The Future of Silver Industrial Demand

Commissioned by the Silver Institute

Prepared by GFMS Ltd

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GFMS

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Units used:

supply and demand data are given in units of metric tonnes.

1 Moz = 31.103 t (metric tonnes)

1 tonne = 32,151 troy ounces

1 tonne = 1,000,000 grammes (g)

Terminology:

"-" = not available or not applicable

0.0 = zero or less than 0.05

"dollar" refers to the US dollar unless otherwise stated.

Prices:

Unless otherwise stated, US dollar prices are for the London Silver Market fixing.

Table Rounding:

Throughout the tables and charts, totals may not add due to independent rounding.

1. Introduction & Executive Summary

1.0 Introduction

In recent years, silver industrial demand has greatly expanded its role in the global silver market. This has largely been due to tremendous growth in industrial offtake itself, although weaker performances elsewhere (photography and silverware in particular) have helped to further raise its share of global fabrication demand

To put silver's industrial demand growth into perspective, in 1990 it stood at 273 Moz, representing a respectable 39% of total fabrication demand. By the turn of the millennium, the global total had grown by 100Moz, which saw its share exceed 40% for the first time. After a setback in 2001 (when the technology bubble burst), industrial offtake grew uninterrupted for the following six years. This culminated in a record high of over 465 Moz in 2007, which accounted for 55% of total silver fabrication.

Although silver demand suffered after the global economic crisis that began in the latter part of 2008, by 2010 industrial demand had already recouped most of the lost output. In fact, although restocking of a (heavily) depleted supply chain accounted for much of the improvement last year, it is also clear that industrial demand resumed its long-term secular rise, a trend which is set to continue over the entire forecast period under review in this report.

It is not surprising, therefore, that industrial demand has garnered such attention. The Silver Institute, in recognition of its significance for the future of the silver market, has commissioned GFMS to provide greater insight into this sector. This report therefore aims to build on the work that GFMS has published in the *World Silver Survey*, by examining in greater detail the role that these uses are likely to play in the future.

We make a realistic assessment of the future prospects of total silver industrial demand, and where the growth opportunities are likely to emerge. In order to do so, we have first assessed the scope for growth in the established end-uses. Second, the potential market impact of 11 more recent applications of silver, ranging from wood preservatives to superconductors, are also analyzed. By bringing together these two components, we have generated a five-year forecast for global silver industrial demand, covering the period 2011 to 2015.

Industrial Demand Forecast

(Base Case Scenario, million ounces)

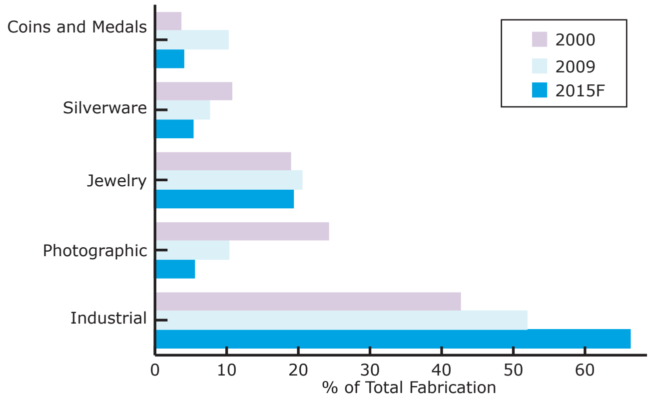
	2010	2015F
Industrial Demand	487.4	665.9

1.2 Economic and Price Forecast

The economic outlook provides the most important basis for determining the prospects for global silver industrial demand, while prices are generally more of a secondary concern. In terms of the former, healthy western market growth over the past decade has been an important contributory factor to the strength in silver industrial demand, but arguably of greater relevance has been the performance of many developing countries, and especially markets such as China and India. To put this into perspective, during 2000-08, GDP growth in China and India averaged 9.9% and 7.1% respectively, compared with a far more modest 2.7% and 2.2% for the European Union and the United States (respectively).

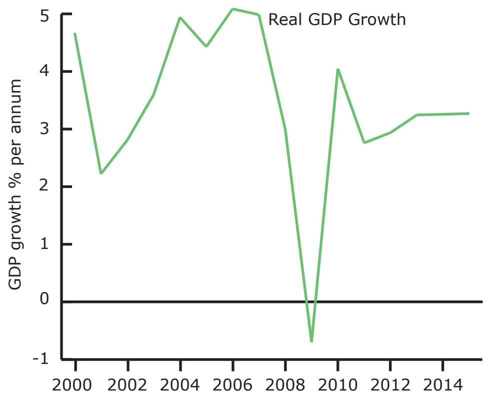
As a result of this strong economic growth, each country has undergone a period of rapid urbanization (which extends back much further than the past ten years), a by-product of which has been a jump in both infrastructure and consumer spending. It is of little surprise, therefore, that both have seen a jump in per capita GDP, with, for example, China realizing a threefold increase over the past decade (although it still remains relatively low, compared to western markets). The following commentary focusses on GFMS' most likely outcome for the global economy, termed the Base Case forecast. (Alternative economic scenarios, and their impact on industrial offtake, are considered in Chapter 5.)

Industrial Demand's Growing Importance



Source: GFMS

GDP Growth Forecast: GFMS "Base Case"



Source: GFMS; IMF

Following last year's healthy rebound in global GDP growth to 4%, 2011 is expected to see a marked slowdown, to a rate of 2.8%. This is for two main reasons. First, it will partly reflect the absence of several stimulus packages, which helped lift economic growth last year. Second, inflationary concerns, as a result of these stimulus measures, but also because of rising commodity prices, will see governments look to either curtail expenditure, or tighten monetary policy (although the ability to do so will be limited, with unemployment levels in many countries remaining stubbornly high). Looking further ahead, GDP growth is expected to edge higher, averaging 3.2% over 2012-15, although this will still fall short of the performance during 2000-08, when world GDP growth averaged 4%.

In terms of the price outlook, silver prices are forecast to continue rising this year, with the annual average comfortably eclipsing the 1980 record high (although in real terms the 2011 forecast average will fall short of the $55 posted in 1980). This will be driven in large part by further inflows of investment demand, and supported by additional growth in fabrication demand.

However, higher silver prices will tend to see efforts increase in terms of thrifting or substituting away from the white metal. That said, because of silver's unique technical properties, the ability to switch in favor of an alternative metal has so far been restricted to a few applications (such as multi-layer ceramic capacitors, which have migrated away from silver:palladium to copper:nickel compositions). Instead, the use of silver in several established applications, particularly in the electrical sector, could potentially be replaced with nano silver. These uses would therefore continue to benefit from silver's technical properties, although the absolute volume of silver demand could, in some cases, be somewhat lower. However, any substitution favoring nano products, although encouraged by prevailing high prices, is only likely to emerge over an extended period of time, and potentially beyond the scope of this forecast (allowing not only for regulatory approval, but also the time required for a supplier to qualify and then "roll out" a new product).

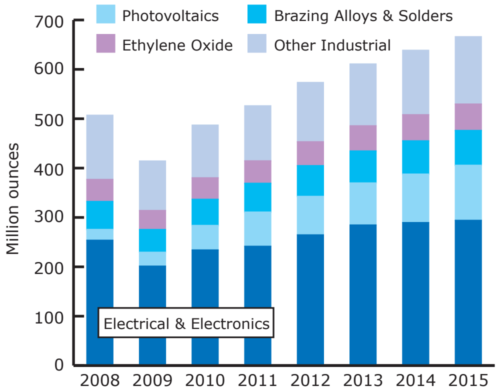
Looking ahead to the remainder of the forecast, annual average prices are then expected to drift lower, in reflection of less robust investment in the silver market. Even so, it is worth stressing that both prices and investment flows will remain at historically elevated levels in 2012. Indeed, next year will mark only the second occasion when prices will have achieved over $30 on an annual average basis, in nominal terms. Thereafter, silver prices will continue to respond to what will be a less supportive investment climate. Part of the shortfall, created by weaker investment offtake, will be absorbed by continued growth in world fabrication demand. In particular, record levels of industrial and jewelry demand will offset faltering offtake in photography and coins & medals (although following an initial bout of weakness, by 2015 silverware could recover to 2009 levels). Although prices are therefore forecast to drift lower through to 2015, average prices are still expected to exceed 2009 levels by this point.

1.3 Industrial Demand Forecast

Before considering the outlook for silver industrial demand it is worth briefly reviewing recent developments in this sector. Following a relatively subdued trend in the 1990s, during which growth averaged 2.5% per annum, the next decade saw a ratcheting up of this performance, with industrial offtake rising by 3.7% (on average) through to 2008. Although 2009 saw a sharp decline, this proved to be largely a "one-off" event, with global industrial offtake last year quickly recouping much of the lost output.

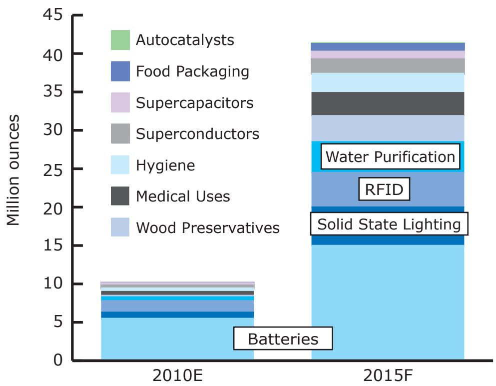
Looking ahead, a bullish picture for the future of silver industrial demand emerges. From an estimated volume of 487.4 Moz in 2010, the global total is expected to post an interrupted period of growth through to a record high of 665.9 Moz in 2015. Although it is important not to overlook the contribution from 'new' industrial uses of silver, it is also apparent that much of the growth in the global total will be driven by stronger demand for a number of the established uses, two key examples of which are outlined below.

World Industrial Fabrication



Source: GFMS

Silver Demand for New Industrial Uses



Source: GFMS

First, the robust increase in the manufacture of electrical contacts reflects the success of an established use, for example in terms of its development in the auto industry. The use of electrical contacts in cars has risen rapidly, not simply in response to an increase in the volume of vehicles made, but also because the number of end-uses for contacts, has expanded. Indeed, the list of core uses has grown considerably, from controlling windshield wipers and seat adjustments, to managing navigation systems. Features that were once the preserve of high-end automobiles have, over time, become an industry standard. Legislation has also played a critical role in the auto industry, as it has mandated for ever greater safety features. As a result, the latest electrical circuitry, used in (for example) speed or distance limiters, will most likely form part of an industry standard in tomorrow's auto market. Electrical contacts therefore offers an example of an established end-use that is in the process of effectively re-inventing itself.

The second example concerns the development of the photo voltaic (PV) industry, which demonstrates how exogenous factors have had (and continue to have) a material bearing on a long-established use of silver (in this case, its use as a conductive paste). Although it is often referred to as a "new end use" of silver, the use of the white metal in PV was first developed over two decades ago, but until recently silver offtake in this field remained slight. The market for PVs then changed dramatically, as growing environmental concerns increasingly focussed on generating power from fossil-free sources. From this point, silver offtake soared, from around 3 Moz in 2004 to around 50 Moz in 2010. Further robust growth is also forecast for the PV industry, with silver demand in 2015 expected to be more than double the already elevated total for 2010.

In forecasting silver industrial demand, therefore, we must consider which other established uses may go the way of these two examples. In addition to these segments, there are also a number of new uses of silver that merit attention. Although the total contribution from the new uses is expected to be more modest, at least within the confines of this five year outlook, there is the potential for a number of these segments to boost their silver consumption, if only beyond the scope of this forecast. As Chapter 5 shows, there are a wide range of industrial uses for silver that have been, and continue to be, introduced. Indeed, we would contend that those we have highlighted represent only a subset of potential new demand in the industrial sector, (not least in terms of the prospects for nano silver, where new outlets are frequently being discovered).

Nonetheless, the analysis in this Chapter highlights the often modest amount of silver used per unit in many of these categories. In other words, while it is clear that a growing range of applications, such as medical, food hygiene and water purification, have already gained (and continue to gain) commercial success, the total volume of silver demand for each application can often remain relatively modest.

It is also worth noting, however, that this has often been the case in many of silver's established uses. In the cell phone industry, for example, where per unit silver consumption is estimated at 250mg, it has required worldwide sales of 1.6bn units in 2010 to generate annual silver demand of around 13 Moz (source: Umicore Precious Metals, GFMS). Likewise, silver consumption per button battery is also extremely small, yet *en masse*, the sector forms a respectable portion of the industrial silver market. Should the

Silver Consumption by End-Use, 2010 © GFMS Limited

	Silver Consumption per Unit of Demand[4]	Product Demand[5]	Total Silver Consumption[5]
Cell phones	250mg/handset[1]	1.6bn	13 Moz
PCs & laptops	1g/unit[1]	690m	22 Moz
Automobiles	10-30g/vehicle	72m[3]	36 Moz
PDPs	10g/screen	19m	6 Moz
Thick film PV	0.15-0.25g/cell[2]	14GW	47 Moz
Button batteries	1g/unit	156m	5 Moz

Source: GFMS, [1]Umicore Precious Metals, [2]Technic Inc; [3]Light duty vehicles, Global Insight; [4]indicative and/or average metal content; [5]estimated

number of independently small-scale users in new areas of demand therefore proliferate, their combined total consumption has the potential to make a sizable impact on global silver demand.

