Indium and gallium overview

This report outlines the principal uses, market drivers and price trends for two little-known but increasingly in-demand metals, indium and gallium. Supply-side constraints due to Chinese export restrictions and the marginal cost benefit of production to bauxite and zinc miners offer an opportunity to western mining companies to exploit this niche sector of the metals market by developing alternative deposits.

7 October 2011

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This report has been commissioned by South American Silver Corp, which is developing the Malku Khota silver-indium-gallium project in Bolivia. We will initiate coverage of South American Silver in Q411.

Strategic metals akin to heavy rare earths

On the periodic table indium and gallium lie separately from the much-touted rare earth group of elements, and are deemed strategic metals due their rarity, restrictive supply base and increasing demand for use in high-end technologies (flat-screen TVs, smartphones and photovoltaic cells used in solar panels). In fact, indium is one of six materials assessed as most critical along with some key rare earths in the short term (zero to five years) by the US Department of Energy in its Critical Materials Strategy.

By-product mining from zinc, bauxite and silver ores

Most indium and gallium production results from processing zinc, bauxite, tin and, to a lesser extent, silver ores, and so relative market supply is governed by the respective health of these commodity markets. The long-term growth for zinc is estimated at 1-3% pa versus c 15% for indium presenting a clear supply deficit, especially if indium market growth continues at this pace and remains primarily a by-product of zinc refining. Further, with silver's diversified set of end uses and its characteristic as a store of value, it could be seen as a best-case scenario for stable mine production of indium and gallium.

Indium and gallium recycling, specialist and expensive

Due to indium and gallium production being a by-product of processing ores, a growing global industry has arisen to recover the metals, either in a spent form from manufacturing processes or from recycling indium- and gallium-bearing scrap materials. Recycling as a new source of material, though expensive and highly specialised, has exceeded primary production in recent years.

Reduction in carbon emissions driving future demand

Policymakers worldwide are being driven towards cleaner forms of energy, including solar and nuclear. Both are consumers of indium and gallium and, outside of the consumer electronics industry, drive strong demand growth (estimated at 15% per year for indium and c 15-20% for gallium).

Investment summary: Strategic commodities

Introduction: Strong fundamentals

Over the past 12-16 months we have seen extensive media coverage surrounding rare earth elements, as China continues to restrict its supply to the world markets. However, little or no news surrounds a broader group of metals, encompassing not only the valuable group of rare earths, but also some minor metals, including indium and gallium. This report provides a brief overview of the key supply and demand characteristics and general market outlook for these two relatively unknown metals.

Indium and gallium: What are they?

Indium and gallium are relatively rare metals that have electrical and optical properties that make them highly sought after by technology firms. The primary use for both metals is varied, from the manufacture of flat-panel display screens and high-brightness LED lights, to photovoltaic technologies used in solar panel construction, among many others. Semiconductors are a further important end use, with gallium arsenide (GaAS) the predominant compound used. Other compounds such as gallium nitride (GaN) and indium gallium nitride (InGaN) are also used.

How are they produced?

Currently, the main sources of indium and gallium arise as a result of processing zinc, bauxite, tin and silver ores. No significant economic natural occurrence of indium or gallium has allowed a mine to operate purely to produce these two metals alone. Therefore, a key sensitivity to the supply of these metals is the condition of the prevailing zinc and bauxite markets. With mainly industrial uses for zinc (47% used in galvanising processes, 33% in the manufacture of brass/bronze and alloys according to the LME website) and aluminium (26% used in transport manufacture, 22% for both packaging and construction purposes, LME website), there is an obvious disconnect between the market drivers for aluminium and zinc and those of indium and gallium. This could lead to price instability resulting from inconsistent production, and affect the supply of these specialist metals as by-products.

The amount of indium in zinc ores varies from deposit to deposit. It cannot be considered recoverable in the short term solely on its own merit as global zinc reserves are huge (estimated at 46 years at 2008 production levels of zinc ore per year). In the current market, over 90% of mined indium is recovered during the refining of zinc and, with the exception of a few vertically-integrated producers that both mine and refine metals, such as Teck Cominco, most of the economic benefit from these rare metals goes to the smelters, limiting the market incentive for mining companies to produce more indium.

