Copper

A material for the new millennium

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Executive summary

INTRODUCTION

One of the earliest metals to be worked by man, copper, in the form of bronze, took humanity out of the stone age and helped to propel us into the civilised era. Several millennia later and copper is still at the forefront, this time of the electronic age. In the next few decades copper will help to consolidate advances in telecommunication and Internet technology. The prospects for copper in the present decade are therefore good and despite the onset of the US-led recession in 2000, demand should pick from 2002–2003 with a return to reasonable industrial growth rates in the developed world.

THE MAIN END USE SECTORS

The five main end uses for copper are:

- building and construction
- electrical and electronic products
- industrial machinery and equipment
- transportation equipment
- consumer and general products.

Under normal business conditions, demand for copper increases sharply when spending on capital goods rises and the housing and construction cycle is at its peak.

MARKET OUTLOOK

The industrial slow-down in 2000–2001 produced towards the end of that period worrying signs of a growing gulf between production and consumption. Rising supply from new production has added

some 3 million tonnes of copper since 1995. While there was strong demand for copper in the US and Europe up until 1998, demand has since cooled and the situation has worsened significantly by 2001.

However, in the long term there is a view that world copper prices will rise due to the dearth of new mining projects in the 2001 economic climate and steadily rising metal demand led by China. In order to meet increased demand there would have to be new mining capacity, including recycling of scrap copper and existing mines tapping idle capacity in order to meet demand in the following 10 years.

In the first half of 2001, US copper consumption fell 6.4% or by 100 000 tonnes and western European consumption was down 44 000 tonnes or 2.1% over the same period. But US demand is predicted to pick up, perhaps as early as the beginning of 2002, as leading indicators show a bottoming out and an upturn. This should also lead industrial production, which has been falling in line with the indicators, upwards again.

China showed 13.6% growth in demand up to June 2001 and could overtake the US as the world's number one copper consumer in the next 20 years. China imports annually about 2 million tonnes of blister and concentrate copper as well as scrap to boost its smelter production. Chinese production was increasing modestly in 2001 and 2002 because there were few new projects that would be in production in the next two to three years.

SOME SUPPLY TRENDS

In 2000 copper had a good year with continued strong global growth led by China and the US finally taking up the supply surplus. However, by 2001 the picture had changed quite dramatically with a much weaker economy in the US and lower growth expectations for the EU.

The consequent slump in demand has resulted in a renewed supply surplus, which will be modest due to industry rationalisation and the impacts of high-energy costs. The copper market in 2001 moved into deficit and refined metal stocks at commodity exchanges have fallen. Industry stocks are projected to reach price-critical levels in 2001/2002 and the market will become increasingly vulnerable to supply disruptions. Beyond 2003, the economic cycle will have run its course and copper demand will flatten in mature, developed Western economies. This will leave the market delicately poised and producers will be largely determining their own destinies when deciding the

timing of commitment to new projects, according to the ICSG. In the second half of this decade demand should pick up strongly feeding fears about a shortfall in supply.

Regional influences

Latin America

Chile – the 'Saudi Arabia' of the world's copper industry

The country has always had a considerable presence on the world's copper stage with mines like the 800 000 tonnes per year Escondida, the 510 000 tonnes per year Chuquicamata and the 340 000 tonnes per year El Teniente, the world's largest underground copper mine. In 2001, Rio Tinto indicated that it may invest $US1.47 billion as part of a near $3 billion overall consortium investment to expand output at Escondida, the world's biggest copper mine.

Argentina

In mid-2001, Canadian miner Noranda Inc. announced that it had bought Argentina's El Pachon copper project from debt-burdened Canadian gold miner Cambior Inc. and its Bolivian partner Minera S.A. for $30 million. Noranda had been looking to increase its copper reserves. El Pachon is located 185 kilometers (115 miles) west of San Juan in central western Argentina near the border with Chile where Noranda already has mines and smelting operations. The deposit contains mining reserves estimated at 880 million tonnes grading 0.62% copper, representing 12 billion pounds of copper. EL Pachon also includes recoverable molybdenum and precious metals. The deposit is mineable by open pit.