Many of the new uses addressed in Chapter 5 center on silver's antibacterial qualities. Washing machines, face creams and socks, to name but a few, are products which actively market their use of silver. These show how the inclusion of silver can make the difference between an "ordinary" product and an extraordinary one. There is, in essence, nothing new about these products, apart from the fact that they now contain silver. Given that the metal itself is one of the key selling points, its use provides a competitive advantage, rather than a necessary cost. Other new uses of silver tend to make use of its conductive properties, including solid state lighting and Radio Frequency Identification (RFID) tags. Such products build upon silver's known credentials in this field, and further expand its presence in products affecting day-to-day activities. Looking ahead, the number of such products, both antibacterial and conductive, is set to rise further, which will ultimately translate to an increase in silver offtake. That said, we would caution that it may be beyond the forecast timeframe before we see more noteworthy volumes of silver consumption emerging.

In addition to the demand-led rise in silver offtake, there are a number of other factors that underpin our bullish outlook for industrial silver demand. First, a wide range of applications fall under this one heading, ranging from PV cells and brazing alloys & solders to ethylene oxide. This diversity affords silver industrial offtake far greater resilience than many other areas of silver demand, as weaker consumption in one segment may well be offset by gains in another, potentially entirely unrelated, area of industrial fabrication. Second, silver can be considered to be almost indispensable in terms of the unique properties it offers.

The myriad of uses reflect silver's unique properties, which often make it technically difficult, or economically infeasible for this metal to be replaced. And herein lies the key to maintaining and growing industrial demand; the lack of readily available alternatives has contributed to a low price elasticity of demand. In addition, there has been little evidence of a tangible shift towards using other materials (in contrast to the gold market, where industrial demand has often suffered from substitution away from the yellow metal). In spite of this, the size and weight of electrical circuitry has been driven significantly lower over the past 20 years, as part of incessant trend towards product miniaturization. The consumer electronics industry bears testament to this trend. For example, the table above indicates that average silver consumption per cellphone currently stands at 0.25g, compared with around 0.35g per handset in 2005 (source: Nokia); in the space of just five years this represents a decline of close to 30%.

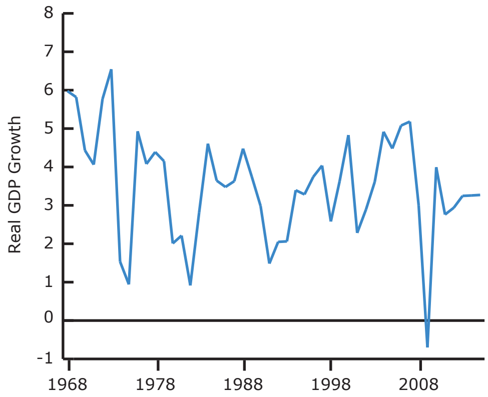
On a more positive note, silver is not always the first target for cost-cutting, as other cost considerations (such as silicon, in terms of PV) may supersede those of silver, which often forms a relatively small share of the cost of the final product. Third, silver enjoys an increasingly high profile among the wider public, in part because of its long-standing and positive association generated by the jewelry and coin sectors, but also because of the introduction of a growing range of consumer items (as discussed above).

In conclusion, therefore, we expect to see robust gains in industrial silver demand over the forecast period. Strong growth in many established uses will be augmented by increased offtake in a range of newer uses. This outcome will be underpinned by silver's unique properties, which ensure its future as an indispensable component across a range of industrial uses. Between 2010 and 2015, we therefore expect to see close to 180 Moz added to the global total, with world silver industrial fabrication, in the final year of the forecast, setting a new record high of 665.9 Moz.

2. Historical Review

This chapter analyzes some of the key trends in industrial silver fabrication covering the period from 1990 through to 2010. This timeframe saw a number of substantial changes in demand, with the implementation of new technology and the growing importance of the developing world playing a pivotal role in influencing industrial offtake. Furthermore, in spite of a long-term trend towards smaller and lighter finished products, which has led to a notable drop in the amount of the white metal used in silver-bearing industrial components, the absolute growth in industrial demand has comfortably offset this development.

Annual World GDP Growth Rate



Source: IMF, GFMS

Overall, therefore, industrial demand for silver has enjoyed a near uninterrupted period of growth, with fabrication rising by 84%, or over 230 Moz, between 1990 and 2007. Then, from late 2008 the global economic crisis had a pronounced effect on demand due to a marked fall in the sale of consumer electronic products and a decline in construction. This was magnified by destocking throughout the supply pipeline, as the replacement of sold stocks weakened noticeably, causing industrial fabrication in 2009 to weaken by 19%, compared with the 2007 record level. One of the few occasions a fall of a similar magnitude was witnessed was during 2001 when the bursting of the technology bubble saw industrial fabrication fall by 36 Moz (almost a tenth), with the United States, as the world's largest industrial fabricator seeing a 17% year-on-year decline.

Looking back over the past 20 years, silver used in industrial applications has principally been affected by trends in industrial production and economic growth, rather than by movements in silver prices. In the main, the lack of price elasticity has been due to the limited availability of substitute materials that have existed, particularly in electrical and electronics, which accounts for the bulk of silver's use in this field. In spite of the lack of substitutes, thrifting has been a constant feature of silver industrial demand over the past two to three decades. In particular, the trend towards increasingly small consumer electronics has driven down the size of electrical components, which in turn has seen an associated fall in the use of silver in this circuitry.

Another key factor underlining the success of silver in industrial demand has been the growing myriad of uses in which the metal has been employed, ranging from the ethylene oxide industry and photo voltaics, to a whole host of consumer electronic products, the demand for which is indelibly linked to the performance of the global economy.

In contrast to gold, silver fabrication is increasingly dominated by its industrial element; industrial demand accounted for less than 40% of total fabrication in the early 1990s but this grew to 52% by 2008, with the sharp rise in sales of household consumer appliances, whether basic white goods (fridges and washing machines, for example) or household electronic devices such as plasma display panels (PDPs) used in flat screen televisions, largely responsible for the increase, with the rapid growth in developing world consumption integral to this outcome. The fall in consumer spending, due to the financial crisis then led to industrial demand in 2009 falling back, to account for 41% of total fabrication. However, the robust recovery witnessed in 2010 suggests this decline was a temporary aberration, with the previous upwards trajectory expected to be restored over time.

In terms of the major industrial players, the industrialized world has historically dominated industrial demand for silver, with the United States, Europe and Japan together accounting for over half of the global figure (basis 2010 data, compared with around 60% in 1990). Furthermore, following the 2001-related fall in demand, this group has enjoyed a period of rapid growth in the use of silver for industrial applications, which carried through until the recent economically driven decline in 2008.

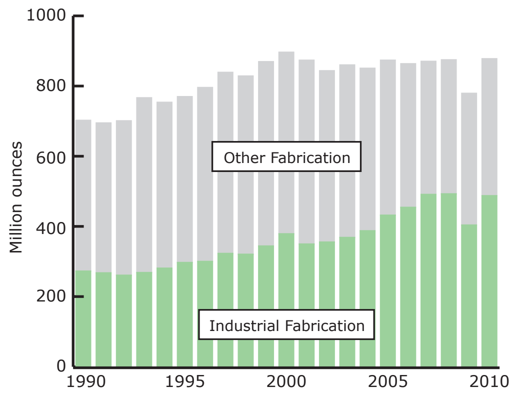
On a country basis, the United Sates has been the largest silver industrial fabricator over the past twenty years. In 1990, its output stood at 49 Moz, accounting for 18% of the global total. From this point, US demand increased appreciably thanks largely to growth in electrical and electronics, as well as the ethylene oxide (EO) industry. In terms of the latter, it is worth noting that the petrochemical industry (for the production of polyester intermediates) has used silver oxide since the 1970s. Since then, petrochemical plants have grown in size, not least in terms of the amount of fine silver consumed per installation. During this time, the United States has remained the single largest supplier to the industry, both at a domestic level and for export markets, which have increased considerably in the last decade as developing world demand has surged.

Turning to photo voltaics (PVs), which forms a subset of electrical demand, the industry has experienced rapid growth in recent years; measured in terms of gigawatt (GW) output, global production, as recently as 1999, stood at just 0.3 GW, compared with 7.3 GW recorded in 2009, using an estimated 28 Moz of fine silver. And, while the United States accounts for less than 10% of global solar cell production, the country is responsible for the bulk of silver powder and flake production used by this industry.

Developments in PVs have also benefited another of the top industrial fabricators, namely Japan. While the country has benefited from technological developments in electrical and electronics fabrication as a whole, the recent expansion of the domestic silver paste sector, more specifically, has also boosted silver demand. As a result, total Japanese industrial fabrication demand nearly doubled over the review period, rising from just 47 Moz in 1990 to a peak of close to 91 Moz in 2007. In between, the bursting of the technology bubble in 2001 saw offtake fall by almost a quarter that year. More recently, the impact of the 2008/09 financial crisis in Japan was also severe, resulting in a material downturn in the country's electrical and electronics industries, with GFMS estimating that industrial silver demand fell by 50% in 2009 (from the 2007 peak). Even so, a large part of these losses were offset by a strong recovery in 2010, highlighting the underlying strength of the country's industrial silver demand.

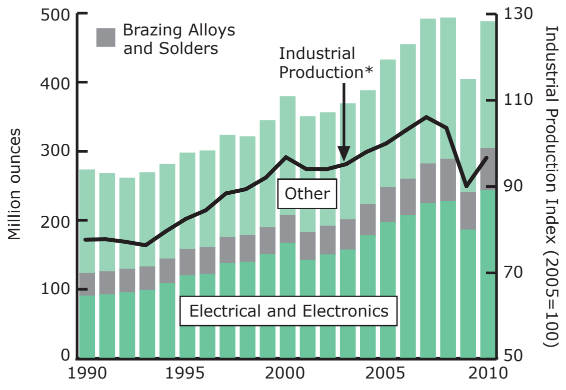
In terms of the European Union, industrial fabrication has risen steadily over the last twenty years. In 1990, this region accounted for almost a quarter of global output, with Germany easily the largest contributor, accounting for more than one-third of the European total. That said, over the last decade, European offtake has faltered, with industrial silver output in 2008 7% below that recorded in 2000, while the recessionary conditions in 2008/09 saw this fall to 30% below the 2000 level. However, not all countries in the EU have witnessed a material decline in industrial demand; German offtake in particular has risen by almost one-third over this period (with the country still in a competitive position to supply companies, assembling a finished product, that have relocated from Germany to eastern Europe).

Industrial Share of Total Silver Fabrication



Source: GFMS

Components of Industrial Demand



*Advanced economies; Source: GFMS, IMF

Elsewhere in the EU, however, offshore relocations to the developing world, have impacted silver industrial offtake. (The transfer of production capacity has typically reflected the developing world's lower labor costs, the availability of less expensive real estate, as well as often direct access to a rapidly growing domestic market, help to provide a competitive advantage.)

Turning to the developing world, over the past twenty years, this region has seen its industrial offtake rise noticeably, the result of which has seen a number of developing world countries emerge as some of the largest industrial fabricators (on a global basis). Looking at this timeframe in more detail, in 1990, the developing world's share of total industrial demand stood at just 14% or 37 Moz. Since then, this has risen steadily, although perhaps not as rapidly as many would have expected, with a share of around 40% achieved in 2008. The main reason for this is that a sizable slice of offtake in one of the largest fabricators in the developing world, namely India (second only to China), is largely price sensitive and has therefore been, at times, adversely impacted by rising and volatile rupee prices.

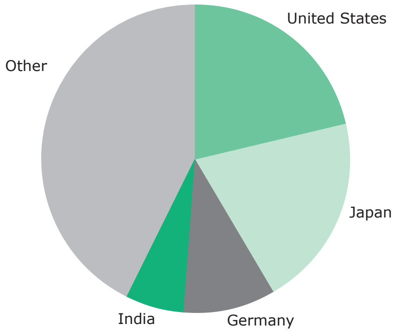
The principal areas of silver industrial fabrication in India are the electrical and electronics sector, brazing alloys and solders, although other uses of silver such as plating, pharmaceutical and associated chemicals, foils and jari (traditional clothing) also feature. While growth in the former two industrial categories are largely dependent on the economic environment, the remaining categories are typically price sensitive, the performance of which is therefore partly contingent on rupee price developments.

As well as India in the developing world, China has also taken its place as one of the leading global industrial fabricators. Similarly, the country has enjoyed robust growth in recent years, particularly in the electrical and electronics sector. This has been partly the result of factory relocations from higher production cost countries, combined with the strength of the domestic economy that has seen consumer purchasing power increase dramatically over the last decade.

Chinese industrial demand at the start of the millennium was "just" 30 Moz, accounting for 8% of global output. However, the last ten years have seen a more than doubling of Chinese industrial demand, to a then record high of 78 Moz in 2008 at (which represented 16% of total global industrial fabrication). Although 2009 saw a drop in offtake, this proved to be short-lived, with 2010 seeing a new record high.

