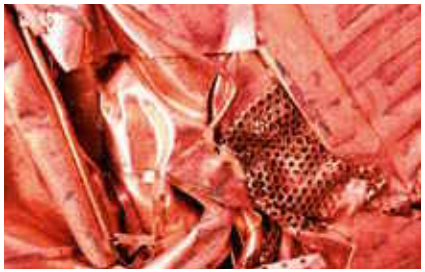
Curious about Copper

be Curious



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This publication from the European Copper Institute looks into the intriguing world of copper and reveals how one of the world's most reusable resources plays a vital role in enabling many aspects of 21st century life, as well as life itself.

Through the centuries, mankind's use of the Earth's natural resources reveals a remarkable journey. Each and every material has unique properties and, among these, metals stand out for their diversity and versatility. Our focus is on copper and the very special properties that enable its sustainable use across a vast range of applications.

A sophisticated, global supply chain delivers over 20 million tonnes of copper products annually. We may not always see it – copper is often hidden behind walls or inside equipment, below as well as above the ground, or covered by protective insulation – but almost every moment of our lives is impacted by the benefits provided by the products of this valuable resource.

Copper plays a crucial role in today's global society – to our health and well-being, in the home as well as in business and industry. We aim to ensure that the benefits of copper, with its capacity for infinite recyclability, are enjoyed by future generations.

Curious to know more?

Then read on – we hope you, too, will be fascinated by the world of copper.

Embracing sustainability in the 21st century

Both mankind and the planet have been through radical changes during the ten thousand or so years since copper was first exploited for its unique properties. The importance of copper, however, continues. It is an essential nutrient, vital to our health and well-being, and its natural antimicrobial properties were known and put to good use by the ancient civilizations of Egypt, Greece and Rome. Today, copper is a key component of some of modern society's most important technological developments, including the CERN Large Hadron Collider and renewable energy sources.

Our industry is focused on the core business of copper. Together with our stakeholders and society in general, we are also looking closely at global issues such as sustainability, climate change, and carbon footprint. Health, safety and the environment remain a top priority and we have taken a number of important steps in each of these areas. In 2008, copper's safe production and use was assessed by the industry and endorsed by the EU authorities through a copper risk assessment.* This proactive initiative was the first of its kind to be completed by any industry in advance of Europe's new REACH chemicals legislation.

The risk assessment, performed over an eight-year period and at a significant cost of €8 million, has been independently reviewed and provides top quality data on production and use, safety, worker health and the environment. It also provides the copper value chain and public authorities with a solid scientific platform on which to base future regulatory initiatives.

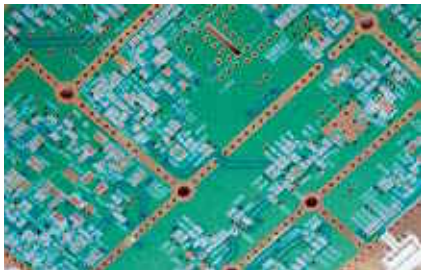
The inherent sustainability of any industry is growing ever more important in today's world. The threat of global warming leads the drive to lower greenhouse gas emissions at every level, from individual consumers to global industry sectors and governments.

While the copper industry and its customers benefit from the infinite recyclability of copper, without any loss in performance, the industry is continuing to invest in further production and product improvements. Our well-established investment in life cycle data provides a solid platform for the development and provision of the information required by the construction industry and by the manufacturers of consumer and industrial goods and services.

** Dossier available on ECI website*

A powerful medium

Copper's main use – some 65% – is as a highly efficient conductor of electricity. This, combined with mechanical properties that enable it to be drawn into flexible shapes, helps copper reduce energy losses in electricity systems and contribute to safety and reliability. It is estimated that 1 tonne of copper used to improve energy efficiency in an electricity system will save, each year of its working life, 200 tonnes of CO_2 emissions.



Copper has been used since the beginning of the electrical age for wires and cables, from extra high voltage underground cables, to low-voltage wiring and power appliances. Copper and copper alloys are also used for electrical contacts in switchgear, domestic plugs and sockets. In computers, chips are mounted on lead-frames pressed from strip made of special copper alloys. This enables the very precise pattern required to be achieved every time. Ultra-thin copper foil, less than the thickness of a human hair, also provides the etch plate for most printed circuit boards.

Magnet wire, which is copper wire insulated by an enamel coating, is used extensively for the windings of electrical motors and transformers. These range from very large generators, used for example in power stations and wind turbines, to the small motors used in consumer goods such as appliances, hairdryers and power drills. Increasing the copper magnet wire content in an industrial motor increases its efficiency, improves industry competitiveness and reduces greenhouse gas emissions.