Peru

In Peru, a Canadian consortium, with Rio Algom (33.75%), Noranda (33.75%) and Teck Corp (22.5%) and Mitsui (10%) is near to completing the development of the $2.2 billion Antamina copper and zinc mining project. The project, if it goes according to plan, will boost the country's

copper output by 50%. The mine is located in the northern Andean region and is estimated to have 500 million tonnes of reserves and the potential to produce 600 million lbs (272 400 tonnes) of copper per year over its 20-year life. Concentrate production is planned to start in the first quarter of 2002.

North America

The US copper industry, which had to cope with a major restructuring in the 1980s and then again in the late 1990s, when it was affected by the global tide of mergers and acquisitions, was in serious trouble in 2001. In mid-2001, the US copper industry was racked by weak demand and depressed copper prices. Two copper producers, Olin and the world's number two producer, Phelps Dodge, warned production closures and layoffs were inevitable. In addition to the poor industrial climate, the US industry in 2001 was also suffering from high inventory levels, a strong dollar and high energy costs.

In 1999, BHP announced the closure of its troubled US copper division, which includes the San Manuel smelter and four mines – San Manuel, Pinto Valley and Superior in Arizona, and Robinson in Nevada.

Poland

The largest copper company in Europe, KGHM Polska Miedz SA of Poland, has been partly privatised since 1997. But the company has been buffeted by political disputes between labour unions and the government, which controlled more than 50% of KGHM stock. The long running failure to undertake a radical root and branch reform in the 1980s has been blamed in part for the company's poor performance since partial privatisation.

Australia

Construction of the Olympic Dam copper and uranium mine expansion project was completed in 1999–2000. The expansion has increased copper smelting capacity from 85 000 tonnes per year to 200 000 tonnes per year.

Two key suppliers of concentrates from the region, the BHP Ok Tedi mine in Papua New Guinea and

the North Ltd-owned Northparkes mine are said to have taken 'holidays' on long-term agreements, preferring to sell direct into the spot market. An expansion at Northparkes increased production from 20 000 tonnes to 65 000 tonnes per year between 1996 and 1997.

Western Europe

The role of Western Europe in the supply of mined and refined copper has varied between 300 000 tonnes and 400 000 tonnes per year since the 1990s, but overall it continues to remain the smallest of the six World Bureau of Mining Statistics (WBMS) reporting regions. Spain, Portugal, Sweden and Norway are the main Western European producers. However, high costs have led to the closure of the Minas Rio Tinto-owned Cerro Colorado copper mine in Spain. The closure was due to the high cost of production at the mine combined with low copper prices. There is also lower production at Portugal's Neves Corvo, because of low ore grades, and mine closures in Sweden and Norway.

East-west trade (CIS)

In the CIS, copper supply to the west has remained steady since 2000. Russia is the most important producer in the region and Norilsk is by far the largest refinery with a nameplate capacity of 425 000 tonnes per year. Although production has fallen well short of this for some time, it has nonetheless crept up in recent years, reaching 320 000 tonnes in the late 1990s.

In Kazakhstan, output at the Balkhash complex fell short of planned levels in the late 1990s, at 95 000 tonnes, although this was 16 000 tonnes higher than 1996 levels.

In Uzbekistan, copper output is hovering at around 100 000 tonnes from a nameplate capacity of 140 000 tonnes per year, virtually double the 59 000 tonnes produced in 1994, having increased steadily in the intervening period.

SX-EW technology

One of the major developments in copper production since the 1980s has been the development and expansion of SX-EW technology and the setting up of plants based on this technology. SX-EW is

generally used to treat low-grade copper oxides deposits, which are usually the weathered portions of deeper sulphides ores. Prior to the arrival of SX-EW, this material was regarded as waste. The result was that over a number of years the oxide ore was simply stockpiled and the major copper companies accumulated substantial volumes of this oxide material. The electrowinning process is a fairly old one, but it is only relatively recently, following the developments of special reagents, that the technology of solvent extraction has become effective on a large scale.

