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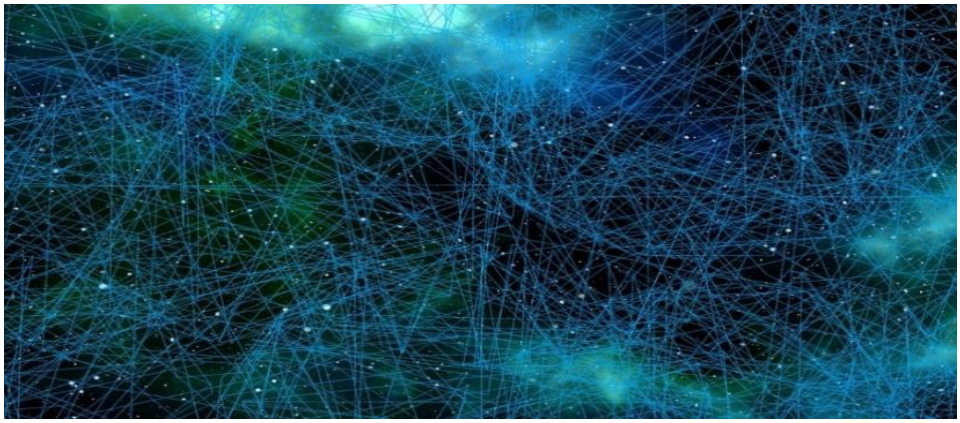
Market Trend Report

Silver and Global Connectivity



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Today, silver is found in nearly all electronic devices. With the greatest electrical conductivity of all metals, silver is playing a critical role in the latest technological advancements. Silver's inherent conductivity is an important asset in the miniaturization of electronics; allowing electrical currents to flow in even the smallest semiconductors and computer chips.

This report examines silver's role in applications related to the new globally connected world. As connectivity becomes the defining feature of the modern economy, resources must be gathered to invest in a better informed and connected global economy. This report will look at the potential demand for silver as a result of increased global connectivity and connecting once 'unintelligent' goods to a greater ecosystem through the 'Internet of Things.'

CRU estimates that silver consumption in electronics and electrical applications, excluding solar PV cells, was 224 Moz in 2020, and forecasts a 10% increase in demand to reach 246 Moz in 2025. A significant portion of this increase will come from a variety of different connectivity-related applications, where CRU anticipates more dramatic growth rates. As an example that is illustrative of this wider trend, CRU expects silver demand in radio-frequency identification (RFID) tags, used to wirelessly connect objects for tracking, monitoring and numerous other purposes, to increase by as much as 400% over the next decade.

1. Global connectivity

Connectivity is a leading driver of the modern economy and is arguably the defining feature of the 21st century. The world is becoming more connected through the billions of physical devices that connect to the internet, providing increased access to information, global markets and communication, and as a result boosting productivity, and strengthening supply chains. Connectivity has become even more important due to the impact of the Covid-19 pandemic, which has caused a dramatic uptick in the number of employees working and students learning remotely. Silver is a critical part of numerous connectivity-related applications, and as these end uses grow and others are developed, silver use will increase.