The excellent signal-carrying capacity of copper data cables makes them popular for use in computer networks. High throughput copper data wiring is used to provide telephone, internet and digital television services within the modern home and office.

When it comes to electrical power, copper delivers three essential properties: conductivity, ductility and joinability. As an electrical conductor, copper is only bettered by silver, which is too expensive for volume uses.

Ductility is the property that allows copper rod to be drawn, or pulled, through dies of decreasing diameter at speeds of 120 km/hour into long lengths of wire which are spooled onto drums. Copper is soft enough to be easily handled, yet durable enough to withstand bending and twisting which makes it ideal for use in electrical installations. As for joinability, copper connections are easily made through a variety of simple joining techniques that maintain a good and durable contact for years, if not decades.

To make copper wire, pure copper metal (cathodes) are loaded into the top of a furnace for melting. In a continuous process, molten copper is channelled from the bottom of the furnace onto a revolving moulded belt or wheel, where it solidifies into a rectangular bar.

This then passes through a series of rollers to form circular 'wire rod', typically 8mm in diameter, which is cut and packed into large coils ready for subsequent use by the wire & cable industry. Final products include wires for distributing electricity throughout our homes (2.5mm diameter) all the way down to a few 10s of microns for use in computers and consumer electronics.

Copper at the heart of the home

The majority of Europeans take for granted the lighting, heating, communications, running water, domestic appliances and entertainment systems in today's homes. All of these are reliant on copper components. In addition, copper and brass are widely used in both utility and decorative items such as cookware, door fittings and furniture. Copper also supports renewable energy and plays an essential role in the solar thermal heating and cooling systems, wind turbines and photovoltaic panels that are increasingly incorporated into 21st century homes.

Copper plumbing systems ensure the long lasting trouble-free and safe delivery of water for drinking, washing and heating. They are used in buildings of all types, from hotels and offices, to private houses and apartments. These buildings also remain secure thanks to locks and keys made from copper alloy components that ensure reliability, strength and freedom from corrosion.

Air is cooled by the refrigerant circulated through copper tubing in air conditioning systems of all sizes, from small window-mounted units to the largest commercial versions. Copper tubes can be shaped without deformation of the tube walls and play an essential role in the efficient working of industrial and domestic fridges and freezers.

There are many millions of kilometres of copper cables and wires and billions of brass contacts behind the sockets and switches that ultimately deliver the electricity needed for the equipment in our homes.

Brass, one of the better known copper alloys for durability and resistance to corrosion, is also ideal for the precision manufacturing required in clock and watch-making.

Its excellent durability means that a copper component can often outlive the product or application of which it is a part. In buildings, a copper roof or copper guttering and downpipes can last for hundreds of years. Over time, copper used in outdoor applications will oxidize and take on its familiar green patina.

As well as for their practicality, copper and its alloys, such as bronze, are favoured by artists and designers for their aesthetic appearance, both as decorative items around the home and in large works of art for indoor and outdoor public spaces.

To produce tubes, copper is heated to its melting point of 1084°C and then cast into cylindrical shaped billets. These are softened by heating and extruded (pushed under pressure) through a die to produce hollow “mother” tubes. Successive drawing and heat treatment produces tubing of the right diameter. Tubes for drinking water and heating are usually produced in straight lengths for installation by the plumber. Those for air-conditioning are produced in large coils which are cut to size, by the air-conditioner manufacturer, depending on the size of the heat exchanger inside the final unit.

On the move with copper

Copper and copper alloys are found in all forms of transport: aircraft, cars, buses and trucks, trains and ships. They are also integral to the transport infrastructure itself, such as traffic management systems and safety surveillance.

Copper has a long tradition of use in marine environments. The blades of a modern ship's propeller, even those mounted in the steerable pods on the luxury liner Queen Mary II, are cast in copper-nickel-aluminium alloys. The precise shapes are designed to combine maximum propulsion efficiency with minimum corrosion from sea water.

Hybrid cars may require up to 33kg of copper for the electric motor, battery, wiring and other components. The energy and communications systems within all modern passenger cars rely upon a highly complex wire harness linking up hundreds of individual connectors. The harness's copper conductor and the copper alloy connectors must be able to withstand stressful operating conditions without risk of failure.

More complicated still are the connectors in aircraft engines while, on the ground, the essential airport lighting systems for aprons, taxiways and runways use thousands of metres of power cable.