SX-EW production is usually cheaper than the conventional method, particularly if the deposit is a waste dump, which requires no mining. In addition, labour costs are low; because fewer workers are employed energy costs are reduced; as no smelting occurs maintenance costs are lower; because plant design is simple the costs of shipping concentrates is avoided.

SX-EW producers, led by Magma, Falconbridge and Cyprus Minerals in the late 1980s and early 1990s, now have electrowon brands registered on the LME and COMEX. A major expansion in SX-EW plant capacity in the 1990s took place in Chile, and output now totals over 1.1 million tonnes per year. Indeed, global SX-EW capacity as a percentage of refined western copper output now exceeds 20%.

The role of secondary copper production

The estimated world copper scrap consumption is around 4–5 million tonnes per year compared with global primary copper consumption of around 13–14 million tonnes per year. However, the recovery rate of refined copper from scrap declined to less than 15% in 2000 compared with 18% in 1995. The reason for this decline is partly due to the low price for copper.

SOME DEMAND TRENDS

A major boost to copper demand has been in the new fields of electronics, computing and telecommunications. As these industries are still far from mature it is safe to assume that the demand for copper in these sectors is set to continue for some considerable time.

Computers

The worldwide personal computer (PC) market can be expected to continue to post double-digit growth through 2001 and beyond. Shipments are estimated to have reached 151.6 million units in 2001, according to research done by Dataquest. The PC market is responsible for the greatest usage of electronic connectors as well as being the largest consumer of copper alloy strip products.

The industry sees considerable room for growth in the Far East markets and points to the fact that Japan is about five years behind the US in the extent to which personal computers have become established in homes and small businesses. About 15% of Japanese homes have PCs, compared with 43% in the US. However, the North American home PC market is still far from saturated, and will not be for many years, although it is likely to grow at a slower rate than in other regions.

The growth in network computers (NCs) in the developed world, as a result of efforts by leading computer software and hardware companies to work together to develop common standards to enable NCs to work with many vendors' servers, should help stimulate computer demand and therefore the demand for copper wire and alloy strip products. NCs, introduced in 1996, are simple to use, lightweight 'client' devices that provide users with easy access to corporate data, intranets and the Internet. It is estimated that some 60% of businesses are deploying NCs as of 2001.

Automotive applications

Electrical and electronic applications are the major consumers of copper and copper alloys in motor vehicles and will be responsible for the major increases over the next five years. This growth will be driven by the implementation of smart sensors, smart airbags, electronic throttle control and improved exhaust sensors. Beyond five years, it is possible that electric power steering, electric braking and even hybrid vehicles may become commonplace. This should have a positive effect on copper content, but alloy selection, new wire technology and a significant increase in small motors may affect whether a particular copper alloy or product form increases or decreases.

The average copper content in passenger cars was 60 lb, as of 2001, compared with less than 55 lb in 1995. Light trucks averaged 61 lb, compared with some 50 lb in 1995.

Concept vehicles

Concept vehicles displayed at various motor fora since 1999 tend to fall into two primary categories, small roadsters and large vehicles. The large vehicles include new SUVs, pick-up trucks and a combination of car and truck platforms, which could be the basis for a new type of vehicle. Examples of this new type of vehicle include:

- Cadillac Evoq Roadster. This Cadillac resembles a luxury version of the Corvette, with two seats, rear wheel drive and a 4.2 litre supercharged V8 engine. Electronic features include night vision radar, a dashboard PC with Internet access, rear back-up sensors and rear view cameras that replace conventional mirrors.
- Ford Thunderbird. This two-seater roadster with classic Thunderbird features is officially listed as a concept car but indications from Ford are that this will be in production for the 2001 model year.
- Hyundai Santa Fe. The Korean auto maker is proposing to manufacture this SUV for the 2001 model year with a price of less than $20 000. It is smaller than a conventional SUV and if produced, will be aimed at the economy segment of younger buyers.
- Lincoln Blackwood. The Blackwood is a concept truck that combines the luxury and amenities of the Lincoln Navigator with the cargo capacity of the F-150 pick-up truck. The covered bed is lined with wood trim and has two rear hatches that open out instead of down (like a typical pick-up). The vehicle also has leather seats, satellite navigation and electronically adjustable pedals. This vehicle went in production late into 1999 with a $50 000 price tag.
- Mercedes M Class. Although first shown as a concept vehicle, Mercedes commenced production of this vehicle in 1999–2000 in a bid to expand its line of SUVs.
- Mitsubishi Mad Max SSU. This concept vehicle has a wider base (three inches wider than a Chevy Suburban) and lower profile than most SUVs. Mitsubishi used a 310 horsepower, twin-turbocharged 2.6 litre V6 engine with a five-speed automatic transmission. The SSU has all wheel drive, active yaw control and 20 inch wheels for improved stability and cornering. The body is designed with no central roof pillar with both doors opening from the middle of the vehicle.
- Nissan SUT. Nissan presented a new product type designated SUT for sport utility truck. It is similar to the Lincoln Blackwood with four doors, a pick-up truck bed and removable seats for increased carrying capacity.