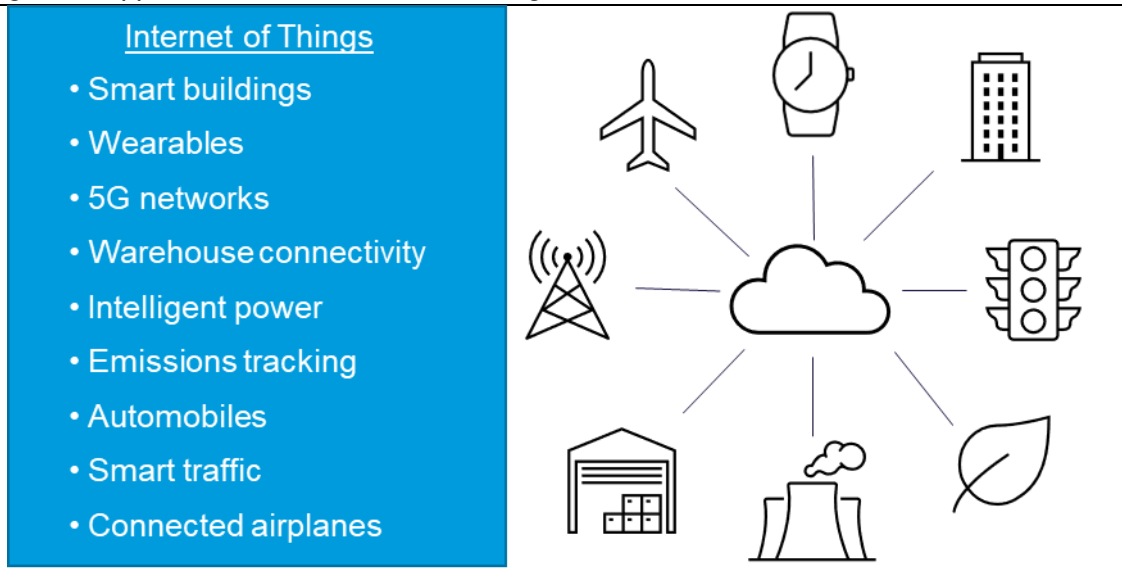
Nearly every nation is investing in the infrastructure needed to increase productivity, spur economic recovery and develop future competitiveness through global connectivity. However, the digital economy transformation is taking place at differing speeds across regions, depending greatly on the overall economic health of the region. For example, the Asian Development Bank estimates that the Asia-Pacific region will need to invest $26 trillion by 2030 on physical communications infrastructure such as 5G networks. These investments are top priority for many countries and encounter little public pushback because most agree that improving connectivity is a desirable public good. The Global Connectivity Index measures a country's investment, information and communications technology maturity and digital economic performance. The USA leads this index, with Singapore and Switzerland taking up the number two and three spots respectively. China, the world's second largest economy, makes this list at 22nd, a significant improvement from 34th position which they held as recently as 2015.

The following sections discuss key areas where connectivity applications are growing in importance, and where silver is used within those sectors.

1.1. The Internet of Things

The trend towards global connectivity has led to the emergence of the 'Internet of Things' (IoT), which describes the network of historically non-communicative physical objects that are now able to relay information through the internet. Today, there are billions of devices connected to the internet including smartphones, exercise equipment, white goods, and automobiles. Cisco Systems, a major technology company with a focus on networking and communication products, predicts that by 2030 there will be a half a trillion devices connected to the internet. In 2010 a symbolic milestone was reached, as the number of things connected to the internet exceeded the number of internet-connected people for the first time. Silver is used in the circuit boards that make many of these devices connected and "smart."

Figure 1: Applications of the Internet of Things



Source: CRU

As 5G communication networks[1] roll out, the network will offer more speed for the many devices consumers will use daily, and will also enable a variety of new devices and applications to be developed. 5G networks are the next major evolution of mobile communication technology; it is not simply an incremental improvement over 4G but a leapfrog step in technology. This may stimulate the miniaturization of devices, resulting in the need to engineer technology into smaller spaces, which in many cases will rely on the conductive properties of silver. As well as enabling wider use of silver-containing electronic devices, some of the main components required for a 5G network will themselves increase the demand for electrical materials that may contain silver. For example, a network carrier, such as AT&T, Telefónica or Vodafone, will reportedly need at least 400 more transmitters in an area compared to current 4G towers.

In industry, smart factories are equipped with advanced sensors that work with software and robotics to create high value data. The goal of these digital technologies is to increase automation in all aspects. The smart factory predicts when machinery will need servicing. The machines learn how they can improve their performance through self-optimization algorithms. This leads to higher productivity and improved quality of product, reducing manufacturing errors and helping cut costs.

[1] 5G refers to the fifth generation of mobile communication, a major evolution over the fourth generation brought about through several key technologies, offering ubiquitous resilient high-speed and high-volume connectivity. Refer to the Silver Institute's 2017 report "Silver's Role in a Future 5G Connected World" for more information.