Based on another key property – its resistance to corrosion – copper and copper alloys lead the field when it comes to reliability even in the harshest of conditions.

Copper nickel tubes, for example, offer strong resistance to corrosion in seawater environments and are widely used in shipboard condensers, oil rigs, and desalination and power plants.

Each high speed train uses about 20 tonnes of copper-containing components, mainly in the voltage transformers and drive motors. The pantographs of high-speed trains place huge forces on the overhead wiring systems that supply the current. Special copper alloys have been developed to maintain the required contact as train speeds continue to increase. CuproBraze heat exchangers provide the most effective engine cooling while withstanding the extremely harsh environments experienced by transcontinental trains.

To manufacture the hundreds of copper connectors used in every modern automobile, copper and alloying metals are cast and rolled into a continuous strip that is wound into coils, typically weighing 15 tonnes. The strip is then further processed into the required thickness and width. Complex shapes, produced to high tolerances, are pressed from the strip at high speed, while off-cuts are returned to the supplier for re-melting and reuse.

Healthy living with copper

As an essential trace nutrient for all higher forms of plant and animal life, copper is required as part of a healthy diet. It enables normal functioning of the brain, the nervous system and the cardiovascular system. It helps transport iron and protects cells against destruction by oxidation. Copper is also necessary for bone growth and strength, as well as for a healthy immune system.

As with many things in life, it's a question of balance. ECI's copper risk assessment (see page 3) established that the minimum daily dietary intake of copper for adults is 1mg with a maximum threshold of 11mg. With actual intakes ranging between 0.6 and 2mg, deficiency may be more of a concern.

A balanced diet is essential to achieve the health and well-being that adds to the quality of life. The copper ion we need in order to achieve this can be found in seafood, nuts, legumes, liver and green leafy vegetables.

In farming, copper-based chemicals prevent fungal growths on vines and other crops. Its use in feed supplements helps promote healthy growth in livestock. Copper alloy products are used in marine environments, such as the cages for fish farms, as this limits the formation of algae and seaweed that restrict the flow of oxygen to the fish.

Copper's antimicrobial properties have been utilised for centuries and are still in use today. Ancient texts from Greek and Roman times refer to the healing properties of copper and its use as a sterilizing agent. The sailing ships that transported products, such as wool and tea, between Europe and the Far East in the 19th century were fitted with copper-plated hulls, a practice introduced in the previous century by Britain's Royal Navy. This minimised marine growths which would otherwise slow their passage through the water.

Today, these properties remain equally important. In hospitals, copper tube is used for the supply of medical gases. MRI scanners, which give us accurate diagnostic images of our bodies have copper-based fast superconductors at their centres. Copper's antimicrobial properties are currently under trial to assess the effectiveness of copper touch surfaces in reducing the risk of hospital-acquired infections. In March 2008, the USA's Environmental Protection Agency approved copper as an antimicrobial agent.

Science has demonstrated the naturally antibacterial properties of copper in the fight against potentially life-threatening infections. For example, the viruses from the influenza family, including H5N1 (bird flu) and H1N1 (swine flu), are rapidly inactivated on contact with copper. Copper piping helps limit the spread of Legionnaires' Disease, as well as combating gastro-intestinal infections by reducing the risk of water being contaminated by the *Escherichia coli* or *Listeria* bacteria.

Among the main conclusions of the copper risk assessment, accepted by the European Commission and EU Member State experts, is that the use of copper products is in general safe for Europe's environment and the health of its citizens. The assessment determined safe levels for copper in freshwater and marine waters, soil, and freshwater, estuarine and marine sediments. The copper levels measured in European waters, sediments and soils are usually well below these safe threshold levels.

Playing with copper

It is not only our working lives that are improved by copper's benefits - many of our leisure experiences also make use of the exceptional characteristics of this metal and its alloys. These characteristics appeal to artists in many different media – from sculptors to musicians, and from chefs to jewellers.

Most of us enjoy music, whether playing an instrument or listening to it through sophisticated sound systems, where oxygen-free copper is used to connect components and in speaker wire. Copper is also used for the voice coils in speakers.

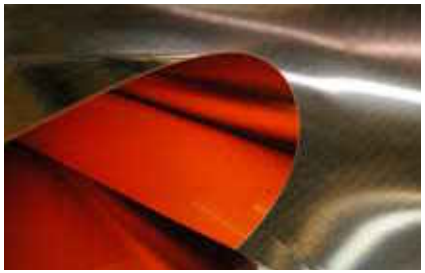
Copper alloys, usually a particular type of bronze known as bell metal, are used to make bells of all sizes. Some bells, still in use today, date back several centuries. Brass instruments not only deliver the required resonance, pitch and tone but benefit from copper's antimicrobial properties which prevent the build-up of harmful micro-organisms.