Hybrid electric vehicles

The impact of HEVs on copper is an increase of 70–100% over a conventional internal combustion engine (ICE) vehicle. These vehicles are expected to become increasingly popular in the coming years. Toyota recently unveiled the Prius HEV for sale in Japan. This vehicle uses the Toyota hybrid system that combines a high efficiency gasoline engine with electric motors to maximise energy efficiency and reduce emissions. Energy saving features include automatic engine shut-down when the vehicle is stopped and regenerative braking that converts kinetic energy into electricity to charge the battery.

Wireless communications

The 1990s can be called the decade of wireless communications, with upgrades from analogue to digital systems taking place in many parts of the developed world. By 2000, smart telephones had emerged, offering two-way paging, fax, e-mail and voicemail. The market for personal communication systems (PCSs) is not the cellular customer, but rather the well over 1 billion wireline customers in the developed nations as well as the potential several billion in undeveloped countries. By 2001, nearly 5 million people worldwide were signing up every month for new digital wireless telecommunications services. The best estimate for PCS handset growth is around 80% per year. At the end of the 1990s, demand in the developed world was high and emerging in the developing markets. However, 2000–2001 witnessed a slow-down in demand growth in the developed world, although growth in the emerging markets continues. The impact of this growth should result in an increase in demand for copper wire and alloy products for use in the base stations for wireless communication and telephones.

Smart cards

The global market for smart cards in 2000 was estimated at $7.6 billion from $1.2 billion in 1996. However, to 2005, the market can be expected to mature and growth rates of 16% will be seen, reaching $16 billion.

The widespread acceptance of smart cards by consumers would undoubtedly damage the US coinage market for copper alloys, a roughly 74 million lb market. But the upside is that if the electronic purse catches on, every check-out counter in every store will need a smart card reader complete with electronic interconnection products.

Copper-nickel sheathing

The need for sheathing materials with built-in anti-fouling characteristics has provided considerable potential for copper-nickel alloys to provide the sheathing for off-shore oil and gas rigs. These are used on the rigs' jackets, cables, tension legs, concrete structures and other floating off-shore structures. The potential for the further use of copper alloys for marine applications is substantial. However, the market for copper alloys has been somewhat restricted due to the lack of valid cost-comparison data based on first costs and lifetime costs, poor understanding of fabrication and operational requirements and by the better targeted marketing of stainless steels and titanium.

However, the level of interest has risen significantly over recent years in copper nickels and aluminium bronzes for seawater piping applications. Copper-nickels are now being considered for use in situations where stainless steels do not conform to Norsok standards for use at temperatures exceeding 15 degrees centigrade.

The CDA's goal in 1997 was to increase the markets for copper alloys for marine piping applications in 2002 by 20 000 tonnes and an additional 5000 tonnes of C70600 (copper-nickel) alloy for sheathing of off-shore structures. Although increases were witnessed up to 2001 they were believed to be off their 2002 target. A key activity is to conduct a survey of new build projects, for both shipping and off-shore applications, to determine potential expansion of the market for copper-nickel.

Telecommunications: new applications

Telecommunications is copper's sixth largest market in the US today, worth some 600 million lb per year. However, 20 years ago telecommunications was copper's largest market in the US by a fairly substantial margin. This began to change when wire gauges started to get smaller as electronics improved, and subscriber carrier, or multiplexing, systems were deployed in the telephone companies' subscriber loops.