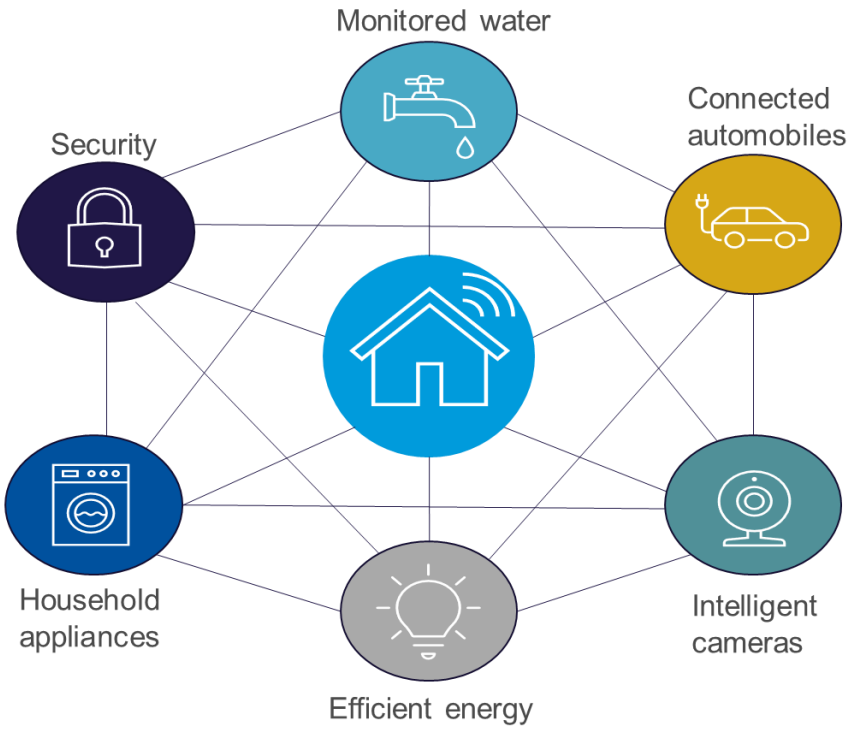
Workplaces are also benefiting from the IoT. The Covid-19 pandemic has accelerated the hybrid workplace where organizations are facing challenges in how to collaborate without relying on face-to-face meetings, in-office file servers, and various other conveniences that have been taken for granted as part of the physical workplace.

A related technology under development is augmented reality, in which hardware such as smartglasses, handheld devices or heads-up displays seamlessly enhances real-world objects by providing computer-generated perceptual information in real-time. Silver nanoparticles could be key in manufacturing a transparent screen for augmented reality displays.

1.2. Connectivity and the consumer

Consumers interact with home automation, wearables, white goods, and healthcare; a homeowner's smartwatch can share information with home lighting to turn on the lights as the homeowner walks in the door. Automated HVAC allows for systems to adjust temperature automatically based on occupancy, time, and distance away from a sensor. Not only does this improve the lives of those occupying a residence, this creates a more eco-friendly world, since heating or cooling need only be applied when necessary. In addition, occupancy sensors can reduce lighting needs by not only turning off the light when an occupant leaves the room but adjusting the amount of light needed based on the time of day and incoming light from any windows. Many of these devices will have silver in their circuit boards or electrical contacts.

Figure 2: The connected home



Source: CRU

1.3. The automotive industry

According to a 2019 study "Semiconductors – the Next Wave," by Deloitte, the major professional services company, 40% of a vehicle's cost is accounted for by electronics, a substantial increase from historical levels: in 1990 this number was just 15%. Silver is used

extensively in electrical contacts throughout vehicles' electronic systems in switches, relays, connectors, breakers and fuses. Silver is used in automotive glass to defog and defrost the windows, which is understood to currently be the largest single application of silver in the automotive space. Future vehicle developments, particularly the electrification of the fleet and the increasing introduction of automated driving and autonomous vehicles, are likely to substantially increase this proportion.

Electronic control units (ECU) were once used only to control the engine and transmission of the car, but they are now increasing in line count, complexity and sophistication. Some modern vehicles today have up to 150 ECUs onboard. Autonomous vehicles' use of LIDAR[2] and other sensing technology, as well as on-board GPS and other connectivity requirements, could be particularly important for silver usage. Silver will also play a role in the associated infrastructure needed for electric vehicles. Silver is used in the electrical cables and contacts needed in the charging infrastructure. Vehicle connectivity with on-board GPS, the internet, and passengers' phones is already relatively common in newer vehicles and will become even more so in the future.

Connected cars can potentially deliver a safer and more convenient ride for passengers. ABI Research, a global tech market advisory firm, reports that around 30 million connected cars were sold globally in 2020 and expects this to increase to 115 million by 2025. As on-board software becomes more important to vehicle operation, particularly for battery electric vehicles, the ability to update software over-the-air becomes increasingly useful. The connected car becomes more powerful and safer as it perceives and reacts to its surroundings through assorted sensors and feedback mechanisms. The dissemination of this location and other data to a centralized source could help solve traffic congestion problems, reducing pollution and speeding up journeys.

Another major opportunity for connectivity to be used more widely, thereby driving silver demand, is within the logistical backbone of many countries' economies: over the road trucking. Connecting trucks and their cargo to the internet or some other connected tracking devices helps logistics keep track of the millions of tractor trailers on the road. Sensors on cargo can track sensitive merchandise, whether this is temperature sensitive produce or high-value jewelry.

