) and India (4%). China's 2011 production volume (measured by REO) was 96.9k tons, over 90% of total world production.

Distribution of global rare earth resources (2009)

China has 23% of the world's rare earth resources



Source: USGS, CSRE.

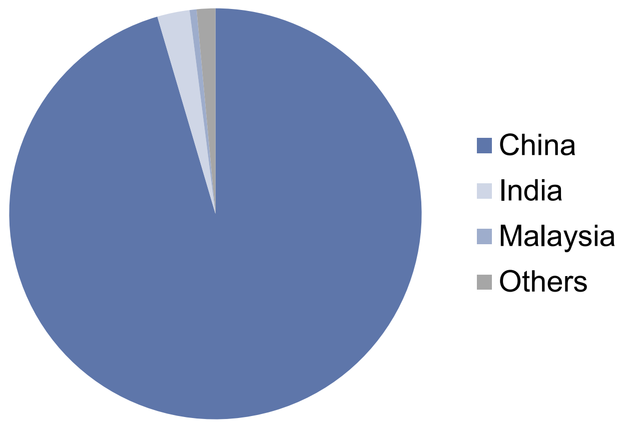
Rare earth supply and demand: Supply divergence, MRE and HRE scarcity value to increase

The supply side of the rare earth industry is characterised by the persistence of a "black market supply chain" in China, despite repeated bans and continued rare earth capacity release overseas.

We believe that the Chinese government will increase crackdowns on illegal capacity in 2014 and 2015, slowing medium and heavy rare earth supply growth; meanwhile, rising overseas rare earth capacity utilisation and newly constructed mines coming on line should increase oversupply pressure of light rare earths. Overall, we believe that supply trends will diverge for light vs. medium and heavy rare earth elements.

We expect rare earth new materials development to drive continued demand growth. Because of their unique electron structures and heat-resistant properties, rare earth elements have broad applications in traditional industries such as petrochemicals, metallurgical machinery and glass & ceramics, and in new materials fields such as NdFeB permanent magnets and catalytic materials.

Global rare earth production (2011)



Note: US and Australian rare earth mines had not yet come on line in 2011.
Source: Wind.

As emerging industries have developed in China, the percentage of rare earth consumption by new materials fields has increased from 27.3% in 2002 to 66.2% in 2011. We believe economic reform in China will decrease the use of rare earths in traditional fields, while the outlook for policy support of rare earth new materials remains optimistic in our view.

Rare earth resources have broad applications in strategic developing industries

REO indicates "rare earth oxide

Light Rare Earths (more abundant)	**Major End Use**	**Heavy Rare Earths (less abundant)**	**Major End Use**
Lanthanum (La)	Hybrid engines, metal alloys	Terbium (Tb)	Phosphors, permanent magnets
Cerium (Ce)	Auto catalyst, petroleum refining, metal alloys	Dysprosium (Dy)	Permanent magnets, hybrid engines
Praseodymium (Pr)	Magnets	Erbium (Er)	Phosphors
Neodymium (Nd)	Auto catalyst, petroleum refining, hard drives in laptops, headphones, hybrid enginesmetal alloys	Yttrium (Y)	Red color, fluorescent lamps, ceramics, metal alloy agent
Medium Rare Earths (less abundant)	**Major End Use**	Ytterbium (Yb)	Glass coloring, lasers
Samarium (Sm)	Magnets	Thulium (Tm)	Medical x-ray units
Europium (Eu)	Red color for television and computer screens	Lutetium (Lu)	Catalysts in petroleum refining
Gadolinium (Gd)	Magnets	Holmium (Ho)	Magnets

Source: The U.S. Department of the Interior, U.S. Geological Survey, Circular 930-N.

We prefer rare earth downstream materials - NdFeB permanent magnets and catalytic materials

NdFeB magnets: Rare earths are most widely used in NdFeB magnets, which have broad applications in the energy-saving and environmental areas, including wind power generation, energy-saving appliances, automotive electric power steering systems, micromotors, and new energy cars. In addition, they are used in electronics, including hard drive voice coil motors and magnetic resonance imaging. We see demand growth for NdFeB in 2014 and 2015 mainly coming from the expansion of new industries, including energy-saving and environmental industries, and higher penetration of NdFeB in downstream sectors such as new energy cars, wind power and energy-saving appliances. We estimate China NdFeB demand will reach about 92,800 tons and 100,300 tons in 2014 and 2015, up 10% and 8% respectively.