Demand increases

In the 1980s the fax revolution began to take place and many second telephone lines were being installed to service it, a trend that shows no sign of abating. More recently, the Internet has prompted

many people to install yet more lines. The growth of housing stock in the developed world, particularly the US, along with home offices and growing affluence in general, have added to the increase in the number of global telephone lines in service. Throughout the technological changes of the last two decades, copper has continued to reign supreme in the final leg of the telephone network, sometimes referred to as the distribution part of the subscriber loop, sometimes as the last mile.

Demand decreases

On the negative side for copper, subscriber carrier systems in the developed world have become ever more common. Rarely do copper wire pairs get installed today all the way from a telephone central office to a home or business, except in lightly populated areas or in a retrofit situation. Instead, subscriber carrier feeder systems are installed which terminate in remote, unmanned network interface units, from which individual wire pairs radiate out to each customer. Feeders now are typically installed in fibre optics, not copper. Before the advent of subscriber carrier, the feeder part of the loop used about 60% of all the copper in the outside plant of the telephone system; now it uses very little.

xDSL technology

Digital subscriber line (DSL) technology is an innovation that enables copper transmission wire to be used far more effectively. Indeed it is estimated that xDSL could use up to 99% of copper's transmission capability not now used by voice telephony. This new technology was developed originally in the early 1980s by Bell Labs, refined by Bellcore and taken up by a large number of commercial vendors. DSL uses the capabilities of very large-scale integrated circuits to send large quantities of error-free data.

Several versions of DSL technology have been developed, collectively known as xDSL. The most commonly cited is asymmetric DSL, or ADSL, which features a larger bandwidth going downstream than upstream, and is supposedly best adapted for home use.

The deployment of copper-based xDSL systems provides a moving target for fibre optics or other competitors such as wireless systems in the outside plant, and should maintain copper as the standard for the last mile. ADSL is seen by the telephone industry as an interim technology for the next 40 years. If that proves to be the case, incremental additions to the telephone plant will continue

indefinitely in copper, since it is unlikely there will be any driving force to change that. The outside plant will continue to require a large, steady supply of copper exchange cable both for these new additions and for the replacement market.

Cable TV

Cable TV companies are traditionally entertainment-oriented, so many of the early Internet offerings featured use of the TV set rather than a home computer. But as sophisticated cable modems evolve, they are being tied into computers as well. The industry is well on its way to standardising on cable modem protocols.

Premises wiring

Premises wiring consists mostly of 24 gauge copper twisted-pair wires for local area networks, used to connect pcs. The business took off in the 1990s as we rapidly moved from mainframe computing to PCs tied together, usually in a star pattern using Ethernet protocol. Most of the horizontal wiring is 4-pair, while higher pair counts are used in vertical runs. 4-pair wire contains about 10 pounds of copper per 1000 linear feet. Thus a market of 100 million copper pounds, which is an order-of-magnitude number for annual shipments, would translate into about 10 billion linear feet of 4-pair cable. Nearly all of this is used in the commercial and, to a lesser extent, industrial building markets. Dozens of companies manufacture this cable and are associated in an active organization known as BICSI to share technical and standards information, and to promote their latest products in this fast-moving marketplace.

The residential market

CDA has identified what it sees as an exciting new market for premises wiring as its main promotional thrust in telecommunications for the immediate future: residential wiring. As of now this market is relatively untouched, but the Internet and the means to deliver it, whether xDSL, cable modems or wireless systems, need good wiring in residences which currently does not exist. The CDA has identified that the biggest market for home Internet and computer use is in the US among young people who are buying their first homes.

For now, copper's position as the dominant transmission medium in the distribution part of the telephone system's subscriber loop appears to be well entrenched and resistant to penetration by fibre optics. xDSL could use the 99% of copper's transmission capability not now used by voice telephony, and this makes copper a moving target, better to resist penetration by fibre optics or coaxial cable in the cable TV system.