1.4. The aviation industry

Silver is a critical component of the electrical structure of airplanes. The greater volume of electrical circuitry and contacts in modern airplanes – for ever more complex and widely deployed entertainment systems, communication devices, cameras, sensors, etc. – is also increasing the silver used in each newly constructed or refurbished plane.

A rapidly growing subsector of the aviation industry for silver demand growth is unmanned aircraft systems (UAS), commonly referred to as drones. Almost 900,000 recreational and commercial UAS (weighing more than 0.55lbs or 250 grams) are registered with the USA's Federal Aviation Authority FAA as of September 2021. These are finding applications within a wide range of industries including construction, fire monitoring, insurance, utility, and law enforcement. For example, telecoms and aviation industries use drones for beyond-visual-line-of-sight capabilities. Drones mapping and surveying, and aiding in visual inspections, currently account for the majority of commercial drone applications. Future possibilities include increasing use in home and business deliveries as payload capabilities increase, and

[2] LIDAR stands for "light detection and ranging" or "laser imaging, detection, and ranging". An emitter determines distances between objects using laser scanning, creating 3D representations of the environment. These can be used by autonomous vehicles for obstacle detection and avoidance.

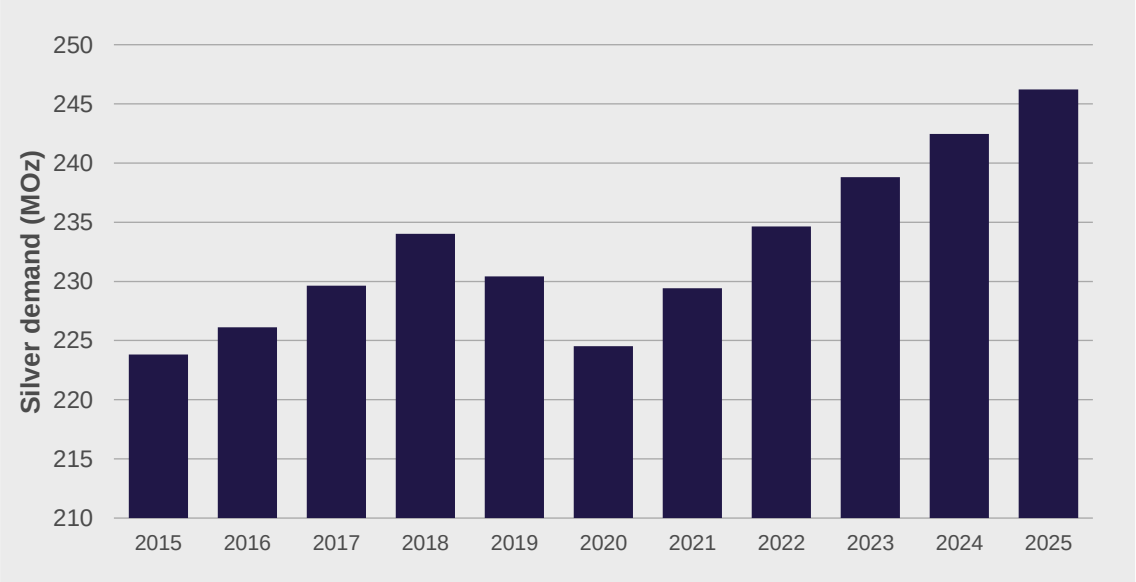
drones develop full airspace awareness, reaching full autonomy. Drone use is expected to continue its rapidly accelerating growth, but regulators will need to create an open and trusted environment to keep pace with the rapid technological developments. Connectivity is critical to the successful deployment of drones in all of these commercial activities for the direct control of the drone itself, for the feedback from the drone of any collected data, and for the monitoring of its payload. The miniaturization of drones requires smaller and more flexible electronics, increasing the application of silver within this sector.

2. Demand for silver in electronics and electrical applications

More than one-third of total silver industrial fabrication demand[3] comes from electronic and electrical applications. Silver's use in electronics is primarily the result of its exceptional conductivity – it is the most conductive metal. In many applications this conductivity allows for miniaturization, improved performance, and other benefits that can outweigh the higher unit price of silver compared to copper and other conducting metals.