Indium and gallium as a result of silver mining

Indium and gallium are also associated with some silver deposits. Demand fundamentals are stronger as silver has a highly diversified range of uses, from electrical and biotechnological applications to it being a store of value similar to gold. Silver deposits are also volumetrically far smaller than the vast majority of bauxite deposits and many zinc deposits. This means overall accessibility to indium and gallium can be enhanced due to their potential to constitute a larger part of the revenue stream alongside that of the primary mineral (ie, silver) mined in these smaller-scale operations. So, indium and gallium production as a result of mining silver can be seen as a more attractive and stable alternative to production through refining zinc or bauxite.

Indium production

Indium production from refineries (treating mined and secondary recovered sources) has risen with the increased demand for the metal by the electronics industry. As an indication of this trend, data published by the USGS had world-refined indium production in 1972 at c 70 tonnes. This remained flat until the mid-80s, when we can assume that the widespread production of consumer electronics, including the introduction of home computers and greater production of integrated circuits, led to a significant rise in demand and therefore production. Since the late 1980s refined indium production has grown steadily year-on-year, with 2010 total primary production reported at 570 tonnes, and total supply of approximately 1200 tonnes including secondary supply.

Secondary recovery (recycling) of indium

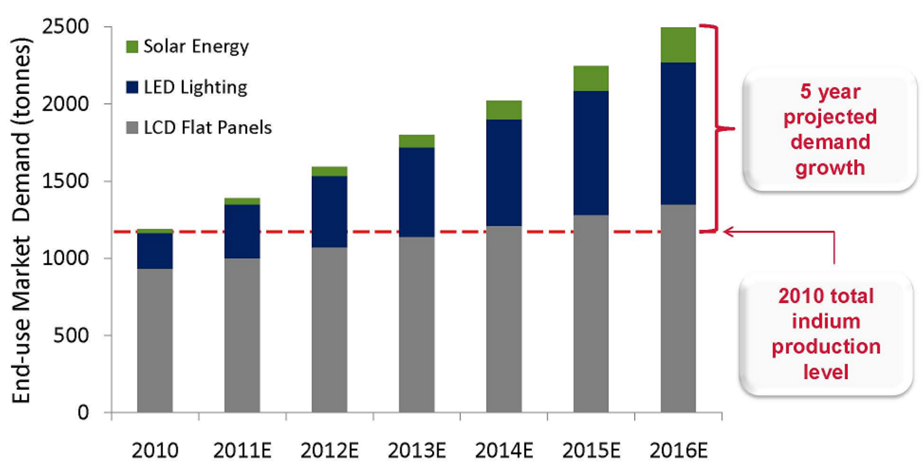
Due to the relative scarcity of indium, there has been an increased focus in China and Japan to produce indium from means other than mining. The secondary recovery of indium has mainly resulted from spent indium tin oxide (ITO) sputtering targets. Sputtering is a process used in electronics manufacturing to apply ITO to transparent and conductive electrodes for thin film solar panel applications. Due to the current application process, a significant volume of indium is produced as 'scrap' with only around 30% of ITO deposited on the surface.

Indium demand

The demand for indium has risen alongside its increased consumption in the electronics industry. The following exhibit illustrates the forecast 15% annual growth rate for indium demand over the next four years.

Exhibit 1: Indium demand by end-use

Note: 2011 to 2015 demand forecasts based on 15% annual growth on 2010 actual demand.



Source: South American Silver company reports

Indium end uses

The principal form of indium used in the manufacturing industry is indium tin oxide (ITO). The primary end use for ITO is in manufacturing flat-panel screens, which accounts for c 70% of all indium produced, with a further 25% used in LED lighting. Currently there is no viable alternative to indium in either of these applications, with all substitutes too inferior to use. Due to the relatively small amounts used in LCD and LED manufacture (approximately US$2 of indium is used in constructing one flat-panel television), the cost of indium use is relatively inelastic and so a significant rise in indium's price is unlikely to restrict its use. Developing photovoltaic technologies for the production of solar panels presents a growing sector for indium consumption; however, key questions remain over the magnitude and rates for growth in solar technology and how it will impact future indium prices.