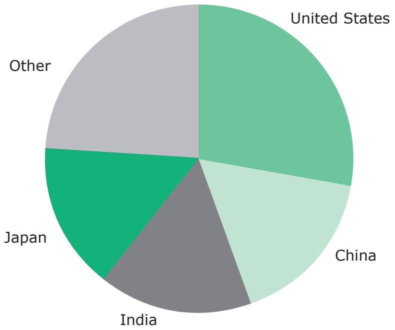
The main growth segments for China have been in electrical and electronics, largely as a result of export led fabrication. However, more recently, rising domestic demand (the result of China enjoying average annual GDP growth of almost 10% during 2000-2008) has also contributed to this robust performance. In addition, China also witnessed firmer brazing alloys and solders demand, largely as a result of the massive investment in public infrastructure, housing and commercial developments in China's lower tier cities and rural areas. Stronger export demand, however, also played a role in lifting demand in this segment.

Main Industrial Fabricators, 1990



Source: GFMS

Main Industrial Fabricators, 2010



Source: GFMS

3. The Role of Silver in Industrial Demand

3.1 Introduction

One of the underlying themes that emerges from this report is the unique technical proficiency of silver, which not only makes it suitable for a range of applications, but limits the ability of industrial users to switch in favor of lower cost alternatives. This chapter seeks to identify some of the key technical properties and how these relate to a given application.

The analysis will then review the production profile of a select number of uses, highlighting silver's role, from the raw material (such as bullion or grain) through to a semi-manufactured product, the penultimate stage before the final item, such as a photo voltaic (PV) panel, is assembled. To this end, the accompanying flow diagrams (see pages 14-15) highlight, quite succinctly, the various production stages that have been identified for a range of industrial products. In constructing theses charts, however, what has also emerged is the importance of silver powder as a key intermediary in many silver industrial applications. Much of this product is consumed in countries different to where it was fabricated, this chapter will also consider the growth in silver powder trade and the main countries involved in this market.

Product Derived from First Transformation from Bullion

Source: GFMS

	2010E market share
Semi-manufactured products	38%
Powder and flake	23%
Silver nitrate	14%
Coin blanks	12%
Silver oxide	7%
Plating salts	6%

The table above provides a broad indication as to the relative importance of the main intermediate silver products that are fabricated, before final assembly takes place (for example, of PV cells). Importantly, the table reflects global silver demand, including photography and jewelry, hence the dominant share occupied by semi-manufactured products (which are used in jewelry & silverware, as well as the brazing alloys & solders market). Excluding non-industrial uses for semi-finished pieces would therefore see powder and flake occupy top spot in this table. The relatively small share occupied by silver nitrate reflects its position as an intermediary in the fabrication, for example, of silver oxide. The 14% share shown above for silver nitrate therefore largely reflects its consumption in photography.

3.2 Technological Advantages of Silver

Silver enjoys a number of technological benefits, which makes it ideal for a range of industrial applications. In particular, the metal is one of the best electrical and thermal conductors, which makes it the "metal of choice" for a variety of electrical end-uses, including switches and contacts. This encompasses the use of silver in electronics in the preparation of thick-film pastes, including silver-palladium for use as silk-screened circuit paths, in multi-layer ceramic capacitors, in the manufacture of membrane switches, silvered film in electrically heated automobile wind shields and in conductive adhesives.

Contacts provide junctions between two conductors that can be separated and through which a current can flow. Silver conductive inks are also now used in the area of printed electronics, to meet the need for low-cost processing in the high-growth and emerging markets such as Organic Light Emitting Diodes and sensors, as well as for radio frequency identification tags. The ease of electro-deposition of silver from a double-alkali metal cyanide, such as potassium silver cyanide, or by using silver anodes accounts for its widespread use in coating. Silver is also used as a coating material for optical data storage media, including in DVDs.

The unique optical reflectivity of silver, and its property of being virtually 100% reflective after polishing, allows it to be used both in mirrors and glass coatings, cellophane or metals. Batteries, both rechargeable and non-rechargeable, are manufactured with silver alloys (increasingly silver:zinc) as the cathode. In spite of their relatively high cost, silver cells enjoy superior power-to-weight characteristics than their competitors.

Silver, usually in the form of mesh screens but also as crystals, is employed as a catalyst in numerous chemical reactions. For example, silver is used as a catalyst in the production of formaldehyde, a chemical widely used in the manufacture of other organic chemicals and plastics. Silver is utilized as a bactericide and algicide in a wide range of applications, including water purification systems, surface treatments and disinfectants.

The joining of materials (called brazing if done at temperatures above 600º Celsius and soldering when below) is facilitated by silver's fluidity and strength. Silver brazing alloys are used widely in applications ranging from air conditioning and refrigeration equipment to power distribution devices in the electrical engineering and automobile industries.

3.3 Production Stages

As highlighted above, one of the key themes that emerges from this report is the vast range of applications in which silver is used. However, in terms of the intermediate production stages, many uses of silver do share common traits, such as the manufacture of silver nitrate, which is then converted into powder or flake. The flow charts on pages 14-15 highlight the various production stages, as well as the commonality that exists in the production of what can often be quite distinct industrial segments. As a result, to avoid duplication, the following commentary focuses on some of those uses, which highlight these manufacturing steps. It is also worth bearing in mind that production phases not involving silver, such as the fabrication of silica for PV cells, are not covered in this analysis.

Looking first at the manufacture of **PV** materials, what immediately stands out is the considerable number of production steps that characterize this industry. Although there is a degree of uniformity across markets in terms of the intermediate stages, the starting point will vary by location. In other words, US and Japanese manufacturers (which currently dominate this market, in terms of the silver-related steps) will typically start with four 9s large bars, whereas those located in Europe will initially require four 9s grain. The raw material (characterized by extremely low impurities, such as lead and bismuth, each of which is strictly controlled) will then be dissolved with nitric acid to produce silver nitrate.

The importance of fabricating a consistently high quality of silver nitrate will also encourage some manufacturers to purchase this salt from third parties, essentially as a hedge against any failure emerging in their factory. In many locations, the availability of high grade (four 9s and above) silver nitrate has become increasingly common, particularly given the decline in photographic demand. However, a combination of high import duties, of around 3.7%, and the low added-value margins available on silver nitrate, means that third party sales are typically restricted to markets in which the salt is produced, or a within a free trade bloc, such as the European Union.

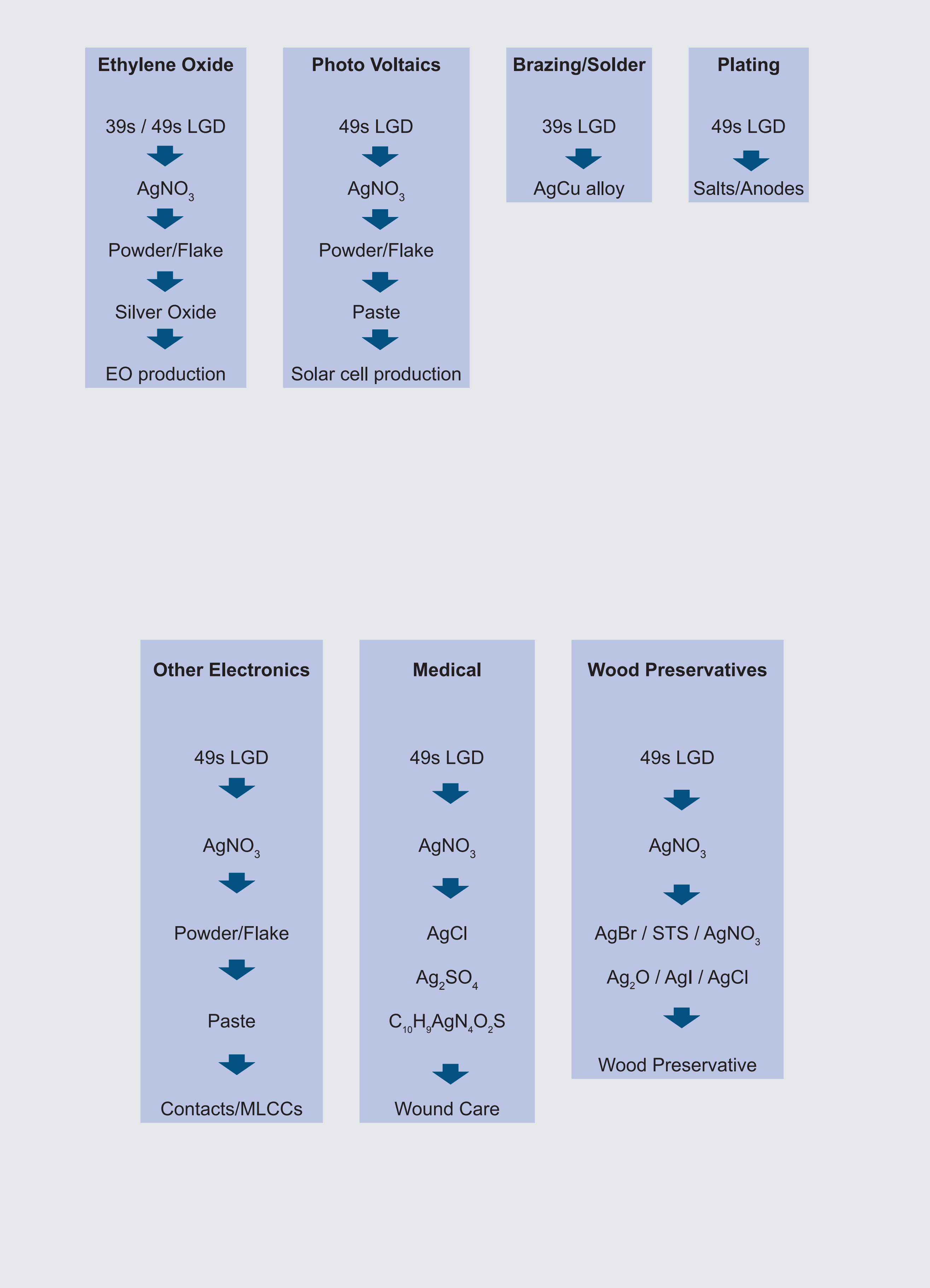
The next process involves silver nitrate being crystallized to form silver powder or flake. For many operations this represents the last internal stage, before the powder (which appears to be a far more common output than flake) is then delivered to a paste house. Our information suggests that this market is dominated by the United States and then Japan, both of which feature just a few large operations. In contrast, the Chinese silver paste market, which is growing rapidly, is far more fragmented, although there are signs of the industry now consolidating, and there is a growing presence of foreign-owned paste houses.

The rising importance of the Chinese paste industry reflects the growing significance of Chinese PV cell manufacturers. It is also worth noting that this represents the final production leg, aside from the actual installation of the cell itself. As just noted, China's expansion into this area has seen the country emerge as a clear market leader in the production of both thick and thin film PV cells, having comfortably overtaken Germany, which had dominated this field for several years.

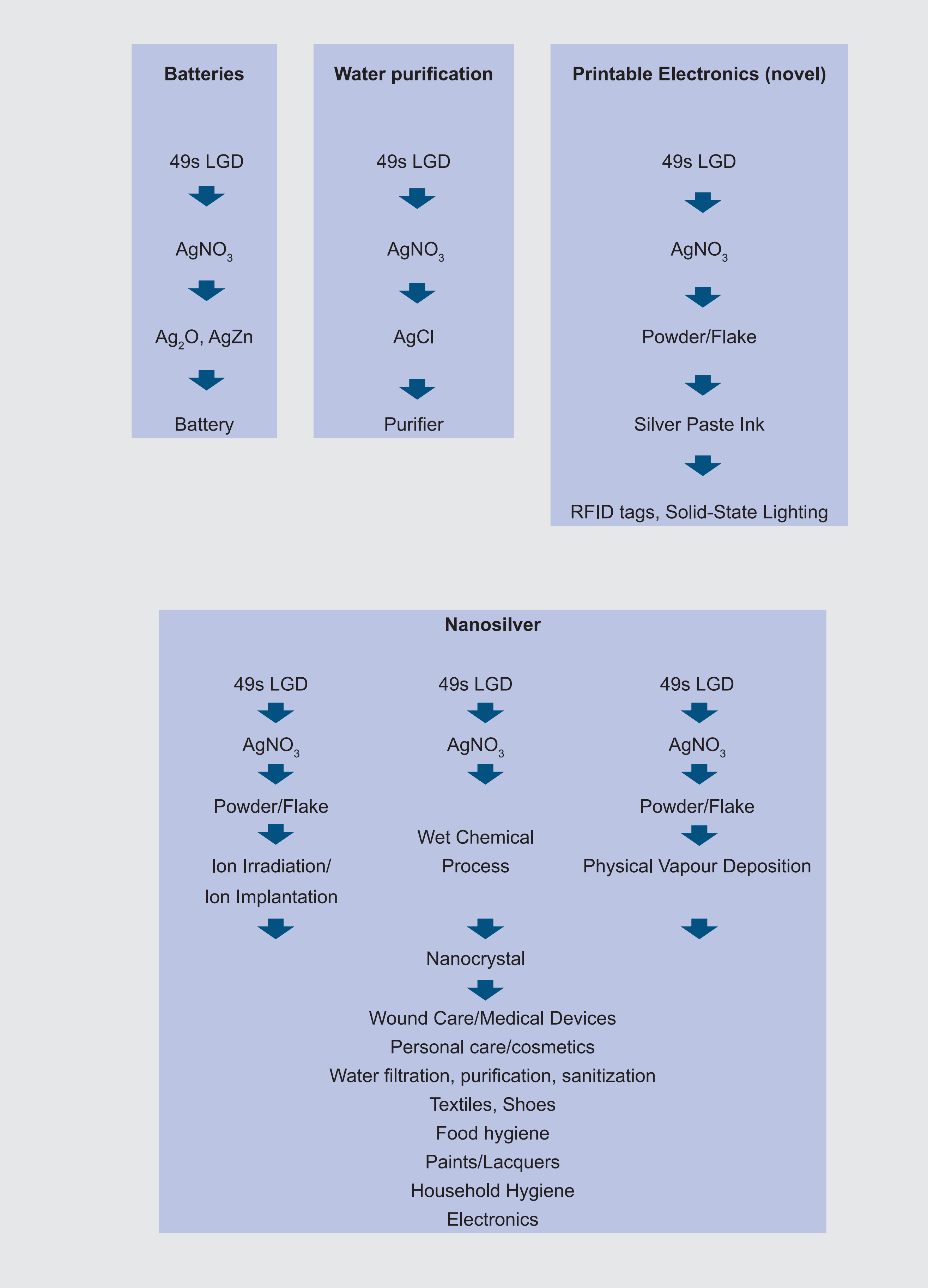
Turning to the **ethylene oxide** (EO) industry, the starting point is the in-house production of silver nitrate (or its purchase from a third party). The salt is then combined with potassium oxide to produce silver oxide. This represents the last internal production stage, before the silver oxide is used as a catalyst in the production of EO, which is then converted to ethylene glycol, a major constituent of polyesters and epoxy resins (see page 16 for an illustration, showing how the silver catalyst is incorporated into an EO plant, courtesy of The Dow Chemical Company). In terms of the production process, the various stages are heavily concentrated. For example, the United States dominates the out turn of silver oxide for the EO industry, followed by Japan and then the European Union.