Rare earth catalytic materials: Rare earth elements make excellent catalytic materials which are widely used in fluid catalytic cracking, vehicle exhaust purification, and industrial exhaust purification. We expect demand for automotive catalysts to continue growing rapidly thanks to the government's commitment to air pollution control. China plans to increase its diesel emission standards from the current National Standard III to National Standard IV in 2014, and will impose National Standard V in trial areas, including the Beijing-Tianjin-Hebei conurbation, Yangtze River Delta, and Pearl River Delta in 2015. We estimate China's automotive catalytic converter market in 2014/2015 will reach 14.231/19.195 mn, up 39%/35% yoy, thanks to a booming Chinese auto market, market share gains for domestic-made automotive catalytic converters, and replacement demand for spent catalysts.

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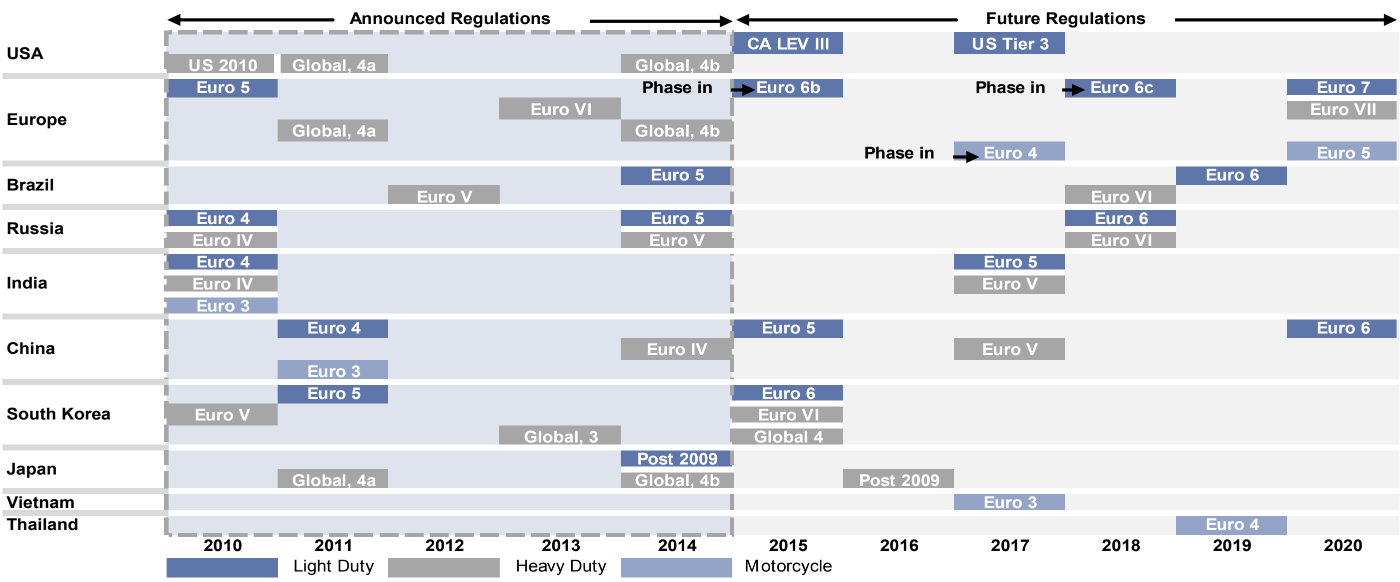
We expect demand for NdFeB in China to grow in 2014-15