Copper is popular in art, jewellery and other crafts because of its malleability and its lustre. Both copper and bronze are highly favoured by sculptors because of their attractive appearance, longevity, ease of casting and corrosion resistance. The original bronze doors from the Florence Cathedral Baptistery, made by the famous Italian sculptor Lorenzo Ghiberti, date from the 15th century.

Copper is still widely used in the kitchen by both professional and amateur chefs. Its excellent heat conductivity helps copper pans to respond rapidly to temperature changes and to distribute heat efficiently. Internal surfaces are often coated with tin to stop reactions with acidic foods. Not only does it cook like a dream, copperware provides a beautiful addition to any kitchen.

The castability of copper alloys enables a bell to be made by pouring the molten metal into a precise mould, so that it rings consistently and clearly at the desired pitch and timbre.

The production of a trumpet – which comprises lengths of tubes, valves and the trumpet bell – exploits a variety of metal-forming operations. Brass tubing is extruded and drawn through a die, containing an internal mandrel (a tapered steel rod), to maintain the hollow core. It is then bent into the desired shape without deformation of the tube walls.



Instrument valves are formed and precisely drilled from tubes. The bell itself is worked by hammering sheet metal and spinning it around a wooden shaper. The edges are then joined, or brazed, to form a single piece. All components are soldered or screwed together and polished to achieve the characteristic bright finish.

Mixing with copper: the alloy story

No metal is more suited to alloying than copper, a practice dating back to the beginning of civilization, but still, very much in used in many modern-day applications. Formed by mixing various compositions of metals in the molten state, alloys are used to expand properties for specific end uses. Two of the earliest and best known alloys – still very much in demand – are bronze where copper is mixed with tin, and brass where it is combined with zinc.

Today, copper is also alloyed with a whole range of metals, including aluminium, nickel, silicon, manganese, silver, and tellurium. The European industry is expert at exploiting copper's versatility for innovation as new alloys are developed to meet increasingly critical needs in applications such as electronics, superconductors, transport and healthcare.

Brass is widely used in the many fixtures and fittings that make up modern plumbing systems for drinking water, heating and gas distribution. The addition of 2-3% of other metals maintains corrosion resistance and offers superior processing characteristics, allowing precise thread patterns to ensure tight, leak-proof connections. Other brasses include naval brass, which contains a small amount of tin to further improve corrosion resistance. Nordic Gold, used for the higher value Euro coins, contains small amounts of aluminium and tin. Manganese brass is used for US coinage.

When tin is added to copper, the resulting bronze offers corrosion resistance, hardness and durability. In its basic form, it is used mainly for castings, including ship propellers, sculptures and bells. To achieve low friction, a little phosphorus is added to create phosphor bronze used in bearings and bushes. Silicon bronze is used for industrial fasteners, while aluminium bronze, which offers strength and corrosion resistance, is used in architectural applications.

For several thousand years, copper and its alloys have played an integral part in global trade and business. Copper nickel alloys were first used in coins around 170 BC. Since 2001, several EU Member States have adopted the Euro. Coins with a value of between 10 cents and €2 contain a minimum 75% copper. Coins can be produced with precision by stamping rolled copper alloy strip to the desired shape and design, and can keep their shape and appearance for centuries and longer.

Copper nickel tubing is used in power and desalination plants, and by chemical and petrochemical processing industries due to its excellent corrosion resistance. Nickel silver is, in fact, an alloy of copper, nickel and zinc. Its main uses are in silver plated cutlery, known as EPNS, as well as in coins and musical instruments.

A number of elements are alloyed at low levels with copper to produce enhanced characteristics, in particular for electrical applications. Tellurium improves machinability, while zirconium copper is used for welding electrodes and switchgear.

Adding beryllium to copper improves its mechanical strength and is used in springs. The addition of magnesium gives additional strength to overhead contact wires for trains and trams. Chromium and zirconium are added to copper for steel casting moulds.

The future is bright

Inventive research and innovation place new demands on existing materials. Researchers continue to exploit the long-established and well-recognised properties of copper and its alloys in developing new services and applications.

In one of its most spectacular and futuristic applications, copper provides the matrix in the superconductors used in the CERN Large Hadron Collider. Less dramatic perhaps, but nevertheless playing an essential role in modern medicine, are MRI scanners which rely on copper-based superconductors to create their images.