The construction of EO plants is also dominated by a few large entities, with the United States again appearing at the top of this list. The installation and management of EO plants is a little more diverse, but what is more important, in terms of the long-run prospects for this segment, is the growing size of each plant, both in terms of the contained EO tonnage and the silver oxide content. Although, as discussed elsewhere in this report, the technology is long established, the consumption of silver per plant has increased significantly, from around 200,000-250,000

Industrial Silver Applications: Silver Related Production Stages



Industrial Silver Applications: Silver Related Production Stages



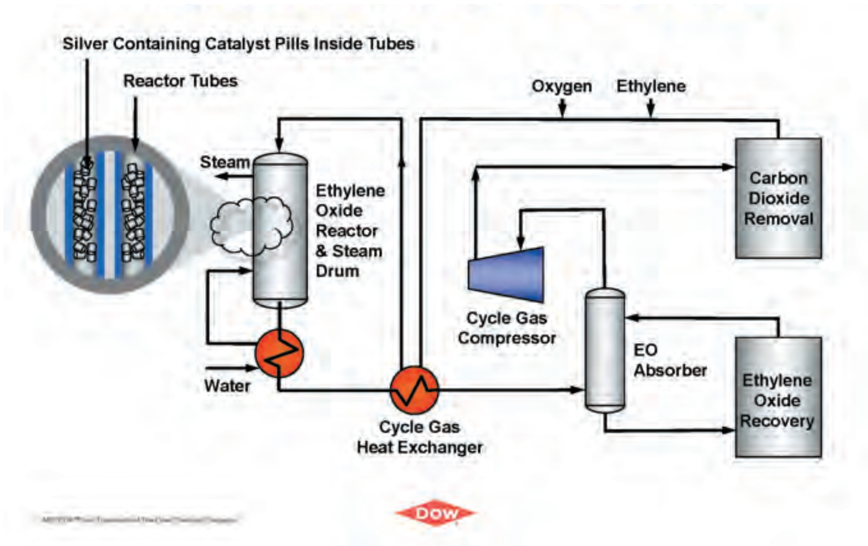
ounces of metal in the 1970s, to comfortably in excess of 2.0 Moz per installation in today's market.

The **brazing alloys & solders** market offers a different production cycle from that described above, this representing a more traditional "metal bashing" industry. Here, in terms of the initial input there is far less focus on impurities, with brazing alloy manufacturers (solder offtake is relatively trivial) being capable of using a range of inputs, from three 9s bars to high purity silver scrap, including coin bags. That said, coin bags (a feature of the US market) are especially desirable because of their high copper content (a 90% silver coin bag will consist of 10% copper by weight), which together are used to produce silver-copper alloys in a variety of formats, including strip, wire and granules. The alloy composition (in terms of the relative share of silver and copper, as well as other base metals) will vary considerably, depending on such characteristics as: the desired strength of the alloy, its required melting point, or its conductivity.

Turning to, what might be termed "new uses" of silver, these feature a variety of approaches, in terms of producing a silver-bearing intermediary. It is also important to note that a number of methods exist in which silver is consumed depending on the favored technology and the application for which it is required. The following commentary therefore does not claim to be exhaustive but instead highlights a small sub-set of the procedures that are followed (but which may not necessarily be the most commonly used in a particular industry).

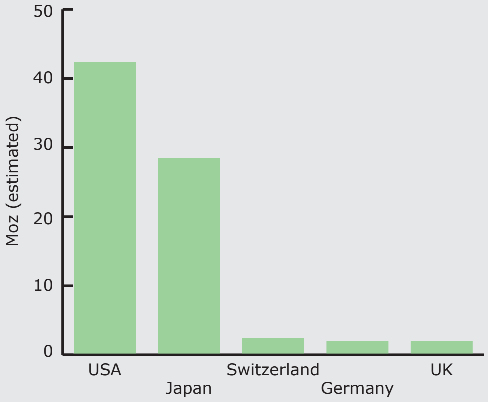
In terms of the **wood preservatives** and **water purification** sectors, our research indicates that each sector will initially require high purity silver, in either bar or grain form. The silver nitrate, which is then derived, will be used to produce a range of silver-bearing salts. Companies involved in the manufacture of wood preservation products and intermediary formers of formulations, that have wood preservation characteristics, are evaluating compositions containing silver from a number of different silver chemicals for this purpose. As discussed elsewhere in this report, the absolute volume of silver consumed can often be quite modest. As a result, the companies involved in these industries will often lack the in-house capabilities to produce silver bearing salts and will therefore frequently purchase these near-commoditized (and thus low margin) intermediates from third parties. Their competitive edge will therefore stem from producing, for example, a value-added silver-bearing solution.

Silver Use in METEOR™ EO Process



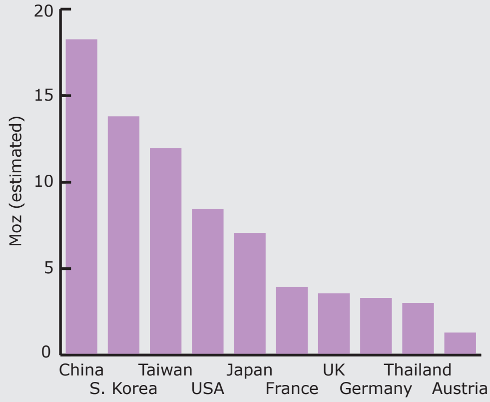
Silver Industrial Fabrication: Defining the Country of Origin

Top Five Silver Powder Exporters, 2010



Source: GFMS

Top Ten Silver Powder Importers, 2010



Source: GFMS

GFMS' statistical database, covering global industrial fabrication, stretches back to 1990 and features country-by-country statistics (this also applies to all other areas of global silver supply and demand). However, in compiling this data, there is the risk that some silver demand may be double-counted. In other words, silver offtake may be captured twice if, for example, separate production stages take place in different countries. GFMS strives to avoid this problem by adhering to a clear methodology, which measures silver offtake at the first point of transformation. (This approach has ultimately worked thanks to the extensive and long established network of contacts that GFMS have built up in every major industrial fabricating country.)

As the preceding commentary in this chapter highlights, silver offtake typically involves several stages, often occurring in a number of countries. In this regard, a review of the trade in silver powder clearly highlights this issue, not only as it forms the starting point for a number of silver industrial applications, but also because of the extent to which the powder trade has developed in recent years (encouraged, in no small part, by the duty free status it attracts). The following analysis, as well as the above two charts, will therefore help to draw a distinction between silver industrial *fabrication* and *consumption*.

Before looking at the data itself, it is worth highlighting some of the issues in taking trade statistics at face value. In terms of the silver powder trade, this will often include silver flake shipments. It is, however, extremely difficult to separate the two as few countries provide this split, and so the analysis here will cover both segments. Secondly, in keeping with trade data in general, the above charts must be treated with some caution. The frequent mis-categorization of products can both under and over-inflate reported trade flows. Finally, there is also the risk that cross-border trade, involving subsidiaries of one company may not always entirely appear in the trade data.

The risk of double-counting, mentioned above, immediately stands out from the data shown in the above two charts; the top two exporting countries (which, together, comfortably dominate the outbound trade of silver powders) also feature in the list of the most prominent silver powder importers. A more detailed review of their data reveals that the United States is in fact by far the largest provider of powder to Japan. This trade is one example as to why the United States has seen its share of global silver industrial fabrication rise over the past 20 years, in spite of ongoing relocations of manufacturing facilities to lower cost areas. In other words, while there has been a tangible shift where semi-finished silver products (silver powder and oxide, for example) are assembled into finished items, the impact on the location of the top silver industrial manufacturers has been less noticeable. This has been largely due to, for example, the United States retaining its competitive edge in this field.

The difficulty in separating fabrication from consumption is also highlighted by the development of China's silver industrial base, at various stages along the supply chain. Over the past ten years, the country has enjoyed a more than doubling of its silver offtake for industrial applications. However, over the same timeframe, China's consumption of silver powders has also surged, highlighted by the jump in imports from less than 3 Moz in 2001 to around 19 Moz last year. Both developments are consistent, for example, with China having established itself as a market leader in the production of PV cells, as well as boosting its own capacity in the delivery of locally made powder to paste houses. However, care still needs to be taken in correctly identifying the origin of the silver demand, with the United States and Japan providing much of the silver powder for this industry.

4. Industrial Applications Today

4.1 Introduction and Summary

Silver's main industrial end-use is in electrical and electronic applications, accounting for a little under half of the industrial total. Brazing alloys and solders are also significant, representing just over a tenth of the total. The highly diverse remainder covers such end-uses as mirrors, batteries or ethylene oxide catalysts.

Silver Industrial Fabrication © GFMS Ltd / The Silver Institute

(Moz)	1990	1995	2000	2005	2010
Electrical & Electronics	90.0	119.3	166.6	196.2	242.9
Brazing Alloys & Solders	32.6	38.1	40.3	50.8	60.8
Other	149.9	139.6	171.9	184.8	183.7
Total	**272.5**	**297.0**	**378.8**	**431.8**	**487.4**

This list is ever changing, with some dropping off, for example when silver gets replaced by a base metal, and with others being added. An obvious fairly recent example of the latter is photo voltaic cells and, indeed, the list now looks poised for a period of rapid expansion stemming from the myriad of novel uses currently under development (see chapter 5 for more detail).

As noted above, silver can find itself replaced by less expensive rivals, or indeed do the replacing of higher priced metals. The technologies behind such shifts, however, take time to develop, which means that silver industrial demand is largely price inelastic in the short term. Instead, volumes are more a function of the health of the world economy, particularly industrial production growth. This helps explains why industrial fabrication fell by 18% in 2009 as recession struck, yet rebounded by 21% in 2010 despite surging prices.

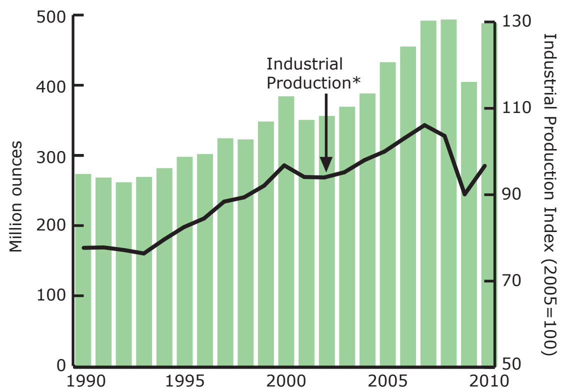
The largest single user at a country level is the United States, with a rough 25% share of the global total in 2010. This was followed by China, Japan, India and the EU, with around 15% a piece (although the Indian figure includes many quasi-industrial end-uses). These shares have changed greatly, with for instance the EU's standing at 21% and China's at 11% a decade ago.

4.2 Electrical & Electronics

As silver has the highest electrical conductivity and the highest thermal conductivity of any metal, the use of the white metal within the electrical & electronics industry is widespread, contributing the largest share to global silver industrial fabrication. The range of uses covered by this broad segment is substantial as it is varied. Some of the more common electrical uses include the production of light and heavy duty switches (for the construction industry), as well as the manufacture of silver paste for the photo voltaic (PV) industry. In terms of the electronics industry, this will feature, for example, the production of silver:palladium pastes for passive electronic components such as multi-layer ceramic capacitors (MLCCs), which in turn will be used in a range of consumer products, including cell phones.