Silver is used in the wires and contacts for high voltage electrical applications in power distribution, including in transmission substations, switchgears, and elsewhere. As described above, it is also used in consumer electronics such as cellphones, laptops, tablets and other portable electronic devices; in addition to electronics for automotive, aviation, general industry and home applications. The use of silver in electrical applications will benefit from the green revolution's need for additional power distribution to connect renewable power, off-grid energy storage, and electric vehicle charging stations. According to the IEA's Sustainable Development Scenario the proportion of electricity generated globally from renewables will increase from 29% in 2020 to 49% by 2030. Meanwhile, the global trends in connectivity described in this report will be the key driver of demand for silver in electronics.

Figure 3 CRU forecast for silver demand in electrical and electronics applications (Moz)



Source: CRU

[3] Note: industrial demand excludes silver used in the fabrication of coins, medals, jewelry & silverware

CRU estimates that silver consumption in electronics and electrical applications, excluding solar PV cells, was 224 Moz in 2020, and forecasts a 10% increase in demand over the next 5 years to reach 246 Moz. A significant portion of this increase will come from a variety of different connectivity-related applications, where CRU anticipates more dramatic growth rates. The following sections provide more detail on some of those applications.

2.1. Silver in printed electronics

The inks used in the production of printed semiconductors often contain silver. The use of printed circuit boards is plentiful in a wide variety of electronic equipment; printed and flexible electronics currently account for approximately 8% of global industrial silver fabrication demand. A key driver of circuit board production will be innovation that leads to emerging market opportunities in cloud computing, AI, automation, 5G and, of course, the IoT.

- Silver is used in electronics in key segments that include consumer electronics, automotive, semiconductors, power distribution, LED lighting, and micro-electromechanical systems (MEMS).
- Consumer electronics is the largest segment in dollar value but growth in this industry will be modest. Each consumer electronic with an on/off switch is likely to contain silver.
- Automotive silver demand is slated to grow with an accelerating BEV adoption and the infrastructure that goes with it.

The semiconductor market, including integrated circuits and on-chip memory devices, grew by 6.5% in 2020, according to The Silver Institute's 2021 report "Silver in Printed and Flexible Electronics."

Printed electronics is an all-encompassing term used to describe manufacturing electronic devices by printing on a variety of different substrates. Inkjet printers are capable of printing electrical circuits that are inexpensive and quickly produced. The tolerances required for functional devices are very tight, particularly for smaller devices and those with greater functionality. Printing electronic devices also increases their physical flexibility.

As global connectivity grows, printed electronics have a potentially important application in sensors that are widely used in the medical, aerospace, automotive and packaging industries. Relatively few printed sensor products have reached commercialization so far, but those that have, are proving hugely important. For example, printed glucose sensors using silver are critical to the medical diagnostics industry; simplifying testing to the benefit of many millions of people.

As technology advances, the printing industry has significant upside risks during this period of rapid development. For example, some materials have surfaces to which traditional printing inks cannot readily adhere. To overcome this, manufacturers are developing unique ink that can print on such materials while still meeting performance requirements.

Flexibility is a key driver of the use of printable electronics. Thin, flexible circuit boards are needed to address application in the medical, security, logistics, wearables, military and consumer market segments. Smart fabrics have a digital component embedded to provide the user greater functionality. These fabrics could help keep the body cool, reduce heart rate or help control breathing.

The Silver Institute's recent "Market Trend Report on Printed & Flexible Electronics" projects that silver demand in printed and flexible electronics will grow from 48 Moz to 74 Moz over the next decade.

2.2. Case study: RFID technology

Radio-frequency identification (RFID) technology, used to wirelessly connect objects for tracking, monitoring and numerous other purposes, provides a good example of how connectivity is driving increased silver demand. Though the resultant consumption in this individual sector is small relative to the size of the overall silver industry, the strong growth is illustrative of a wider trend in silver use across a large number of connectivity-related applications.

Radio-frequency identification (RFID) technology is a cornerstone of many connectivity applications. RFIDs use a tiny radio transponder, a radio receiver, and a transmitter to wirelessly transfer data. This technology has a vast array of existing and potential uses across a wide range of sectors and industries:

- The logistics and supply chain industry have had high adoption of RFID tracking systems to monitor their assets through air, rail, road or ship. Logistic companies have increased visibility over their assets allowing for real-time data of location and time of arrival. RFID technology continues down the supply chain to help workers manage inventory on the shelf.

- Health care has benefited by allowing workers to track people and equipment. Real-time location of life saving medicines and equipment help nurses and doctors treat their patients. It also helps healthcare workers identify and keep tabs on their patients.