Copper's excellent electrical and thermal conductivity put it at the core of the fast-developing world of renewable energy. It is used extensively in wind turbines, photovoltaics, tidal and wave power stations, as well as in solar thermal systems. In the latter, copper is used in the substrate of the collector panels themselves, in the tube systems through which the water or air circulates, and in the connections to a building's plumbing systems.

Together, the battery and electric drive motor of hybrid vehicles require some 20kg of copper. All-electric vehicles could benefit from the recently developed, highly efficient copper motor rotor. In further road-related developments, radio-frequency identification (RFID) is set to be a key technology in toll systems. Here, product tracking and logistics management can use copper-plated antennae to transmit signals.

The business of copper

The copper in use today may have been in circulation for decades or even centuries. Long before sustainability became a watchword for our times, copper's ability to be recycled again and again, without loss in either performance or properties, has been recognised. This makes it economical and sustainable to use without compromising the needs of future generations.

Copper-containing products have a very wide range of life spans, from perhaps months in consumer electronics, such as mobile phones, to centuries in prestigious architectural buildings. When products containing copper come to the end of their useful lives, the recycling industry is able to collect, sort and extract the copper (among other materials) and return it for reuse. Likewise, scrap, offcuts and discards from the processing of copper components are collected and returned for remelting and reuse.

Historically, the inherent value of copper has supported the complex chain of collection, sorting and delivery that makes its recycling and recovery possible. More recently, designs that facilitate end-of-life recovery, higher public awareness of the need to conserve resources and legislation have improved recycling rates. As examples, in the EU, the End-of-Life Vehicles Directive aims to ensure maximum recycling of obsolete vehicles, while the Waste Electrical and Electronic Equipment Directive aims to reduce the amount of this type of waste going to landfill by improving recovery and recycling rates.

As cars, electronics and other consumer durables become more complex, extraction of the constituent metals becomes more challenging. Sophisticated processes now exist, especially in Europe, to extract metals from even the most complex products, such as electronic printed circuit boards, under safe and carefully controlled conditions.

Recycling meets about 40% of European copper demand, although the longevity of copper products and components means they may not be recycled for many years. But, with ever-increasing demand for copper for infrastructure and industrial and consumer goods, particularly in fast-developing parts of the world, new copper has to be continually produced from primary resources via a process of exploration, discovery, processing and refining.

Currently, the world's principal mining areas are around the Pacific Rim and Central Africa. In Europe, the main copper mining countries are Russia, Poland, Portugal, Spain and Sweden.

Mining is a highly capital-intensive operation requiring huge up front investment in equipment and construction before revenue starts to flow from metal sales. Mining companies are therefore increasing in size to generate the necessary capital. London is home to some of the world's largest mining companies. While most do not mine copper in Europe, they need to leverage its sophisticated financial expertise and markets in order to generate, manage and exploit the capital required for their global operations.

Copper exists in naturally occurring ores in concentrations between 0.5 and 7%. The two main extraction processes are pyrometallurgy, which extracts the metal from sulphide ores by heat, and hydrometallurgy, which uses solvents to extract the copper from mainly oxide ores. In the former, the ore is ground and concentrated by flotation at the mine site, to produce copper concentrates containing about 30% copper, suitable for smelting and refining.

At the smelter, the dried concentrate and oxygen are fed into a furnace. The oxygen reacts with the sulphur, present in most ores, in the highly energy efficient "flash smelting" process. Here, the copper is separated from the iron and silicon components in the concentrates. The molten copper is then transferred to the converter where most of the remaining impurities are removed. After further processing, to remove the final traces of copper, the iron and silica materials become slags which are used as construction materials and abrasives.

The copper from the converter is cast into anodes, with about 98% purity. In the final stage of the process, these anodes are immersed in huge acid baths. By passing an electric current between the anode and the cathode-starting sheets, placed in between the anodes, copper ions leave the anodes and plate themselves onto the cathodes resulting in a purity of at least 99.99%. The remaining impurities fall to the bottom of the bath and are further processed to extract the other metals present in the original ore, such as gold and silver.

Copper oxide ores, typically those near to the earth's surface, are particularly suitable for hydrometallurgical processing which avoids the concentration and smelting stages. As a result, it is much lower in cost. In the solvent extraction electrowinning (SX-EW) process, an acid solution percolates through heaps of mined ore in an environmentally-safe closed circuit. The resulting solution, heavy with copper, is collected and fed into electrolytic tanks, containing cathode starting sheets, and the final product is obtained through the same electrolytic refining process.