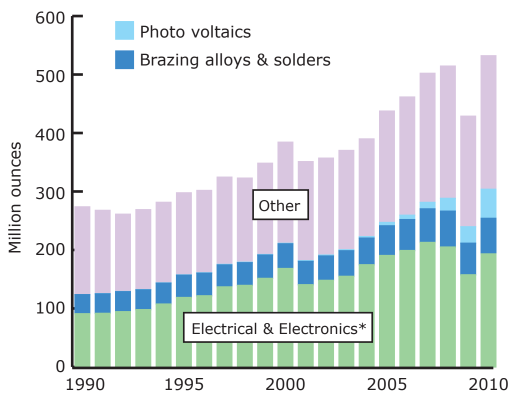
Over the last twenty years, electrical & electronics demand for silver has enjoyed a near uninterrupted period of robust growth. From a low base of some 91 Moz in 1990, this segment enjoyed an impressive increase of 152 Moz or 167% to reach an all-time high of 242.9 Moz last year. In fact during this time the

World Industrial Fabrication



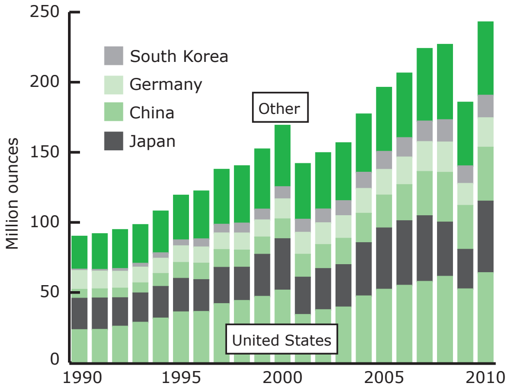
*Advanced economies; Source: GFMS, IMF

Components of Industrial Fabrication



Source: GFMS;*excluding photo voltaics

Electrical and Electronics Fabrication



Source: GFMS

(million ounces)	1990	2000	2010
United States	23.3	51.5	64.0
Japan	22.4	36.7	51.1
China	6.3	14.1	38.4
Germany	13.5	14.3	21.0
South Korea	1.0	8.7	16.1
Other	24.5	43.8	52.3
Total	**91.0**	**169.1**	**242.9**

only substantive decline occurred in 2001, during the bursting of the technology bubble and then in 2009 as world economic conditions deteriorated noticeably. As a percentage of total industrial fabrication, there has also been a marked increase, from 33% in 1990 to 50% last year.

Apart from a rapid expansion in PV cells (which, given its growing importance, is discussed separately below), the rise in electrical & electronics demand over the past few decades has owed much to increasing sales of consumer products (ranging from white goods to consumer electronics), as well as improving demand from the construction industry, with the rapid growth in developing world markets integral to this outcome. This development has therefore offset the ongoing trend towards ever smaller electrical and electronic products. In so doing, the silver content of components required for these industries has fallen significantly, although this has been comfortably outweighed by the tremendous growth in unit demand (described above).

Further support has come from the increasing use of silver contacts in automobiles, coupled with robust growth in global auto production over the last decade (notwithstanding 2008 and 2009), particularly in emerging markets.

While the industry has, overall, benefited from growing demand for a range of silver components, the impact of substitution and thrifting has been less clear-cut. For example, technological shifts have, at times, benefited the industry. The DVD market offers one such example. This sector initially consumed gold sputtering targets, a situation which changed during the early 2000s as the industry gradually shifted in favor of silver targets.

In contrast, the use of silver in MLCCs experienced a dramatic fall in 2001, following the spike in palladium prices which saw huge swathes of the market migrate rapidly to base metal (copper:nickel) capacitors. Since then, the shift away from silver:palladium compositions has continued, albeit at a more gentle pace, although there has been some partial offset, with silver gaining at the expense of palladium in the manufacture of precious metal MLCCs.

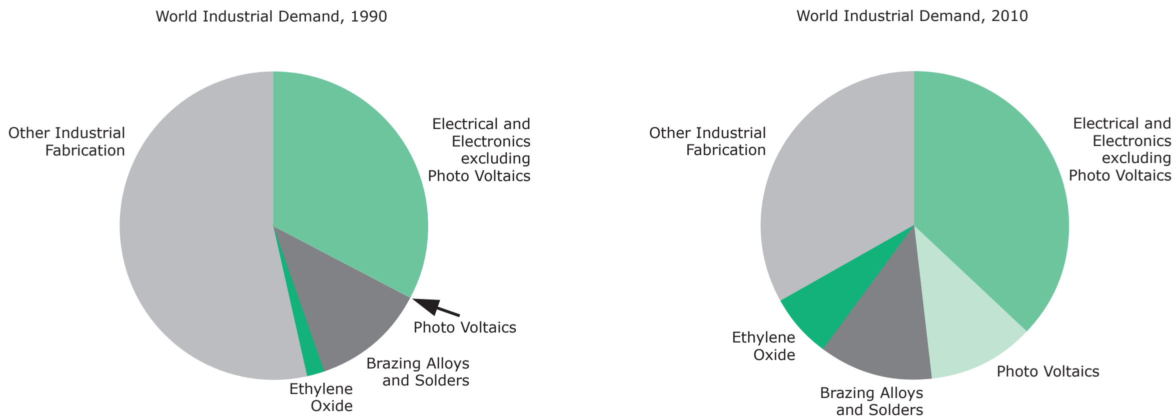
On a regional basis, the United States and Japan have been the world's largest two users for more than two decades, typically accounting for around half of the global figure. Meanwhile, offtake in China and, to a lesser extent, India also increased substantially over the last ten years, as low labor costs and growing demand for consumer goods such as automobiles or household appliances, itself a result of strong GDP growth and ongoing urbanization, have encouraged the transfer of industrial activities from western markets to these countries.

4.3 Photo Voltaics

There are two main types of photo voltaic (PV) cells: thick film and thin film. The former is silver intensive, and requires on average an estimated 3,700 ounces (115 kg) of silver (in the form of conductive paste) to generate one megawatt of power, although amounts vary considerably among different manufacturers. Thin film, of which there are many types, uses far less silver, and some use none at all.

Thick film technology currently dominates total cell production, holding around an 80% market share. This is due to its technical superiority, which outweighs its higher cost. The proportion of thin film is steadily expanding, however, as efficiency improves; some

The Growing Importance of Photo Voltaics to Global Silver Industrial Fabrication



Source: GFMS

forecasts see thin film holding around 30% of the total market by 2013. Other types of PV technology include Concentrating Solar Power (CSP) and organic solar cells, although these use little to no silver.

Silver powder is the main precursor of the conductive paste that is used in thick film cells. In general, the fabrication of powder is separate from silver paste production, and may occur in different localities. Furthermore, paste output and solar cell production may not necessarily occur in the same country. Finally, the installation of a solar cell may well occur in yet another country. Solar cell production and cell installations, for example, would currently see China and Germany dominating respectively.

The rise in solar power is arguably the most significant development for silver demand in recent years. Over the last decade, this sector's offtake has climbed rapidly, soaring from less than 2 Moz in 2001 to an estimated 50 Moz in 2010 (rising by over 70% year-on-year). This year, demand is expected to reach nearly 70 Moz, an increase of around 40% year-on-year. This amounts to close to 25 gigawatts (GW) of power, although only around 22 GW are likely to be installed. Historically, cell production has tended to outpace cell installation, partly to compensate for anticipated cell failures, but also because cell manufacturers have vied to establish economies of scale and market presence.

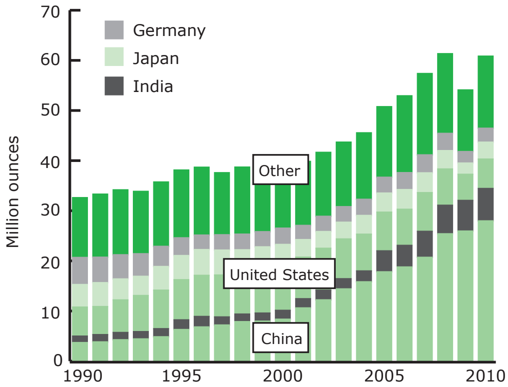
The remarkable gains in PV reflect the fact that it is still an emerging technology in a relatively early growth phase. That said, PV technology is not new; indeed, the use of silver in PVs dates back over 30 years. What is new, however, is strong political will, backed by financial incentives. Around 50 countries have adopted 'Feed-in-Tariff' (or FiT) programs, which guarantee PV energy providers fixed wholesale prices for an extended period of time (typically twenty years), which require regional and/or national utilities to buy this energy at a higher price than conventionally generated power. Germany's position as the world's leading solar market is a result of its extensive legislation providing for often generous in this area.

The ultimate goal for the solar industry is for markets to reach grid parity. Grid parity is the point at which the cost of generating solar energy will be equal to, or less than, the cost of conventionally generated grid power, and, in principle, means that government support is no longer necessary. This has already been achieved in some locations (including some parts of southern California, while Hawaii, Italy and Japan are on the brink of doing so), which have both abundant sunshine and high fossil fuel costs. The level of silver demand in PV is, therefore, contingent on a number of interrelated factors, most notably the sustainability of FiT programmes, political will, global economic growth, energy prices, and developments in technology.

4.4 Brazing Alloys and Solders

Brazing is the joining of two different metals with a third alloy, the latter having a lower melting point than the other two and is the only part to become molten or partially molten in the process. Soldering is in essence the same but at a lower temperature (under 450º C) and this usually uses little silver (a typical alloy is 97% tin and 3% copper or silver). In addition to tin, other metals used for brazing/soldering include cadmium, copper, aluminium or zinc and all are used when they become technically feasible and where permissible (a major issue for cadmium). Substitution is therefore an ever present threat for silver and this explains why the average silver content in brazing alloys & solders has

Brazing Alloys and Solders Fabrication



Source: GFMS

(million ounces)	1990	2000	2010
China	3.7	8.4	28.0
India	1.3	1.8	6.5
United States	5.8	8.7	5.9
Japan	4.5	4.4	3.4
Germany	5.4	3.2	2.8
Other	11.9	13.8	14.4
Total	**32.6**	**40.3**	**60.8**

fallen from easily over a half to perhaps as low as 35% in the last decade. Another threat is the development of new techniques, such as press-fittings in plumbing, that require no brazing or soldering.

The sectors of end-use primarily comprise the so called HVAC/R category (heating, ventilation, air-conditioning and refrigeration), the tool industry, plumbing and automobile production. China is now the world's largest single user, accounting for 40% of the global total in 2010. India came in second with 13%, helping take Asia's combined share to almost two-thirds - up markedly on its 43% share a decade earlier. Global fabrication has also risen notably in the last decade, growing by 50% from 2001 to a peak in 2008 of 61.3 Moz, before the 2009 recession then reduced that year's offtake by 12%. Offtake in 2010 recovered strongly but did not quite regain pre-crisis levels, although that should be achieved this year.

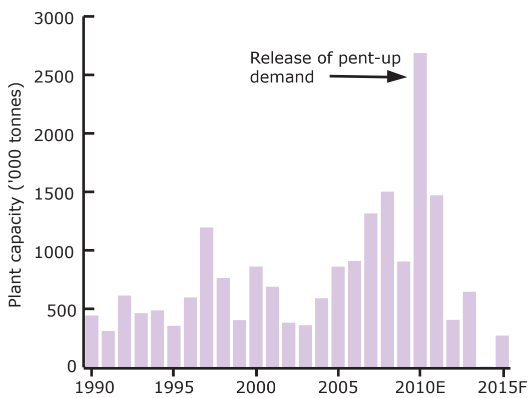
4.5 Ethylene Oxide

The use of silver in the ethylene oxide (EO) industry has arguably been one of the unsung success stories of the silver market over the past two to three decades. During this period, the sector has enjoyed a near uninterrupted, albeit quite variable, period of expansion. This has reflected the surge in demand for an ever greater range of polyester derivatives.

This growth in polyester demand led to a jump in the number of EO plants, from less than 70 in 1980 to comfortably over 100 last year. During this time the center of the industry has also shifted, from North America to the Middle East. In addition, during this timeframe, average plant capacity has more than doubled to over 200,000 tons of ethylene oxide. The third trend has seen the average silver content of each plant rise notably, from around 10% during the late 1970s/early 1980s to around 25% in today's market. These developments, taken together therefore, have contributed to a far larger consumption of silver per EO plant.

Overall, field research indicates that silver consumption per plant initially averaged 250,000 ounces at installation. During the intervening period, this has risen by more than ten-fold, on occasion exceeding 3 Moz. Overall, it therefore appears as though installed silver capacity, on a global basis, may currently exceed 150 Moz. This of course does not represent a market overhang, with only those plants shut entirely (a development which usually affects the smaller, older - and therefore arguably less efficient - plants) or those units that are changed, a procedure which usually occurs every two to three years in the life of an EO plant. In this regard, it is important to note that this does not represent new demand, aside from the silver lost, either during the running of the plant or during the change-out.