Gallium production

Gallium is not found in its elemental form and is instead mined in its most common form as the salt gallium (III). Production is primarily a result of bauxite refining with production capacity in 2010 totalling 256-261 tonnes with estimated 2010 primary production (2011 numbers are not available) from mining of c 78 tonnes. Total 2010 gallium production has been estimated to be around 201-212 tonnes, demonstrating the extent of secondary recovery of the metal (see following section) and also the excess production/processing capacity still available. Gallium consumption in 2010 was reported to be c 280 tonnes, with the difference likely to be a result of stockpile depletion.

Secondary recovery (recycling) of gallium

Gallium's scarcity as a primary ore mineral has led to significant secondary recovery of it. In Japan it is estimated that approximately 90 tonnes of gallium was produced via recycling of scrap materials in 2010, with a further 60 tonnes potentially contained within the liquid phase epitaxy manufacturing 'loop' – gallium not immediately accessible or in usable form for other purposes. Secondary recovery of gallium from semiconductor manufacturing processes is also an important source. Due to the multi-step nature of semi-conductor manufacture and requirement for extremely high-quality control throughout, a much larger volume of gallium is required than is actually yielded in its eventual form within semiconductors. The US Department of Energy stated in 2010 that world gallium recycling capacity was around 42% (partly a result of the aforementioned semiconductor manufacturing process) of world gallium production capacity.

Gallium substitution

Gallium is prone to substitution in the manufacture of semiconductors (replaced with indium) and thin film solar panel technologies (replaced with silicon-based technologies, some forms of thin film cadmium-selenide, or copper-indium-selenide based photovoltaic cells, among others). The current development of these varied forms of solar cell technology means that forecasts of gallium demand remain unclear. Gallium's advantages as a component of solar cell technologies do not appear to definitively outperform those provided by rival materials and compounds.

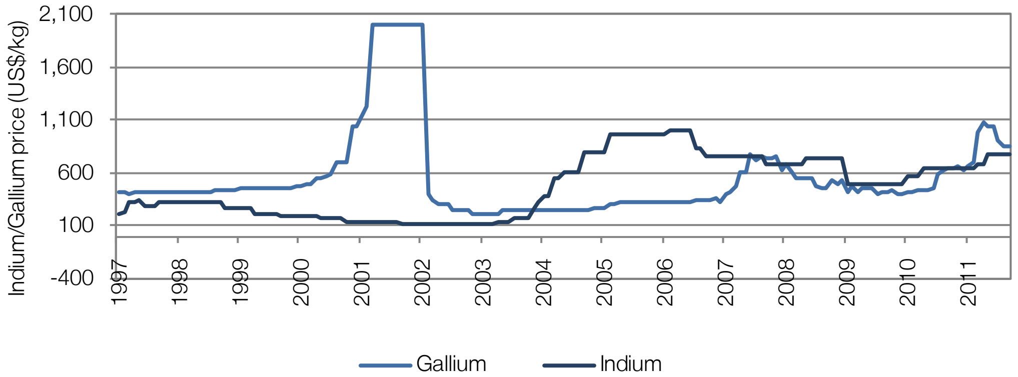
Gallium end-uses

The main uses for gallium are in producing optoelectronics and semiconductors. Further demand for gallium comes from its use as a transparent anode in large area displays and solid state lighting, thin-film transistors, neodymium-iron-boron magnets and batteries, lithium batteries and copper-indium-gallium-selenide photovoltaic cells. Overall, the use of gallium in some electronics is being held back due to its restrictive supply base. The metal is seen as less economically important, with total global production being only around a tenth of the size for that of indium.

Current and future price trends

Historical prices of indium and gallium from 1997 through to present are given in the following exhibit. As shown, the prices of a kilogramme of high purity (99.99%) indium and gallium have closely tracked each other since late 2006; this may be a result of the growth in the smartphone markets, the increased use of LEDs in lighting and demand for optoelectronic devices (Blu-ray, DVD etc).