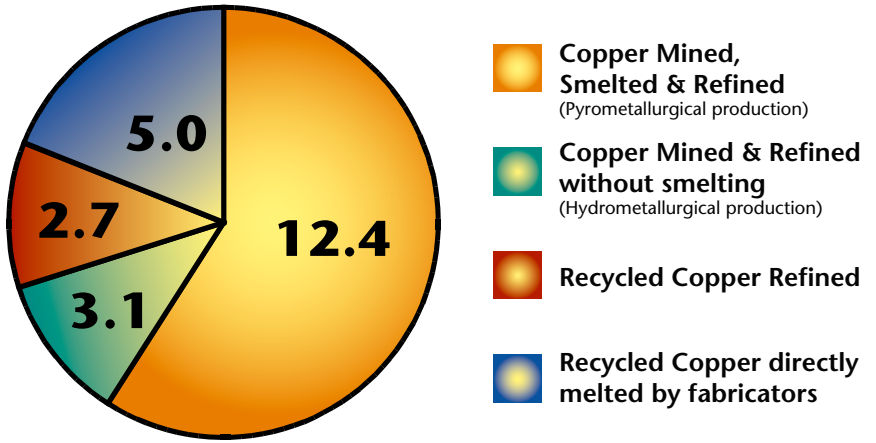
About 15.5 million tonnes of copper were mined in 2008. According to the United States Geological Survey, known global copper reserves are currently put at around 550 million tonnes. However, total resources are much higher and short-term supply limitations, which often result in upward price trends, act as a spur to the exploration of new deposits and the exploitation of others previously considered uneconomic. As copper is capable of infinite reuse in almost all of its applications, it is rarely lost from the world's total copper resources.

Copper cathode, produced using virtually identical methods around the world, is a global commodity. A common, global price is established by the interaction of global supply and demand on the world's metal markets, notably the London Metal Exchange, as well as the Shanghai Futures Exchange and Comex in New York.

Copper is traded directly between metal producers, merchants and users, such as fabricators. The various parties use the exchange prices as the basis for their transactions. The exchanges also make it possible for the mining industry and large users of copper to guarantee prices for future deliveries. This provides a degree of certainty in a world of constantly fluctuating metal prices.

The exchanges also offer a facility to deliver and receive metal, thus acting as markets of last resort. This ensures convergence between the value to financial investors and the physical market price.

2008 Sources of Copper Supply (million tonnes)



Source: International Copper Study Group

Today, Europe has an active copper mining industry and a world-class smelting and refining sector, with European companies pioneering much of the metallurgical technologies used worldwide. It also boasts a well-established fabricating industry, which is the next stage in the copper value chain.

Innovation, proximity to, and close cooperation with customers, plus anticipating market needs, have become the hallmarks of success for Europe's copper fabricating industry. This requires investment in product research and development, plus flexible equipment capable of meeting the highest quality requirements. A handful of large companies characterise the sector, together with a few niche players. In total, the European copper industry employs some 50,000 people directly and sustains the jobs of millions of others by delivering key products into a vast range of business and service activities.

Such is the breadth of copper's applications that the European market has achieved small, but respectable, volume growth even though the Western European market is largely mature. While copper intensive infrastructures are largely well developed, they must be modernised and refurbished regularly. Transport systems are one area that has provided strong growth, spearheaded by copper's applications in high speed trains, airport expansions and, more recently, electric vehicles. Higher rates of economic growth and improved consumer purchasing power in Central and Eastern Europe have also increased demand growth across a wide range of applications.

We hope you have enjoyed this glimpse into the fascinating world of copper. If you are still curious about copper and want to know more, please use the contact information provided, or visit our websites at www.eurocopper.org and www.imaginelifewithout.org.

ECI's European network of eleven Copper Development Associations

The European Copper Institute (ECI) and its network of eleven national Copper Development Associations (see below) are affiliated to the International Copper Association Ltd. (ICA). The European Copper Institute is a non-profit organisation representing the world's mining companies (through the ICA) and the European copper industry. Via its Brussels-based headquarters and its national association network, its mission is to communicate copper's essentiality for health, technology and quality of life. ECI works closely with ICA's other regional offices: Beijing for Asia, Santiago for Latin America, and New York for North America.

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The finest of metals

Pictured right: a quality-control sample of oxygen-free copper from the test bench at Luvata's Zutphen plant in the Netherlands

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