Calculation of market scope for NdFeB in China, 2014E/15E

Downstream Application	Unit Consumption of NdFeB Magnets (Kg)	Semifinished NdFeB Consumption (Kg)	Shipments (Mn)		Demand of NdFeB Magnets (tonnes)	
			2014E	2015E	2014E	2015E
Direct-driven Wind Turbine	1000	1667	0.010	0.015	16,667	25,000
Frequency Conversion Conditioning	0.250	0.417	36.0	40.3	15,000	16,800
EPS	0.15	0.25	8.0	9.6	2,000	2,400
New Energy Automobile	3.00	5.00	0.20	0.24	1,000	1,200
Mini-and-special Electric Motor	0.05	0.08	30.0	36.0	2,500	3,000
VCM	0.005	0.008	600	600	5,000	5,000
DVD Drive	0.005	0.008	400	400	3,333	3,333
Mobile Loudspeakers and V/M	0.001	0.002	1,800	1,980	3,000	3,300
Electric Bicycles	0.25	0.42	24.0	25.0	10,000	10,417
Energy Saving Elevator	6.000	10.000	0.2	0.2	2,000	2,400
Magnetic Separator, Electrical Tool					5,000	5,000
Electroacoustic, MRI and others					27,340	22,417
Total					**92,840**	**100,267**

Source: www.ndfeb1688.com, Company data, Wind, Gao Hua Securities Research.

Emissions catalysts market – emission standards upgrading remains primary demand drivers



Source: BASF, Ministry of Environmental Protection of China.

Beaver pelt to lithium - a commodity odyssey

Eugene King, our Metals and Mining analyst, delves into commodities that are being substituted out.

In the 17th century Canada was colonised and developed at Europe's behest for beaver pelts to make hats. Beaver pelt isn't a very important commodity today, but if you follow the path the French settlers took from the St Lawrence river to Fort McMurray you would start near today's hydro power stations, go past the iron ore mines of Labrador then the gold mines of Quebec and Ontario, to Sudbury, site of one of the world's largest nickel deposits, to Saskatchewan over the massive potash and uranium deposits, eventually reaching the site of the world's largest oil sands deposit in Alberta in Fort McMurray. No one cared much for any of those things in 1670 – the commodity of the day was the humble beaver.

In different periods in history, various materials have been critical for the economy of the day and/or basic survival (e.g. tin, brass, flint rock), or as displays of wealth and power (e.g. gold). The consumption of commodities by the economies of the world constantly evolves and changing demand patterns are driven by three major forces:

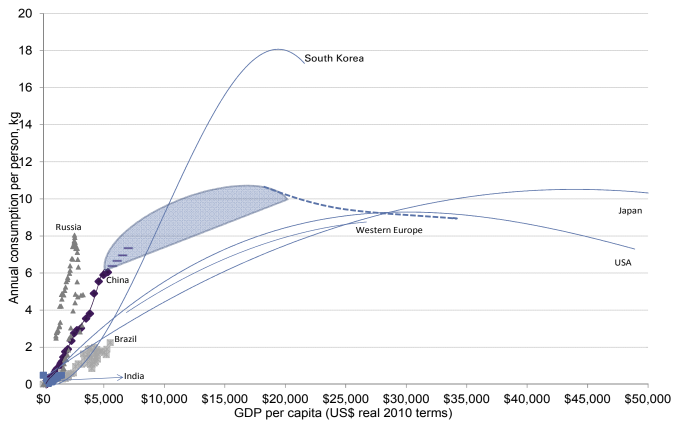
1. the wealth of the economy or the stage of its development;
2. technological innovation; and,
3. relative utility and cost.

The wealth of the economy or the stage of development

Wealth – or the stage of an economy's development – drives consumption behaviour. As an economy becomes wealthier, it naturally starts to build infrastructure (e.g. houses, roads, water transportation, power generation). Following this, its citizens shift from a need state to a want state, in which they spend more on discretionary purchases and luxuries. Early-stage commodities include steel (iron ore), cement and copper. Economies typically reach peak steel consumption at c.US$15k GDP / capita, beyond which point it slowly declines.

Trending in line

Copper consumption versus GDP per capita



Source: USGS, CSRE.

Technological innovation

Another major force that shapes commodity demand is innovation, chiefly through technology. We find new uses for existing commodities and then substitute existing uses. A simple example: demand for tungsten was not high until the invention of the incandescent lightbulb in the early 1900s, at which point demand for wax plummeted as lightbulbs replaced candles.

There are broadly three ways this happens:

1. a technological development creates a new product such as the light-bulb, which in turn creates new demand for a commodity;
2. the development of a direct substitute which either performs the same function at a lower cost or with greater durability (e.g. plastic pipes replacing copper); or,
3. when a new innovation improves utility, even if there is a cost increase (e.g. aluminium substitution for steel in cars).