Changes in Global EO Plant Capacity



Source: GFMS

5. Future Industrial Demand for Silver

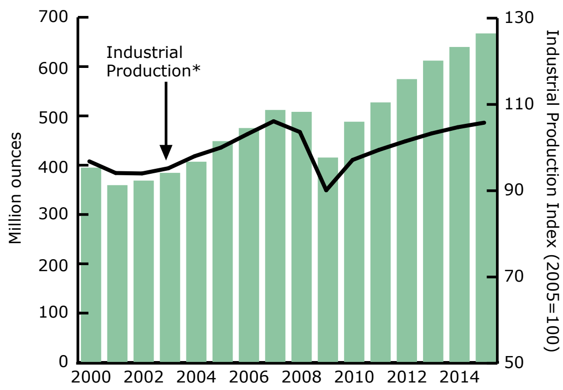
5.1 Introduction and Summary

This chapter provides an outlook for industrial silver demand over the next five years. In terms of recent events in Japan, this would seem to have already had a dramatic impact on commodity prices, as investors reacted quickly to the bearing this disaster could have on the markets. It is extremely unlikely that Japanese silver demand for industrial applications will not be adversely affected, although it is far too early to comment on the likely extent of this. As a result, the demand forecasts contained in this report represent the situation as we saw it before these tragic events unfolded.

The first part of the forecast (section 5.4) addresses the 'established' uses, namely the electrical and electronics sector, brazing alloys and solders, photo voltaics (PV) and other industrial uses. The second part (section 5.5) reviews a number of 'novel' areas of fabrication. In addition to the major end uses of silver already discussed in previous chapters, there are a several new areas of industrial fabrication which in time may boost global industrial offtake. Although many will remain within this "novel uses" sphere, in a research and development phase and therefore still some way from commercial production lines, there are nonetheless a number of applications that have already progressed beyond this stage, with production now established on a commercial scale. Section 5.5 looks at these applications and reviews their current development.

It is worth noting that PV is only a recent addition to the list of 'established' uses, having previously been considered to be one of the 'novel' uses. Such is the level of demand and the strength of the outlook for this application, however, that we now believe it can justifiably be considered to be an 'established' use. While it was not strictly a new use before, as the technology had been established for over thirty years, it has only been following the recent implementation of government incentives that demand for PV has risen sharply. The sector provides a clear example, therefore, of how a 'novel' use can make the transition into a mainstream use, given a supportive environment.

World Industrial Fabrication



*Advanced economies; Source: GFMS, IMF

With regard to the current pool of novel uses, there are two primary areas of development that are expected to provide the greatest potential for silver demand during the forecast timeframe. Firstly, there are applications that utilize silver's antibacterial properties and, secondly, and most likely the main thrust of future demand, are those technologies that benefit from silver's thermal and electrical conductivity.

On balance, however, the main thrust of growth in industrial applications over the forecast period is likely to emerge from several established uses. Given a longer timeframe however, beyond the scope of this report, the potential exists for the new uses segment to realize a more material level of silver demand.

Economic Indicators

(Period averages)	2005-10	2011-15F
World GDP (%)	3.5	3.1
USD/EUR	1.34	1.29
Oil ($/bbl)	73	109

Source: GFMS, EIA, World Bank

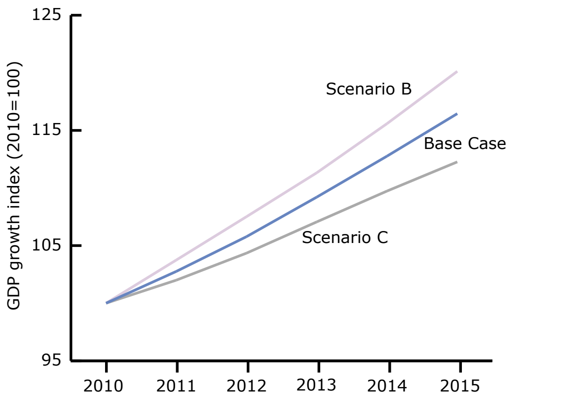
5.2 Economic Forecast

No forecast of silver demand is possible without an evaluation of the macro economic backdrop. Accordingly, this section briefly highlights GFMS' key assumptions concerning variables which have influenced our forecasts such as rates of GDP growth, exchange rates and industrial production.

The global economy shrank in 2009 for the first time in more than half a century, with the drop in industrial production being particularly severe. However, unprecedented government and central bank measures ensured that 2010 saw a marked recovery, which was particularly strong in Asia and more widely in industrial sectors, aided, in no small part, by significant levels of restocking. Under our base case, however, we expect a slowdown in GDP growth and in turn industrial production this year. This will be felt most in developed economies as the effects of fiscal stimulus plans ebb and fiscal austerity measures are introduced in a number of European countries. In addition, a number of emerging markets, including China and India, are experiencing inflationary pressures and as such are taking measures to address this. This leads us to expect slower growth than last year in these countries as well (albeit markedly higher than in the advanced economies).

In 2012 and 2013 we expect a gradual pick up in growth in most economies due to improvements in the underlying world economy. This is the case for Japan and Europe, as growth becomes more self sustaining, and in emerging markets, as they no longer have to take additional measures to quell inflation. In contrast, the United States which is set to have a more stimulating fiscal and monetary backdrop in 2011 and 2012 than its peers, will be forced to take steps to tighten policy thereafter. This will provide strong headwinds against rapid growth and trigger an appreciating US dollar. As a result of these factors we forecast global GDP growth to average 3.3% per annum for the last two years of the forecast. This is higher than in the preceding years but remains constrained by the overhang of high debt levels and elevated unemployment.

Annual World GDP Growth Forecast



Source: GFMS; IMF

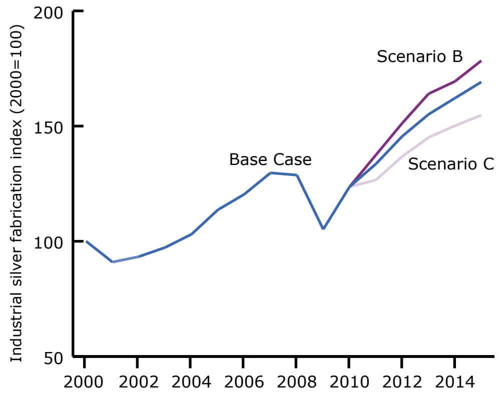
Our most likely alternative outcome (depicted in the charts below as Scenario B) expects stronger growth, particularly in developed economies. Central to this scenario are the policies being followed by the US government and the Federal Reserve. These include a continuation of the current very loose fiscal and monetary policy including the second round of quantitative easing. Such policies are forecast to largely avert a renewed economic slowdown but at the cost of rising inflation, reaching a peak annual average of 8% in 2014 in the US. As a result US and, to a lesser extent, global growth would slow in the final year of the forecast under this high growth outcome. Moreover, the US dollar weakens significantly under this scenario. In many industrializing countries growth is even stronger than under the base case, buoyed by strong export growth to developed markets. However, the growth is somewhat constrained as authorities are forced to take measures to address inflation in already fast growing economies.

Under our more bearish view (labeled Scenario C below), to which we assign a lower but not insignificant probability, we expect the effect of government measures to be negligible on the longer run growth rate as the global economy struggles to escape deflation. Consequently, global GDP growth slows appreciably in 2011 and remains sluggish although improving over much of the rest of the forecast period, particularly in the developed world. The fact that China and India, in particular, are already taking steps to slow their economies means that under this disinflationary view some of these measures could be unwound. As a result, the fall in industrial growth is more muted here than in the United States and Europe.

5.3 Role and Impact of Silver Prices on Industrial demand

As noted elsewhere in this report, industrial silver demand is largely price inelastic in the short term. This characteristic is largely the result of the metal's unique physical properties, which means that substitution may only be feasible in a limited number of areas. Furthermore, the technological change required to enable a shift into or out of silver, when possible, typically takes a fair time. In addition, some companies may have greater exposure to other metals and so might devote research efforts to those metals in a multi-metal bull run. This was witnessed recently when several fabricators focused on minimizing copper use, rather than worry about smaller silver-bearing areas. Another factor that limits price responsiveness is that

Industrial Fabrication - Forecast Scenarios



Source: GFMS; IMF

silver typically represents only a small proportion of costs. This would be most apparent as regards the final consumption item (an air-conditioning unit or a car for instance) but production charges on intermediate semi-manufactured pieces could easily be greater than the value of the contained silver. This stands in sharp contrast to some of gold's industrial elements, with gold potassium cyanide costs for example being over 99% fine metal. The net result of this is that industrial buyers of silver bearing materials will invariably maintain steady orders to meet their internal demands, rather than flex purchases to suit silver's price moves.

A period of high silver prices might, however, induce producers of silver semis to seek ways to trim work-in-progress and thus silver finance costs. This would result in a one-off dip in offtake that would not be apparent from production figures. Despite that, the demand impact of a short to medium term price spike is therefore normally slight but it is important to note that substitution pressures are invariably constant; price differentials mean that researchers will essentially always be seeking avenues to use silver instead of gold or the PGMs and to use base metals to replace silver, the more common route.

So far, we have only considered gross demand but it is also worth considering the *net* figure, fabrication less scrap. Here the price can play a major role as the recovery of silver could be made profitable by a price move above a certain level or uneconomic by a slide below a given point. This would apply to both old scrap (say a discarded photo voltaic cell) or process scrap (a spent silver paste container for example). Of course, legislation might require recovery in many areas but its viability could influence the exactitude of compliance.

5.4 Outlook for "Established" Uses

The forecast for silver industrial demand constructed by GFMS, points to robust growth in the global total through to 2015. As the chart opposite highlights, following the slump in 2009, industrial offtake is expected to achieve a period of uninterrupted growth, under each of GFMS' three forecast scenarios.

Starting with the Base Case (which presents the most likely outcome), industrial demand will realize a series of successive highs, comfortably exceeding 650 Moz by 2015. In fact, industrial offtake is expected to entirely recoup the losses sustained in 2009 as quickly as this year, although the growth rate in 2011 will fall short of the 18% gain recorded in 2010, given that widespread restocking (essentially a one-off event) contributed to that impressive outcome. Further solid gains are predicted for 2012-13, before a modest slowdown emerges in the last two forecast years, although annual average growth is still predicted to then exceed 4%.

GFMS' more optimistic GDP growth outlook (labelled Scenario B in the chart above) contributes to a notably more robust outcome. Although world GDP growth in 2011-12 falls a little short of last year's performance, this still contributes to double-digit percentage gains in global industrial offtake during this period. The slowdown, which subsequently emerges, is partly the result of weaker offtake in India (partially offsetting healthy gains elsewhere), which suffers from the dramatic rise in silver prices.

Finally, GFMS' most subdued economic prediction (depicted as Scenario C above), sees silver industrial demand record only a slight improvement this year, in response to a marked slowdown in world GDP growth. As a result, industrial offtake only posts a record high in 2012. Subsequent years do produce firmer gains, but the market only surpasses 600 Moz in 2015, some two years later compared with the two alternative economic scenarios. The following analysis, highlighting the key end-uses, will concentrate on the response from each segment under Base Case conditions.

As the largest component of silver industrial fabrication demand, **electrical & electronics** will account for a significant share of the increase in overall industrial offtake from 2011 to 2015. The following section will focus on demand excluding photo voltaics, a detailed discussion of which is featured separately below. After a major rebound of more than 20% last year, further increase in electronics & electrical is expected out

Industrial Demand Forecast			© GFMS Limited
	Million Ounces		Avg % Growth
	2011	2015	2011-15
Base Case	526.0	665.9	6.5%
Scenario B	541.4	702.4	7.6%
Scenario C	498.6	609.3	4.6%

Source: GFMS

to 2015. The healthy growth over the forecast will be due to an improvement in world economy, as the recovery of consumer expenditure will lead to higher sales of home appliances and consumer goods such as TV and cell phones. In addition, the robust growth in the automobile industry should also benefit demand for silver contacts. Not only is global auto production forecast to grow on average by nearly 6% between 2011-2015 but, (and arguably at least as important) is the rising number of electronic uses per automobile.

Over the period, we expect western markets to grow at a slower rate, where the focus is more on the replacement of old appliances for new. In contrast, many developing countries will continue to benefit from what is often a rapid urbanization of their population, with the associated rise in infrastructure expenditure and growth in demand for consumer electronics. Looking at the sector on a country-by-country basis, three markets stand out in terms of driving the global electrical & electronics offtake: the United States, Japan and China. The improvement in the United States is mainly because of ongoing strength in the country's automotive and housing sectors, while for Japan strong export of electronics products is the single largest important factor behind the rise. Finally, stable (albeit high) Chinese economic growth and rising disposal incomes will lead to a rapid expansion in domestic consumption, although further onshore relocations (to the mainland) will also contribute to China's robust performance in this sector.

As noted earlier, total industrial fabrication is forecast to rise by 37% from 2010 to 2015 and there are no obvious reasons as to why **brazing alloy and solder** (BA&S) demand should behave differently. It is true that part of the total's growth will stem from the arrival of new end-uses for silver but BA&S' share of industrial demand held steady in the 10 years to 2010 despite the boom in new areas such as photo voltaics.

That record gives us confidence in the ability of BA&S demand to shrug off the ongoing challenges posed by substitution to base metals and the adoption of techniques that use no BA&S. Indeed, fabrication growth of around 37% by 2015 would greatly exceed the forecast rise in global GDP between these dates of 17%, highlighting how BA&S offtake is expected to benefit from such factors as booming sales of cars and air-conditioning units in emerging markets. We would certainly place an emphasis on that, rather than the re-stocking of a denuded supply pipeline as that was very much a 2010-centered phenomenon. Another minor supportive factor is the likely slide in the use of cadmium in BA&S, due to environmental and health issues, with this in effect often replaced by silver.