Exhibit 2: Plot of historic indium and gallium prices, 1997 to present



Source: Thomson Datastream

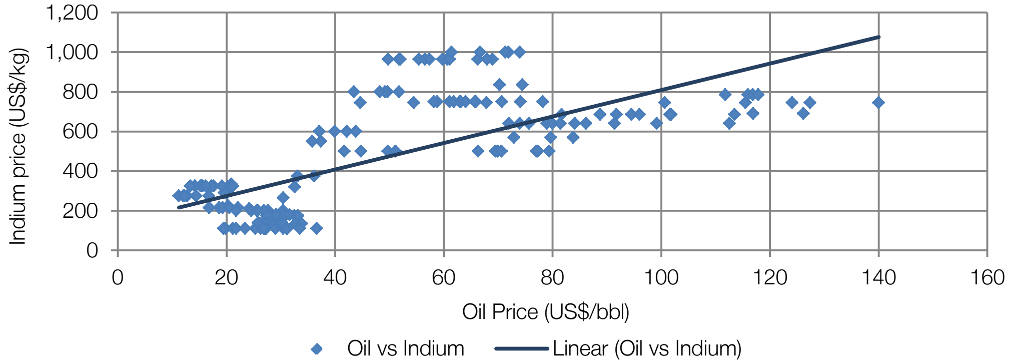
An alternative way to view future indium price trends

We have also attempted to provide a correlation of indium against oil to show the potential for indium prices to change relative to the price of oil. However, this analysis does not allow for the effect of any specific growth in demand for indium, above general economic growth as reflected by the oil price (eg use in new technologies) and is provided here only as alternative way to view long-term price rises in the metal. The outcome has yielded a positive correlation and a similar price for indium of US$809/kg at an oil price of $100/bbl to that of the current price of US$785/kg (as of 9 September 2011) at the current price of a barrel of Brent crude at c US$111 (as of 19 September 2011). Using regression techniques, this allows us to estimate future long-term prices of indium at a range of oil prices (see Exhibit 5). This does not account for the supply and demand dynamics of the rapidly growing indium market, which is primarily produced as result of zinc refining.

Indium vs oil – assumptions and outcome

The production of indium, like all mined commodities, is an extremely energy-intensive process and so the price of a barrel of crude oil can be a proxy for energy input costs generally. As a result, the correlation between the nominal price of indium and the nominal price of oil has been extremely close, returning a Pearson Product Moment Coefficient of 0.71 (on a scale between +1 and -1) for the period 1997 to present, as can be seen in Exhibit 3.

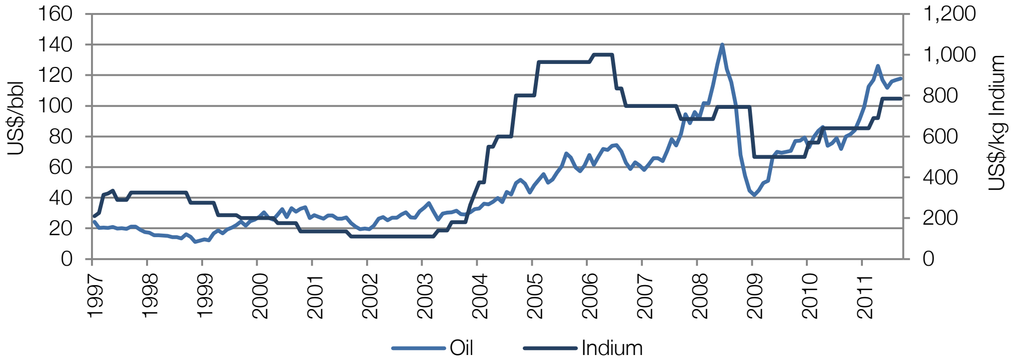
Exhibit 3: Oil vs indium prices 1997 to 2011



Source: Edison Investment Research and Bloomberg

Exhibit 4 provides a plot of oil and indium prices for the period from 1997 to present, showing a strong correlation between the two from late 2008.

Exhibit 4: Plot of indium and oil prices 1997 to 1 September 2011



Source: Bloomberg and Thomson Datastream

The future price of indium can be estimated in terms of the price of crude oil using regression techniques (Exhibit 5). The results of this analysis (using price data for Chinese indium ingots of 99.99% purity) can be used as a general indication of price movements within the indium materials sector at various oil prices, and also as an indication for the potential long-term increase in value of primary (mine) indium production.

