Chapter 4

Market Structure

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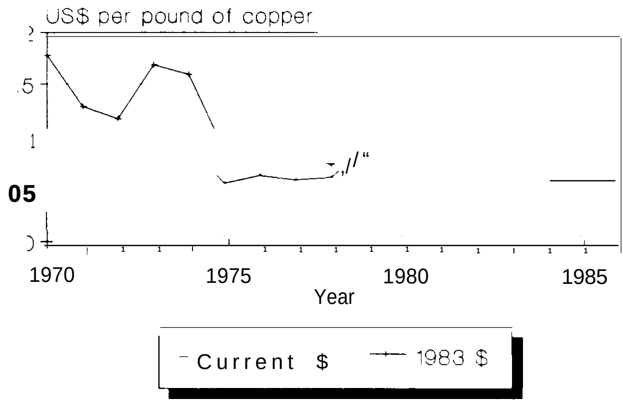
Market Structure

During the 1980s, copper companies worldwide struggled to adjust to a changing market environment. Western world' copper production capacity grew, while consumption declined in industrialized economies due to the 1982-83 **global recession and the aftershock of** the energy crisis. Copper demand in less developed countries (LDCs) also was lower than expected **as** funding for industrial development declined sharply with staggering energy bills and growing international debt. Thus, supply increased steadily despite decreases in demand and the real price of copper during the first half of the decade (see figure 4-1). Significant expansions in government-influenced production capacity, particularly in LDCs, altered the structure of both the industry and the market, From 1980 to 1983, inventories mounted and prices dropped, forcing higher cost operations to reduce output or close. The domestic industry, because of its high wages, strict environmental regulations, and low ore grades, included many high-cost producers and absorbed much of the impact of the shrinking world market. Between 1981 and 1986, U.S. mine production declined 24 percent, while total Non-Socialist World (NSW) mine output fell less than 1 percent.

[1]All data in this chapter, unless specifically stated otherwise, are limited to the Western world, also termed the market economy countries, or the Non-Socialist World (NSW). These refer to all copper producing and consuming market economy countries. This includes Yugoslavia, but excludes Albania, Bulgaria, Czechoslovakia, Cuba, Democratic Republic of Germany, Hungary, Poland, Romania, and the USSR. China is also excluded from consumption and production figures, but is included in trade figures because of the significant amount of copper Imported into China from NSW countries in recent years. A brief description of copper activities outside the NSW market is provided at the end of this chapter.

Figure 4-1.-Average London Metal Exchange Price, 1980-86



SOURCE U S Bureau of Mines data

This chapter reviews the current status of copper markets–supply, demand, and trade–for the United States in particular and the Western world as a whole. The chapter begins with an overview of the events and trends in copper markets since 1980 that shaped the status quo. It then describes copper supply (in capacity, and mine, smelter, and refinery output) and consumption patterns (by product and industrial sector). It also discusses supply and demand trends that are likely to shape the industry for the remainder of this century. Finally, the chapter analyzes recent trends in international trade in copper concentrates, blister and anode copper,[2] and refined products.

[2]Blister is the copper produced by smelting and converting; it is converted to anodes in fire refining (see ch. 6)

OVERVIEW

At the beginning of this decade, the average price of copper on the London Metal Exchange (LME) was 99 cents/lb,[3] NSW stocks were just over 1 million tonnes,[4] and total refined production and consumption were both around 7.1 million tonnes (see table 4-l). That was the post-WWII heyday for the U.S. copper industry. In 1982, when the recession began to ripple through the economy, consumption decreased slightly to 6.8 million tonnes, prices dropped by 32 percent to 67.1 cents/lb, refined copper production rose

[3]All monetary figures ($ and cents) in this chapter are in current (or nominal) U.S. currency

[4]Tonnes refers to metric tons (2204.6 pounds).