At a country level, we may see marked dislocations between the fabrication and the consumption of BA&S, either at the OEM or final consumer level; sales of the final products may well surge in the likes of China and India but this could benefit BA&S fabrication in the industrialized world, unless we see further heavy relocation of either this fabrication or OEM manufacture to emerging markets.

The outlook for silver use in **photo voltaic** (PV) applications remains extremely bullish. Outside of Europe, which has accounted for around 70% of total PV installations to-date, the project pipeline remains strong, with notable additions expected in China, India and the United States. Egypt, Morocco and Israel are also expected to increase installations rapidly, albeit on a smaller scale. These, along with a host of other countries, are expected to drive growth over the forecast window, with total silver demand exceeding 100 Moz by 2015, roughly double the level achieved last year. Overall, the annual average rate of forecast growth through to 2015 is expected to approach 20%. While this might compare unfavorably with a rate of 50% per annum over the last five years, the industry is, to some extent, now entering a more mature stage, having emerged from its initial ramp-up phase.

The growth rate for PV production is, however, likely to be volatile. This is partly because of the difficulty in matching supply (of PV cells) to demand (in terms of installations), itself a function of government incentives, which have often "encouraged" high levels of production, sometimes leading to an oversupplied market. The balance of supply and demand can also vary quite rapidly depending on expectations of changes to incentive programs, which can spur a flurry of demand to lock in contracts at what might be perceived at preferential rates.

Overall, there are a number of factors underpinning our bullish forecast for silver demand in the PV sector. The first of these relates to the outlook for fossil fuel prices. The forecast gains for the oil price (within the confines of this report) will help to narrow the gap between the cost of generating traditional and solar power. This will, crucially, help speed the arrival of grid parity, the point at which the cost of generating solar energy will be equal to, or less than, the cost of conventionally generated grid power, by which time government support should, in many cases, no longer be necessary.

Second, the passage of carbon legislation may force conventional power providers to purchase carbon credits, thus leading to an increase in the price of such power and further levelling the playing field for solar. Third, political commitments will also help to drive PV demand. In particular, the European Union is committed, at present, to sourcing 20% of its total energy mix from renewable energy by 2020, compared with a threshold of around 15% last year. China, meanwhile, plans to increase its renewable energy output to meet more than one-third of its total power needs, compared with a threshold of over 25% last year. Finally, underpinning all of these factors is improving economic growth, which will likely sustain several existing government incentive programs, while also encouraging a number of new opportunities.

There are, however, a few setbacks which may curb the level of offtake over the forecast period. The greatest threat comes from the potential for government incentive programs, most likely Feed-in-Tariffs (FiT) to be withdrawn. In fact, these fears have already been realized in a number of key PV markets. Retroactive cuts to promised financial support (Spain), increased tax on solar energy production (the Czech Republic), earlier-than-planned cuts to incentive programs (Germany) and stalling activity elsewhere (including France and Italy), have affected investor confidence in the future of the industry.

Developments in other renewable energy sources (currently dominated by hydropower and wind energy) may also mitigate solar's gains somewhat. It is also worth noting that solar power represents a tiny proportion of total renewable energy, which itself represents around one-fifth of total energy consumption.

Further downside risk to silver demand comes from the fact that manufacturers will seek to thrift or substitute precious metal content as much as possible, in order to reduce costs. Moreover, the share of thin film technology could exceed 20% by 2015. Nonetheless, thick film technology is likely to remain the clear market leader over the forecast period.

In conclusion, growth in this sector will remain heavily contingent on the sustainability of FiT programs and the health of the global economy. Despite some recent setbacks to FiTs, the long-term political will behind solar appears overall to be positive, as does consumer enthusiasm for green energy. In addition, delivery infrastructure for solar is also likely to improve further. As a result, the PV industry is expected to emerge as an ever-more significant end-user of silver over the next five years.

Established industrial offtake's **other applications** are notably diverse, ranging from decorative plating to silver rods for the nuclear industry. As a result, forecasting typical growth is a hard task. Nonetheless, some themes do emerge. Firstly, many of the sectors are mature, such as the silvering of mirrors, or traditional niches, such as end-use in musical instruments. It is highly likely therefore that their demand growth will be modest but should be largely resistant to substitution as silver would have already been removed if possible. In a similar vein is the use of silver in gold jewelry alloys but this could show more overt growth to 2015 as gold prices are likely to have fallen notably by then.

A second characteristic is that several applications are government controlled, such as the nuclear industry, or form part of large scale infrastructure projects. This means their offtake could be quite divorced from the business cycle, should prove fairly independent of price changes and be relatively resistant to substitution.

Of course, the boundary between what is established and what is novel is a grey area and in some instances we have classified existing niche areas, such as specialized uses in the medical industry, as 'established' but then treat them more as 'novel' when new applications within these broad categories become widely adopted and no longer involve just a few thousand ounces of silver. For the above three reasons, it is probable that growth in this 'other industrial' area in total will lag the electronics and BA&S sectors.

5.5 Novel and New Industrial Uses of Silver

This section addresses a wide range of 'new' industrial applications of silver. This term may appear misleading as many of these products have been technically viable for some years, often capitalizing on silver's well established properties, particularly so its antibacterial and conductive qualities. However, this is one of the challenges that lies ahead for many of these uses; converting a proven technical proficiency into a long-term commercial success.

As the following analysis shows, several applications have or are on the verge of achieving this mantle, but this does not always translate into consuming a substantial volume of silver. In other words, silver offtake per unit of demand for a new use may remain a niche application, in the context of the silver market. This conclusion is implicit from the statistical series constructed by GFMS. Bringing together our estimates for 2010, suggests that the combined total of the 11 uses outlined below amounted to less than 13 Moz, although, by 2015, this could exceed 40 Moz.

Solid State Lighting

Solid-state lighting (SSL) uses semiconductors to produce light with either light emitting diodes (LED) or organic light emitting diodes (OLED), rather than the more traditional electrical filaments, plasma or gas. While there are subtle differences between the two, essentially they both produce electroluminescent light when a current is passed through electrodes. These electrodes can be made of silver.

SSLs could be used in backlighting and signage, although the technology is not yet capable of lighting high performance items, such as televisions. That said, SSLs are already used in traffic lights and in some car headlamps. At present, non-silver alternatives often encounter difficulties with dimming and uneven lighting; printed silver has been shown to perform far more effectively in these circumstances. In addition, silver's efficiency in this application means that the footprint of printed silver can be kept to a minimum, further aiding performance.

While the silver loading of each lighting element is currently small, there is nonetheless considerable potential for growth in this area as demand for SSL increases. As well as the above mentioned advantages, SSL offers high illumination, using considerably less energy than is consumed by incandescent or fluorescent bulbs. In addition, energy efficiency

Nanosilver: An Introduction

Nanotechnology is widely recognized as an emerging field, which in recent years has prompted growing interest from both industry and policy makers.

Nanomaterials have in fact been in use for several decades, but it is only quite recently that nanosilver has found increasing use in a wide range of market sectors, from medical devices to textiles. Although there are different types and in fact names for nanosilver, the underlying material remains the same - extremely small particles of silver. The key distinction between 'nano' and 'conventional' silver is particle size; nanosilver refers to silver particles that range from approximately 1-100 nanometers in any dimension. Their small size, combined with their relatively large surface area to volume ratio, means that their efficacy is achieved at lower concentrations than conventional silver.

Examples of silver products and applications using nanosilver include silver algicides, silver impregnated water filters, pigments, photographics, wound treatment, conductive/antistatic composites, and catalysts. Newer products include nanosilver in textiles, coatings, plastics and medical articles and devices. With regard to regulatory controls, nanosilver currently falls under the remit of the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) in the United States, and is also under evaluation by the US Environmental Protection Agency (EPA). In the EU, there is the potential to monitor its use through REACH.

The potential success of nanosilver is therefore largely contingent on regulatory approval being granted, in various jurisdictions. Should this materialize, the use of nanosilver is likely to expand, notably in health-related and electrical applications. The latter is arguably of particular interest, given that prevailing high silver prices have encouraged efforts in this sector to substitute the white metal with less expensive alternatives. Attempts to do so have often proved unsuccessful, given silver's technical advantages over many competing materials, but the prospect of using nanosilver in this area may offer manufacturers the ability to reduce costs, while still utilizing silver specialized properties.

legislation has led to incandescent light bulbs being banned in a number of countries, such as Brazil and Argentina; in Europe, scheduled phase-outs began last year; and the United States plans to ban their use between 2012 and 2014. Although fluorescent lighting may initially fill the void, the use of mercury in fluorescents and the (arguably) poor light quality they provide, suggest they may only offer a short to medium term solution. The success of this technology could be greatly accelerated depending on the extent to which governments introduce regulation on incandescent lighting.

Furthermore, recent research suggests that cost-effective, high quality, low energy lighting may actually increase demand. SSL is less expensive (owing to its greater energy efficiency), which may encourage consumers to increase energy consumption by making more areas brighter, rather than simply maintaining lighting at current levels. Better technology, therefore, could simply generate greater demand. Although this might negate the intended effect of reducing energy use, this bodes well for silver offtake in this segment.

However, the current barriers to widespread adoption of SSLs are cost and some lingering performance issues. If both of these can be resolved, it would undoubtedly enhance silver demand (albeit from a currently small base, believed to be less than 1 Moz per year). Over the next five years, SSL is expected to expand its market share from less than 10% of the total lighting market to close to 30%. Should silver emerge as the electrode material of choice, therefore, annual demand could exceed 5 Moz by 2015.

Radio Frequency Identification

Radio Frequency Identification (RFID) tags make use of printed silver ink, made from silver nitrate. RFID tags can be used to track inventories and provide an alternative to bar codes, compared to which they can store considerably more data. In essence, their role is to transmit data stored on the tag (usually in a chip) to a reader, via an antenna. Silver can be used in the antenna and to form a bond between the chip and the tag itself. Nanosilver inks have already achieved some commercial use, which consume far less silver compared with conventional inks.

There are two main types of RFID tags, both of which use silver: passive and active. Passive tags do not have their own power source, and can only transmit information once they draw power from the reader, which achieves this by sending electromagnetic waves to induce a current in the tag's antenna. Active tags contain their own power source, and can therefore transmit information to the reader autonomously. These are typically reserved for high value goods, owing to their higher cost and performance capability.

Although the use of RFID tags is forecast to show tremendous growth, the prospects for silver are not necessarily as correspondingly strong. Not only is the actual amount of silver used per tag small in absolute terms (typically less than 10mg per tag and in nanosilver inks 10kg of silver can suffice for one billion tags). At present, the use of silver-bearing tags appears to have gained little ground. This is due to silver's relatively high cost, which has led to both thrifting and substitution, with non-silver printed inks, such as copper, aluminum and graphene taking market share. The uptake of silver-bearing tags may, therefore, be limited to high value, low volume items.

In 2010, global demand was estimated at around 1-2 Moz. However, given that the use of RFID technology is still in its relative infancy, silver should benefit from the sector's anticipated growth over the next five years, even allowing for the constraints outlined above. By 2015, therefore, total offtake has the potential to at least double, albeit from a modest base.

Supercapacitors

Supercapacitors offer a potential growth area for silver, where printed silver can be used as an electrode. A supercapacitor is similar in function to a battery, in that it stores and releases energy. Unlike a battery, however, it can be charged and discharged almost indefinitely, with (almost) no loss of performance. In addition, a supercapacitor can recoup and release power far more quickly compared with conventional batteries. Energy can be captured from a variety of sources, including a braking vehicle, wind power, the national grid or from solar energy.

This power can then be applied in a myriad of ways, including: a source of back-up, should there be grid disturbances or outages; in regenerative systems, such as in hybrid buses, where energy from braking can be stored and then released as the bus accelerates; and in smaller applications such as power tools and torches, which require only small bursts of energy, and benefit from rapid re-charging.

Overall, this technology is likely to achieve commercial success, although the trend towards miniaturization and the use of nanosilver is likely to limit the absolute volume of silver demand. In addition, less expensive alternatives are also likely to develop. Given that this represents a new form of technology that is likely to use, at best, modest volumes of silver, we do not anticipate that more than 1 Moz of silver will be consumed by 2015.

Water Purification

There are several ways in which silver can be used for purifying water. The most widely used applications make use of silver's bactericidal properties, in forms including silver-impregnated ceramic filters, silver deposited on activated carbon, silver nitrate, silver chloride or in tetrasilver tetroxide. Silver is also used as a catalyst for the production of hydrogen peroxide, which is in turn used in water disinfection. It can be used in building water supply systems, pools, spas or personal water purification devices.

In water supply systems, it can destroy bacterial growth in pipes, connections and tanks; in pools and spas, silver ion filtration canisters treat all components; and in personal purification devices, it prevents bacterial and fungal growth that would otherwise block the active charcoal filter. At present, silver-based water treatments are used more widely in Europe than in the United States.

There does not seem to be undue concern regarding the safety of using silver in water purification devices. The World Health Organization (WHO) states that a lifetime intake of approximately 10g of silver can be considered to be the 'no observed adverse effect level' (NOAEL). The maximum contaminant level of silver in drinking water ranges from 0.05mg/L to 0.10mg/L, of which only a small percentage is absorbed. According to the WHO, levels of up to 0.10mg/L would give a total dose over seventy years of 5g of silver ingestion (half the NOAEL level).