The invention of the lithium-ion battery in the 1980s led to its introduction in the 1990s, replacing the long-serving nickel-cadmium (Ni-Cad) batteries. It is these that make modern mobile phones so portable. It is also these that power Tesla's Model S and the other commercial electric vehicles on sale today. Lithium batteries substituted almost all the cadmium in commercial use as well as allowing the development of the modern electric car.

The key takeaway is that as we invent new products and solutions to the challenges of modern life, so we change the demand pattern for commodities. Sometimes, we create markets where previously there werea none (as in the example of the lightbulb) while in other instances we destroy demand overnight.

Relative utility and cost

The value of a commodity changes depending on what it does and how much is costs. For example, copper pipes for plumbing make a lot of sense; they are strong and have anti-bacterial properties. However, as demand for copper increased globally for electrical generation and transition in China, leading to a significant increase in its price, the advantage provided by a copper pipe relative to a cheaper substitute dimished, relatie to the value it offers. This led to a rapid substitution of copper in plumbing applications with plastic, a substitution made possible through technological innovation. These innovations create demand because they serve to either lower cost at the same utility (plastic pipes) or improve utility at a higher price (aluminium in cars and lithium batteries).

Environment and safety come to the fore as economies become wealthier

Another factor to consider in the evolution of commodity demand is social influences, such as safety and the environment. At different stages of economic development, the willingness of the population to accept different standards of safety or environmental impact changes. In an early stage economy, people generally want a consistent supply of power. There is generally little regard to the impact of burning coal on the environment for example. As the economy develops, a move to nuclear power (which would see coal demand fall and uranium demand increase) might seem a good trade-off. But as Germany and Japan have demonstrated post the Fukushima disaster, even wealthier economies are willing to pay more for alternative energy (wind, solar) in the name of the environment and public safety.

Putting wealth and innovation together is a powerful revolutionary factor for commodities

The combined effects of the wealth driver and innovation's impact on demand can create some incredibly rapid transformations in the shape of commodity demand. In 2014, we see three major substitutions unfolding in the commodities market:

Aluminium substituting steel: As the oil price remains over US$100/bbl, automotive consumers are demanding better fuel consumption without any decline in performance and safety. This is a massive challenge for engineers and the secret is lower weight, which can be achieved when aluminium replaces steel components. And it's not just the body – aluminium can be used for the engine block, chassis, body panels and suspension components. This has been made possible by new bonding technologies including adhesives and new welding techniques. It costs more to make a car from aluminium, but the benefits arise from its lighter weight, which sees better fuel consumption and lower CO_2 emissions without compromising safety. It is more expensive than steel, and cars made from aluminium generally retail at a higher price point. However, for consumers wanting to purchase a prestige car which also offers good performance and handling, as well as efficiency through better fuel consumption and lower CO_2 emissions it is a price worth paying. Today there are mainstream, high-volume models from Audi, Jaguar, BMW and Range Rover all made from aluminium. Even the humble Ford F-150 now has parts made from aluminium.

Lithium substituting oil: Staying on the autos theme, the introduction of full electric vehicles (FEVs) from Tesla, Nissan, Renault, BMW and VW in the past two years could have the impact of reducing oil demand in major developed economies. FEVs utilise lithium-ion batteries, sometimes hundreds of kilograms of them, and should radically increase demand for lithium. Another area these new FEVs will likely change is oil consumption. In 2013, the UK Department of Energy & Climate Change stated that transport consumed c.36% of the UK's total energy (c.394mboe) and that road users consumed 74% of this at c.290mboe. As FEVs become more common, and represent a bigger part of the active car population, so this should lower oil demand and see lithium demand increase up to 10-fold. It is not unrealistic to imagine that FEVs could represent 5% of the active fleet in major markets such as California and the UK by 2020, which could reduce annual oil consumption in the transport sector significantly.

Natural gas and coal (and oil): This is a very active story in the US currently, as the benefits from the onshore shale gas revolution impact commodity demand. The area where this has had the biggest impact to date, and will likely continue to in 2014/15, is the switching of coal-fired electricity generation to natural gas. It is cheaper than coal and produces less CO_2 owing to a more complete burn, with both lower sulphur and less particulate release into the atmosphere. This is leading to lower power costs and less environmental damage.