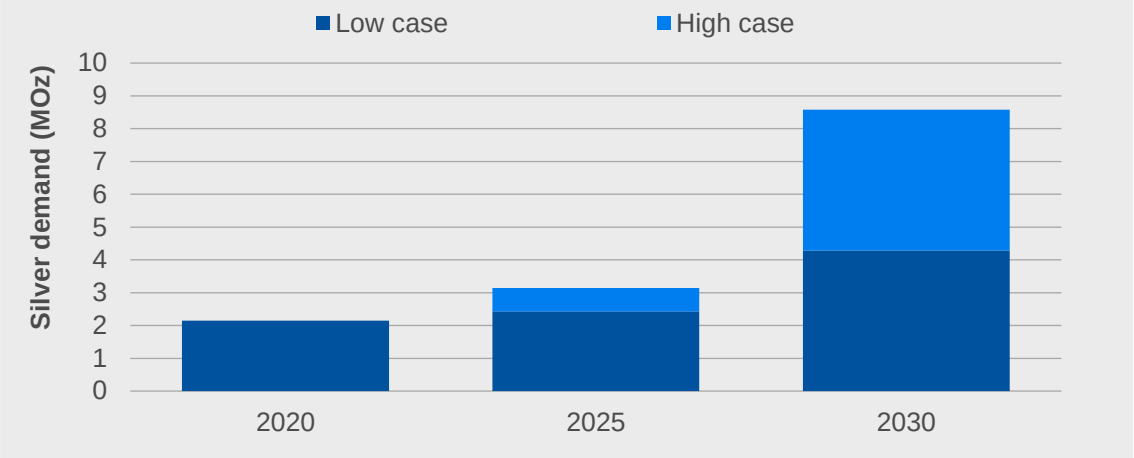
- In industry, RFID tags help identify particular parts that often look similar to others to a human eye. The information provided to the user can then provide instructions for the next stage. The user may be human or a robot. For example, in car assembly, the robot may get information about torque specifications for the fastener. By increasing information sharing from robot to worker, fewer errors are made and productivity increases.

Silver will play a crucial role in helping RFID technology be used in more products. Its connectivity minimizes material requirements compared to aluminum or copper, allowing RFIDs to be scaled down and used flexibly and unobtrusively in a wider array of applications.

Ultra-high frequency (UHF) RFID antennas are usually made of thin metal strips of copper, aluminum, or silver. Copper metal is more conductive than silver ink, but is relatively more expensive for a similar level of performance. Silver ink can be screen-printed onto the substrate, which is the fastest and the least expensive of antenna production processes (the others are copper etching and foil stamping). UHF tags produced with silver have greater flexibility and as printing technologies progress, the amount of silver needed will decrease and cause silver printed UHF tags to be less costly than Al/Cu tags.

As an example of the contribution of connectivity-related applications to overall silver demand, CRU has estimated the total silver demand in RFID tags on a bottom-up basis. The amount of silver in an individual RFID tag is, unsurprisingly, tiny. CRU estimates the amount of silver in a single RFID tag varies between 1 and 3mm3, which equates to roughly 0.001-0.007 grams of silver per tag – an almost infinitesimal amount. When this is multiplied by the vast number of active UHF RFID tags produced per year - approximately 15 billion globally – CRU estimates this results in a total of just under 2 Moz. CRU assumes that the number of UHF RFID tags produced per year will increase from around 15 billion tags in 2020 to between 30 and 60 billion by 2030. This increase corresponds to silver consumption growing to between 4.2 and 8.5 million ounces; at least a doubling of demand over the next ten years.

Figure 4: CRU forecast of silver demand in UHF RFID tags



Source: CRU

In a similar way, various other connectivity-related applications, even if they only require a very small amount of silver per device, can add up to a meaningful volume of silver consumption. The wide variety and increasing number of such applications, combined with growth in the number of devices per application, make trends in connectivity a critical driver of silver use in electronics and electrical end uses over the next 10 years.

3. Conclusions: silver an important part of global connectivity trends

Each of these connectivity applications will require a huge number and a wide variety of sensors, communication, tracking and monitoring devices; many of these will use silver in their semiconductors, electrical contacts, and elsewhere. The underlying infrastructure supporting this connectivity transition, such as the 5G network and the ‘internet of things,’ will itself contribute to increased demand for silver.

As a result, CRU expects silver demand in electronics and electrical applications to increase by 10% over the next 5 years, reaching 246 Moz by 2025. Consumption in various sub-sectors with specific exposure to growth in connectivity will increase at a dramatically faster rate.