Given the scope for water consumption to rise in response to global economic growth, therefore, there is considerable scope for silver use to rise in this application. That said, this is unlikely to reach significant volumes over the forecast period in comparison to established industrial silver users. Indeed, at present, global silver demand in water purification applications is estimated to be roughly no more than 2 Moz per year. Furthermore, silver tends to be used in personal water purification devices, rather than large scale municipal devices, which commonly depend on some form of chlorine (or chlorine compounds) for disinfection. Looking ahead, however, there is considerable growth potential, and offtake in 2015 may reach 2-4 Moz.

Medical Uses

Silver is often used in wound treatments, dressings, powders and creams, which make use of its anti-microbial action against yeasts, moulds and bacteria. It is used in a variety of forms, including silver sulfadiazine, silver chloride, silver sulfate and nanocrystalline silver. With regard to wound dressings, studies have shown that dressings containing silver increase the comfort level for burns patients by minimizing adhesion between the wound and dressing, thereby reducing pain when changing dressings. Furthermore, the frequency of changing dressings might also be reduced, owing to the antimicrobial activity of the silver. Clinical evidence also supports the efficacy of silver as an antiseptic (which can take many forms, including gels, sprays and powders) for infected wounds.

Silver can also be used in catheters, which are made with a silver-based anti-microbial coating, as well as for other medical implantation devices such as prosthetic heart valves and vascular grafts. In urinary catheters, research has shown that the use of silver alloys reduce the incidence of urinary tract infection (UTI) by as much as threefold compared to non-silver bearing types. Despite the initial higher cost of the silver-bearing products, therefore, the longer-term benefits of reduced spending on aftercare may justify the economic cost of using these materials.

With regard to silver demand, current offtake is estimated to be slight. To give an indication of the quantities involved, the silver content in bandages is typically measured in mg/100cm^2, and in creams in terms of milligrams(μg)/cm^2 per application (one of the world's leading bandage manufacturers consumes only around 7,000 ounces of silver per year). Total silver demand in all medical applications, therefore, is estimated to have reached less than 0.5 Moz last year. This is, however, likely to grow strongly over the forecast, and although total volumes are unlikely to have a significant impact on the silver market, silver use in medical applications may grow strongly over the next five years to approach some 3 Moz by 2015.

Food Packaging

Some food packaging uses silver for its hygiene benefits, which is often applied as a coating or embedded in a polymer. Cooking utensils, kitchen detergent and refrigerators also make use of silver's antibacterial properties, also mostly in nano form.

As is the case with nanosilver in general, one issue is the current lack of clarity regarding their use, which opes the prospect for regulations to be applied retrospectively. Although the EU Food Packaging Regulation covers all materials that come into contact with food or drink, nanosilver has not yet undergone new safety assessments. This is because nanosilver has not been deemed an 'existing' product, as 'ordinary' silver has already been addressed. Similarly, the United States has not classified nanosilver as an 'existing' chemical. In addition, in the United States food packaging containing nanosilver falls under the remit of both the Environmental Protection Agency (EPA) and the FDA (Food and Drug Administration Agency), with the former regulating the pesticidal aspect and the latter the container itself. Notwithstanding these concerns, the food hygiene sector is unlikely to become a major silver consumer. It is modest in terms of absolute use; last year we estimated consumption at comfortably less than 1 Moz. Nonetheless, it has the potential to at least double over the forecast period, exceeding 1 Moz by 2015.

Hygiene

Nanosilver is also commercially available in a number of other applications. These include fridges that have been coated with nanosilver to create an anti-bacterial and anti-fungal environment. In addition, washing machines have been engineered to release silver ions through electrolysis, which also works to combat bacteria and fungi. These allow for lower temperature washes with less detergent, enabling consumers to save on energy and water consumption. One such widely available model contains 10g of silver, which is designed to last at least 10 years. This is said to typically release 0.05mg/L per wash, which equates to 2.75 mg of silver ions. Half to a third of these ions are imparted onto the washed items, while the remainder is flushed into the sewage system.

Textiles, including socks, sportswear and bedding have also been produced using nanosilver, for antibacterial protection and odor control. Silver has also been included in products such as air purifying sprays, hair dryers, toothpaste and soaps to name but a few.

Silver is also used for hygienic purposes in other ways, in products such as hospital gowns, bedding, door handles, counter tops, bed rails and paint. Silver use in paints and lacquers is relatively small, and is likely to remain a marginal end-user of silver; a commercially lacquer contains silver particles at a concentration of 100-300ppm silver/kg lacquer. Antimicrobial paint containing nanosilver is also available, although this is expected to be restricted to specialist (and therefore niche) applications. The silver content is higher here, estimated at around 0.4g contained in 1kg of paint.

Finally, cleaning agents containing silver, used in both the domestic and pharmaceutical industries, have also been developed. In totality, however, the use of silver in hygiene products is unlikely to emerge as a major end-user of silver, due to the relatively small amounts of silver required. Over the next five years, total offtake in this diverse range of uses is not expected to reach significantly higher than 3 Moz.

Wood Preservatives

Silver use in wood preservative can take a number of forms including: silver oxide, nitrate, chloride, bromide, iodide and thiosulfate. One argument behind the optimism in terms of silver's potential role in this area followed the voluntary withdrawal of Chromated Copper Arsenate (CCA) in the United States in 2003, which had been the dominant material in the wood preservative industry. As a result, CCA is no longer available for use in most residential applications, owing to toxicity concerns in arsenic and chromium (VI), its two main components.

Silver has displayed a number of characteristics that indicate that it may be a realistic substitute for CCA. It has proven effective in performing the main functions of wood preservation, namely protection against wood decay fungi, efficacy against termite damage, mould inhibition and insolubility in water.

However, it does offer one main drawback, which may well prevent it from becoming a mainstream ingredient in wood preservation. The first of these is its relatively high cost, a major issue for an industry that is characterized by low-margin products. In general, the minimum cost for a silver solution with anti-fungal qualities is around \$0.29/litre, compared to around \$0.11/litre for non-silver, non-arsenate preservatives. Therefore, in order for silver-based treatments to be cost-effective smaller quantities of silver will need to be utilized. With this in mind, we would suggest that further research is necessary to achieve the required balance between performance and cost. The main copper-based alternatives include alkaline copper quat (ACQ) and copper azole (CA).

In addition, silver-based biocides have shown lower leaching rates than some copper-based alternatives, which require more "fasteners" and are therefore more expensive than CCA. Nonetheless, the extent to which silver may come to be used as a significant ingredient in wood preservatives is still heavily dependent on results of further research, which will need to address both cost and environmental concerns.

As a result, we currently believe that these issues are likely to limit the potential take-up of silver-based preservatives. Over the next five years, therefore, global growth is forecast to rise from less than 0.2 Moz in 2010 to just over 3 Moz in 2015.

Batteries

Batteries (predominantly button types) already constitute an established end-user of silver, but have been included in this section as they are an area which, although relatively small now, offers the prospect of far higher demand over the forecast horizon; current annual demand is estimated at around 5.0 Moz of silver.

There are two main kinds of silver-bearing batteries: silver oxide batteries, which generally have a low power capacity, and silver zinc batteries, which boast higher capacity. The characteristics of both include long operating and shelf life, as well as a high performance to weight ratio.

Silver zinc batteries offer the strongest scope for growth over the forecast period, although the silver oxide sector is also likely to show gains. This is due to robust growth expectations in a number of end products, including: smart phones, laptops, and tablets. Performance is the primary consideration here (silver zinc batteries currently offer energy density that is some 40% higher than lithium-ion batteries, a differential which is expected to grow wider), and this is likely to outweigh silver zinc's higher cost.

Another use for silver zinc batteries may be the auto industry, specifically in electric cars. Although research and development is currently focused on lithium-ion batteries, silver zinc batteries may prove to be a safer choice, given concerns regarding the latter's propensity to overheat. Silver zinc has also been billed as a 'clean' technology, due to the fact that both the silver and zinc can be recycled once the battery life has ended.

Silver oxide is also utilized in a diverse range of batteries. At one end of the scale, it is extensively used in button types, that on average each consume one gram of silver, which are found primarily in wrist watches, as well as other small devices, including: hearing aids, cameras and pagers. The oxide also finds favor in large-scale applications, such as missiles, submarines, underwater and aerospace applications, where cost considerations are far outweighed by performance issues. (As an aside, silver-chloride batteries have also been used in these larger applications.) Silver oxide batteries have also found a role in aerospace and military applications, due to their high performance and ability to tolerate high current loads.

Looking ahead, the prospects for battery-related demand are extremely bright. Indeed, by the end of the forecast, silver demand in such applications has the potential to soar to a range of 10 to 15 Moz per annum.

Autocatalysts

The potential to use silver as an autocatalyst first made the headlines three years ago, when Mitsui Kinzoku announced the development of a silver-based technology, which could be used to replace platinum in a diesel particulate filter (DPF). This was initially discussed in the context of off-road applications (such as agricultural vehicles and construction equipment), where emissions legislation was soon to be introduced.

Three years on, and emissions requirements for off-road vehicles have become a reality. In the United States and the European Union (EU), Tier 4 emission standards (and their EU equivalent) will be phased in from the beginning of 2011 and will be fully effective by 2014. In addition to the technology developed by Mitsui, Tenneco (a manufacturer of emission control systems) has recently announced the introduction of another technology which negates the need for PGM loaded diesel oxidation catalysts, which instead are substituted with a silver-based Hydrocarbon Lean NOx Catalyst (HC-LNC).

At present, the exact level of silver consumed per catalyst is unknown. We believe, however, that it is likely to be significantly higher than that required by platinum, although it would of course be considerably less expensive. However, while this may have a bearing (albeit modest) on the platinum market, as a proportion of absolute silver demand, its impact will remain extremely limited, at least in the context of this report's timeframe. That said, the off-road sector does feature a diverse range of applications, although it is too early to say what share of the market this technology might serve, or indeed, whether this silver-bearing catalyst might in fact migrate into the far larger on-road diesel market. Over this forecast, therefore, this technology is unlikely to emerge as a meaningful end-user of silver. We are of the opinion that this is likely to remain a niche product and do not expect annual demand to significantly exceed 100,000 ounces by 2015.

Superconductors

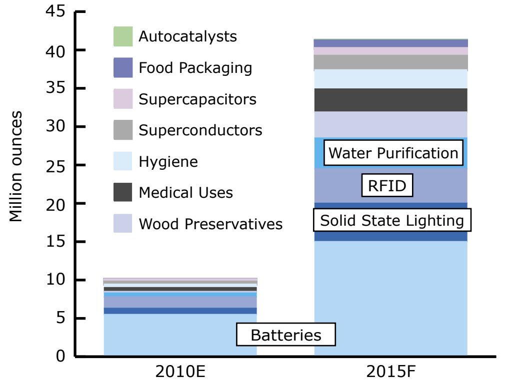
Silver can also be used in superconductors (SC), which conduct electricity far more efficiently compared with conventional cables. In terms of the latter, not only does the age profile of the installed infrastructure increasingly call for renewal investment (conventional cables typically have a life span of around thirty years), but the tunnels that house the cables are becoming increasingly short of space, as a growing number of cables have, over time, been added in order to cater for increased demand for power.

SC cables offer a viable solution to this problem as they occupy around one-sixth of the space required by one conventional cable. Moreover, because of the far greater capacity which characterizes SC, once in place, their transmission power can be increased (up to a far higher level than conventional cables), without having to disturb tunnels in order to lay additional cables. The technology can also be used in a number of other applications, which use the electrical energy passed through the wire to create a powerful magnet, which can, for example, turn a motor. This therefore offers the potential to use SC in applications ranging from hard disks to cargo and passenger vessels, as well as magnetic levitation trains and medical equipment. Although silver is renowned for its conductive qualities, it is not for this reason that it is used in SCs. Rather, its main role is to act as a carrier material, in which a bismuth-based conducting object is embedded. Silver is used because it is a noble metal and so will not react with the conducting material. It also offers fast heat diffusion, which further enhances its efficiency.

There are several types of SCs under development, and although some variants do not use silver, prevailing research indicates that a silver-bearing variant is close to commercial use. At this early stage it is hardly surprising that silver demand remains modest; current production of the wire has only reached around 500km, which equates to less than 100,000 ounces of silver. In Japan, the country's first power grid using SC cables is slated for testing in Yokohama this year, with tests also ongoing in the United States.

With regard to the outlook for silver consumption, this depends greatly on securing contracts with regional or national power grids, which in turn partly depends on the prospects for economic growth, as this will impact a government's ability to support the required capital expenditure. Furthermore, the technology is still in its relatively infancy, with commercial operations in Japan only expected to start in 2015. Its long-term future, therefore, remains somewhat uncertain, as not only is its success highly contingent on large scale government support, but its viability also depends on the absence of alternative, non-silver bearing technologies. As a result, we estimate that demand may still fall short of 2 Moz in the final forecast year, bearing in mind that any large-scale acceptance is likely to only emerge beyond the scope of this report.

Silver Demand for New Industrial Uses



Source: GFMS

About GFMS

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