A second substitution will likely come from compressed natural gas (CNG) vehicles taking share from gasoline (petrol) vehicles. It takes time to achieve and it is a real chicken and egg situation. Consumers will have to get used to the idea of moving away from gasoline and they will also have to get comfortable that there is an infrastructure to support them at gas stations. This is why public transport such as buses in metropolitan areas is the most likely focus. This way, a regional depot can have the infrastructure to refuel and service CNG vehicles. In Australia, when a variation of CNG was introduced called liquefied natural gas (LNG), the entire taxi fleet in the country converted rapidly, followed by large swathes of commuters because LPG was priced 65% below the prevailing petrol price.

The natural evolution of the world's economies will continue to see the commodity mix change. China for example will one day almost certainly produce less steel than it does today. Once it has built all the buildings, roads, bridges, railways, dams and other infrastructure needed for its urbanisation, its steel industry will likely shrink to fit its future demand. But other economies such as India, Indonesia and Vietnam will perhaps rise up, albeit not necessarily at the same rate, and increase their steel production.

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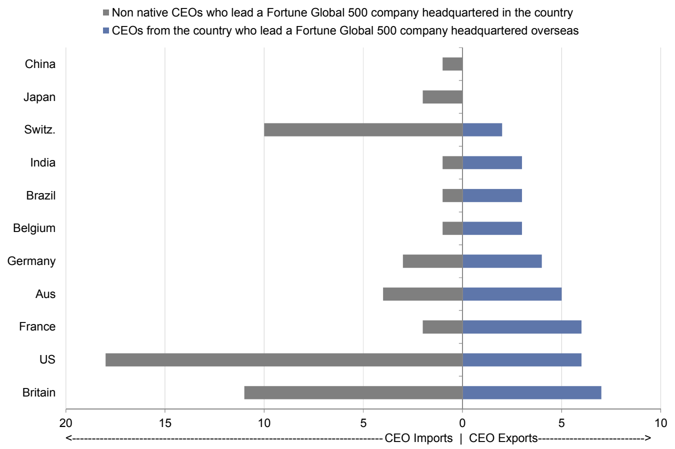
Six of the best – our favourite charts

In our six of the best section, we pull together a pot pourri of charts that we hope you will find interesting. They will be different in each edition but hopefully always of note.

CEO flows

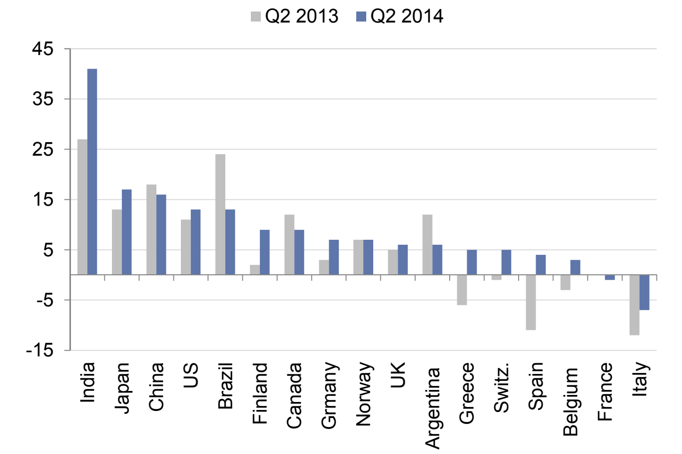
Foreign CEOs of Fortune 500 companies (as of 2H 2013)



Source: HBR.

India improving

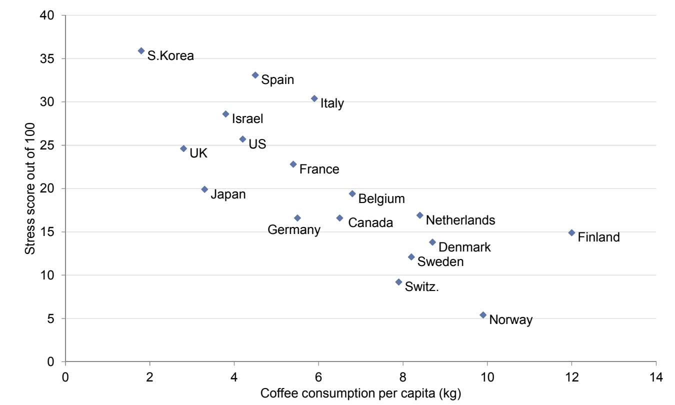
Seasonally adjusted net employment outlook (difference between % of employers anticipating a rise in hiring and those expecting a decrease in employment at their location in the next quarter)



Source: Manpower survey.