Exhibit 5: Estimated future long-term price of indium at varying long-term future oil prices

Oil (US$/bbl)	80	90	100	120	140	160
Indium (US$/kg)	676	743	809	943	1,077	1,211

Source: Edison Investment Research

The same analysis was also performed for gallium. However, the result of this analysis indicated virtually no strength in correlation with oil prices over time and has therefore been omitted from this report. The reasons for a lack of correlation remain unclear. A further correlation was performed for indium against gallium and, as expected from the oil gallium analysis performed, this gave a poor, slightly negative correlation between the two metals, possibly supporting the notion of gallium substitution with indium.

Opportunity to capitalise on supply-side restrictions

The growth seen in developing countries over the last decade has brought with it an ever-increasing appetite for specialist metals. However, only a few countries currently control most of the supply (China being a much-publicised example, with Russia and Brazil also contributing) limiting supply to countries such as Japan, which have an ever-increasing need, but no domestic production of these metals. Consequently, these countries are subject to supply-side restrictions imposed by countries seeking to protect their own dwindling resources.

Supply – western deposits needed to stabilise supply routes

Indium and gallium have particularly restrictive supply bases due the relatively few countries (China, Russia and Brazil) in which they are produced. According to the World Bank website, which lists governance indicators (control of corruption, regulatory quality, government effectiveness etc) for these countries, it is apparent that their respective scores are relatively low. This, along with China exhibiting protectionist traits over its rare-earth resources, could increase the risk of potential supply disruptions and price volatilities.

Demand – slowing global recovery a threat

With end-use for indium and gallium tied to the manufacture of flat screens, LEDs and many other electronic devices, a key sensitivity to their demand is the growth within specific sectors of the electronics industry. The market for LED lighting, as an example, grew from US$5.3bn in 2009 and was expected to increase to US$8.2bn in 2010 (USGS), growth of 55%. The ever-increasing demand for smartphones has also provided significant demand for gallium as gallium arsenide. However, the continuing sluggish pace of the global recovery and potential for further recessionary periods obviously poses a short-term threat to such rapid growth in indium and gallium demand.

Impact of Chinese regulation

In 2010 the Chinese authorities outlined plans to upgrade China's manufacturing industry to address gross environmental issues, the lack of general efficiency in manufacturing processes and, by extension, the squandering of its natural resources. Therefore China's manufacturing base, through tighter regulatory control, could see many of the smaller raw material processing facilities be denied feedstock as larger conglomerates are favoured and restrict access to their materials. These plans are a specific threat to indium and gallium production in China, as aluminium smelters are included in these government proposals. As such, it is possible that consolidating the aluminium smelting industry may result in restrictions being imposed by much larger companies, which would have no vested interest in allowing existing small processing facilities to tap their Bayer liquor to extract gallium.

Conclusions

The current market prices for indium and gallium have recovered well from the lows of 2008 caused by the global financial crisis. Demand continues to be driven by the electronics industry, with particular demand for indium in the production of flat-screen display panels, LEDs and thin-film solar technologies and demand for gallium in the manufacture of LED lights and, again, thin film solar technology. The long-term outlook for growth in the zinc market is forecast at c 1-3% per year, compared to c 15% for indium. This presents a clear supply deficit, especially if indium market growth continues at this pace and remains primarily a by-product of zinc refining. This may well lead to electronics manufacturers pursuing alternative sources, not through recycling metals (which is unlikely given the small amounts used and the cost of extraction from scrap materials), but rather from development of primary indium resources in the ground.

Substitution of both metals could affect demand, especially for gallium. However, with so many new technologies being developed (ie beyond those end-uses, of which some are mentioned in this report) it is hard to envisage a complete collapse in the commodity prices from current trends. The ever-increasing development of new technologies provides as much an opportunity as substitution presents a risk to the demand of such metals. The argument over substitution may well develop into whether lower-quality goods that employ very little indium and gallium may be acceptable to the consumer (this seems unlikely with the current trends in smartphone use and propensity to consume high-end electronic goods).

In conclusion, the supply of indium and gallium by relatively few countries, particularly China, which is increasingly protectionist over its natural resources, plus costly and highly specialised recycling of the metals leads to an opportunity for western countries to capitalise on such supply-shortfalls (and therefore elevated commodity prices) by developing projects in other countries. Such projects would secure ex-Chinese supply routes to western electronics manufacturers – a further parallel to the forces driving western development of so-called rare earths deposits. With such increases in high-end electronics demand, it is now apparent that relying on supply of specialist metals (rare earths, indium, gallium etc) from either a protectionist China or via by-product refining is unsustainable. This will inevitably lead to development of ex-China primary deposits of the metals, which has already started with likes of the development-stage companies outlined in Exhibit 6 of this report and elsewhere.