General engineering

With such a wide range of materials available in a variety of forms, such as sheet, strip, wire and extruded sections, engineering designers are continuing to specify copper alloys for both large and small applications. Copper is used in applications such as large copper brewing vats, but the majority are in the form of machine or plant components and are usually unobtrusive to the layman.

Copper distilling columns used in the production of industrial alcohol, fatty acids, essential oils, etc, are of special interest. The great penicillin plant at Speke, near Liverpool, is a specific instance of the use of copper in this respect. The recovery of extracts calls for fractionating columns, which are 23 ft high and 5 ft in diameter and are built of deoxidised copper sheets. Each column is in seven sections, six of which have riveted copper bubble plates, and each plate incorporates 60 copper bubblers and uptubes.

Copper sheet is very often used for lining the mash tuns and fermenting vessels and the brewing coppers are almost always made of copper, as indeed their name implies. The world famous Guinness brewery in Dublin has 19 of these huge coppers, each of which holds 23 400 gallons. The slotted false bottoms of brewery mash tuns are made of bronze or brass. The round or oval coiled tubes called attemperators, through which cold water or brine circulates in the fermenting vessels, are of copper because of the metal's high heat conductivity, and so are the steam coils in the brewing copper and the various distribution pipes. Copper tanks may even carry the beer away.

In scores of other industries, which are loosely classified under general engineering, copper and copper alloys are used for an infinite variety of applications, ranging from small mass-produced parts in free-machining brass to equipment for the 'space age' industries of rocket production and atomic energy. The giant electromagnets employed in atom-smashers have copper wire windings. A cyclotron at Harwell in the UK has 70 tons of copper strip for this purpose, while 'Nimrod', a more recent machine at the same plant, has more than 300 tons of high conductivity copper bars coiled

around its electromagnet. The proton synchrotron at Brookhaven, New York, which is even larger, can accelerate its bombarding particles up to 30 000 million electron-volts. The electromagnet of this huge machine measures 843 ft across and contains about 4000 tons of iron and 400 tons of copper bars in coils. All these giants have evolved from the original small prototype built in 1930. One of its most essential parts, the magnetron body, was turned wholly out of high conductivity copper.

Semi-conductors

The semi-conductor industry is quickly approaching a point at which conventional designs that use aluminium/tungsten conductors and silicon dioxide dielectrics will no longer allow for the speed and integration expected of newer generations of semi-conductors. The remedy is to substitute these materials with lower resistivity copper conductors and/or lower dielectric constant insulators. However, fabricators face a dilemma over whether to implement both of these technologies together, or one at a time. The global market for conventional dielectric materials in 2001 is estimated to be approximately $360 million and is growing at 20% a year. These materials, typically silicon dioxide deposited by chemical vapour deposition (CVD), are undergoing a dramatic change in performance requirements.

Alloys

Low lead red brass casting alloys

Worldwide regulations now limit the amount of lead permitted in public drinking water supplies. These regulations, in turn, have established an immediate need for a reduced lead or lead-free plumbing alloy. Some of the most stringent are to be found in the European Union and the US. The US Environmental Protection Agency's Lead and Copper Rule applies to public water utilities and establishes a framework to monitor and control water chemistry in order to reduce the water's corrosive power. Utilities are required to chemically treat water in a way that is aggressive enough to leach excessive copper or lead from the water supply system.

Copper moulds

Copper is widely used for moulding applications and is thus a highly prized material in the plastics industry. Copper alloy moulds provide faster cycle times for both injection and blow-moulded parts because of their superior heat transfer characteristics. Faster cycle times reflect better equipment utilisation, forestalling the need to purchase additional equipment. Moulders have found that cycle times can be dramatically cut by inserting copper alloy cores in their moulds.

Bearing and wear applications

Copper alloys have excellent wear characteristics against steel surfaces. The broad family of aluminium bronze and nickel–aluminium bronze alloys in both wrought and cast form offer the best combinations of resistance to wear, abrasion, fatigue, deformation and corrosion. Recommended applications include slides, gibs, wear plates, mould locking devices, sleeve bearings, guide pin bushings, lifter blades, ejector sleeves and pins, and rotating mould components.