Stressed? Drink coffee

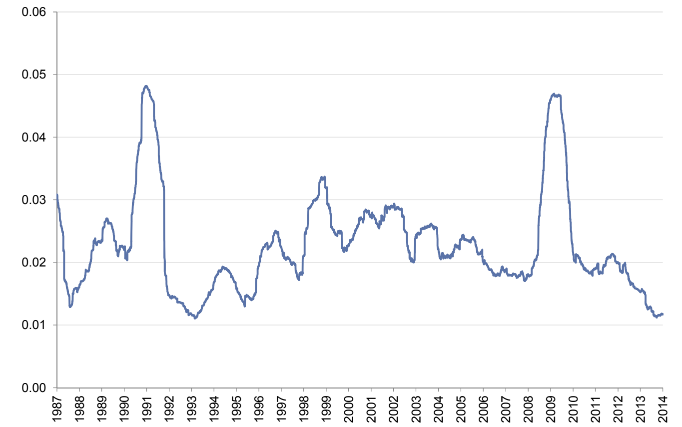
Coffee consumption per capita, kg vs. stress levels



Source: WRI, Bloomberg.

All gone flat

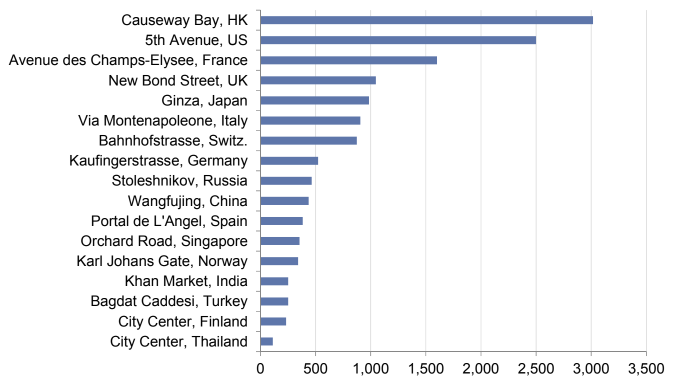
Standard deviation of daily percentage change in oil prices (12-month rolling)



Source: Datastream.

Fields of heaven

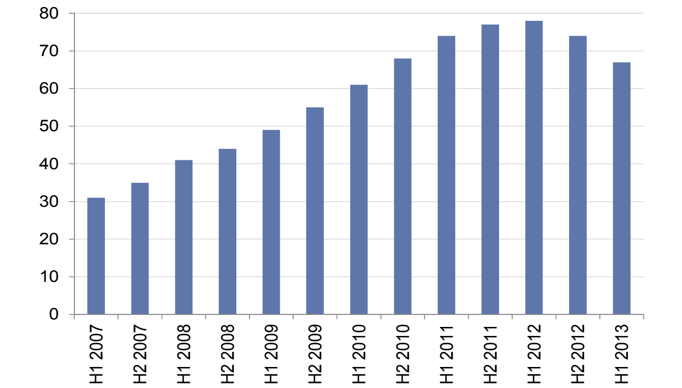
Rental price (in US$/sq.ft) of the most expenive shopping locations in different countries



Source: Bloomberg.

Fewer sore thumbs

Number of SMS messages sent in the UK, bn



Source: Ofcom. Note 2013 shows combined SMS and MMS volume.

Disclosure Appendix

Reg AC

We, Hugo Scott-Gall, Sumana Manohar, Sal Tharani, Chris Hallam, Noah Poponak, Rakesh Patel, Michael Rae, Robert Koort, Neal Sangani, Donald Lu, Will Wyman, Raghav Bardalai, Chris Beaven, Jefferson Zhang and Eugene King, hereby certify that all of the views expressed in this report accurately reflect our personal views about the subject company or companies and its or their securities. We also certify that no part of our compensation was, is, or will be, directly or indirectly, related to the specific recommendations or views expressed in this report.

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	Rating distribution			Investment Banking Relationships		
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