Exhibit 6: Overview of three development stage companies with exposure to indium

Note: Please refer to respective company websites for derivation of project NPV calculations as metal prices used differ between each economic assessment.

	South American Silver	Adex Mining	Argentex
Ticker	TSX: SAC	TSX-V: ADE	TSX-V: ATX
Company description	South Amerian Silver is a development stage company focused on delivering its flagship Malku Khota silver-indium-gallium project in Bolivia to production. Malku Khota is one of the world's largest undeveloped silver, indium and gallium deposits. The company is also exploring for copper-gold at its large-scale Escalones project in Chile. The c 80t of annual indium production expected from Malku Khota will account for around 10% of global, and c 30% of ex-Chinese annual production and will also exceed Teck Cominco's annual production of the metal.	Adex Mining is focused on developing its wholly-owned Mount Pleasant property in New Brunswick, Canada. Mount pleasant is a polymetallic project hosting a tin dominat resource with associated amounts of indium, zinc, tungsten and molybdenum. Adex has udnertaken comprehensive exploration and development work at the property since 2007. Following the conclusion of these works, adex will then make a investment decision by end 2011, with the intention of brining the proejct into production in 2012-2013.	Aregentix is developing its 100% owned Pingiono proprty located in the Deseado Massif, which hosts four other preciosu metals mines, including the Cerro Vanguardia silver-gold mine - the largest in the Santa Cruz region. Pinguino is at an advanced exploration stage, with more than 56,000m of drilling completed to date. The Pinguino project contains two distinct epithermal deposits, containing gold-silver and indium-polymetallic veins.
Market cap (as of 30 September 11) C$(m)	156.8	25.3	45.0
Net cash (debt) C$(m)	30.0	3.7	1.9
EV C$(m)	126.8	21.6	43.1
In/Ga bearing project	Malku Khota	Mount Pleasant Property	The Pinguino project
Project location	Bolivia	New Brunswick, Canada	Santa Cruz, Argentina
Economic assessment	Preliminary economic assessment	Preliminary economic assessment	Preliminary economic assessment
Base case project value (pre-tax)	US$704m ($NPV_5$)	North Zone - US$60m ($NPV_8$) Fire Tower Zone - US$164m (NPV_8)	US$21.9 ($NPV_5$) - oxide resource only
Total capital cost estimate	US$196.7m	North Zone - US$71m Fire Tower Zone - US$130m	US$20.71m (oxide)
Current life of mine	15yrs	North Zone - 10yrs Fire Tower Zone - 12yrs	N/A

	South American Silver		Adex Mining		Argentex	
	Forecast annual production		Forecast annual production		Forecast annual production (oxide)	
Main commodity	Silver	10.5Moz	Tin	N/A	Gold Silver	6,400oz 657,300oz
Indium bearing	Yes	78.9 tonnes	Yes	N/A	Yes	N/A
Gallium bearing	Yes	14.2 tonnes	No	N/A	No	N/A

South American Silver

	Resource Category	Silver (Moz)	Indium (t)	Gallium (t)	Zinc (t)	Lead (t)
Total resource	Measured	33.30	188	139	7,368	22,080
	Indicated	197.00	1,293	943	104,616	183,598
	Inferred	140.00	935	1,001	111,683	164,318

Adex Mining

	Resource Category	Tin (t)	Indium (t)	Zinc (t)	Tungsten (t)	Molybdenum (t)
Total resource	Measured	N/A	N/A	N/A	N/A	N/A
	Indicated	46,793	738	72,909	54,308	34,856
	Inferred	16,727	567	75,270	8,271	5,485

Argentex

	Resource Category	Gold (Moz)	Silver (Moz)	Indium (t)	Lead (t)	Zinc (t)
Total resource	Measured	N/A	N/A	N/A	N/A	N/A
	Indicated	0.03	3.42	68	1,106	1,284
	Inferred	0.05	6.36	91	45,590	133,880

Source: South American Silver Corp., Adex Mining and Argentex corporate websites