Table 4-1.—Overview of U.S. and World Copper Markets: 1980-86 (nominal U.S. cents/lb and 1,000 tonnes)

	1980	1982	1984	1986
Average LME price	99.25	67.14	62.45	62.28
Stocks				
U.S.[a]	314	695	564	225
NSW totai[b]	703	1,100	1,200	796
Total refined production				
U.S.	**1,726**	**1,694**	**1,490**	**1,479**
NSW total	**7,070**	**7,233**	**7,275**	**7,523**
Refined consumption				
U.S.	**1,862**	**1,658**	**2,123**	**2,122**
NSW total	**7,101**	**6,776**	**7,666**	**7,672**

[a]Includes blister and materials in process of refining, plus refined copper held by primary producers, wire and brass mills, and the New York Commodity Exchange.

[b]Includes inventories of refined copper held by the New York Commodity Exchange, the London Metal Exchange, and world refined-copper producers

[c]Includes primary and secondary refinery output.

SOURCE Office of Technology Assessment, from Bureau of Mines and WBMS data

slightly to nearly 7.2 m i I lion tonnes, and inventories shot up nearly 60 percent to about 1.6 milion tonnes.[5]

The short-term factors that caused the market downturn include the high interest rates and veak industrial economic growth that began luring the recession. over the long term, the hift of many developed countries away from manufacturing to service industries; the miniaturization of many electronic parts; the downsizing of automobiles; and the substitution of other materials for copper (primarily aluminum, plastics, and fiber optics) aggravated the drop n demand.[6] Finally, the strong U.S. dollar favored imported copper.

Not all operations adjust their output in response to changes in demand and price; producers consider factors other than current market conditions. Social goals, such as maintaining employment levels and foreign exchange earnings, are important to government-influenced operations. The market conditions for co-product metals are another major consideration. Third, mines that must meet long-term contracts with smelters for concentrates maintain production despite low prices and weak demand. The costs of closing or slowing down an operation also play a role in determining output levels. The influence of all these factors was evident in 1982 when, despite declining demand and prices, 60 percent of the copper producers maintained or increased production. Inventories climbed by 36 percent as a result.

Demand remained stagnant until the economic recovery belatedly reached the copper industry. By 1984, consumption rose to 7.7 million tonnes with refined production at 7.2 million tonnes (see table 4-1). consequently, inventories dropped to 1.2 million tonnes.[7] Even with stronger demand and the reduction of world stocks, however, copper prices stayed low; the average LME price in 1984 was 62.5 cents/lb.

The failure of copper prices to improve in response to the revived market left many domestic producers scrambling to survive. Following the sharp drop in 1982, NSW copper mine production inched upward while U.S. mine production fell slightly. **For most domestic producers, production cutbacks became necessary and high cost mines were closed—some permanently.** The U.S. Bureau of Mines estimates that the mine capacity of major U.S. producers fell nearly 20 percent between 1980 and 1984.[8] Reserves at a few mines that closed were depleted; other mines could only produce economically at prices well above $1/lb. The remaining producers were operating at levels far below capacity, however. In 1983, U.S. copper mines operated at 58 percent of capacity, while Chilean mines produced at 97 percent of capacity.[9] [10]

Domestic producers, saddled with high labor costs, lower ore grades, a high-value dollar, and stringent environmental regulations had to re-

[5]World Bureau of Metal Statistics (W BMS), *World Metal Statistics Yearbook 1987* (May 1987).

[6]*Domestic Consumption Trends: 1972-82, and Forecasts to 1993 for Twelve Major Metals* (Washington, DC: U.S. Department of the Interior, Bureau of Mines, IC 9101, 1986), p.14.

[7]WBMS, supra note 5.

[8]janice L.W. Jolly, "Copper," 1985 *Minerals Yearbook* (Washington, DC: U.S. Department ot the Interior, Bureau of Mines, 1987), p. 327.

[9]Janice L.W. Jolly, "Copper, " *Mineral Facts and Problems* (Washington, DC: U.S. Department of the Interior, Bureau of Mines, 1986), p. 201.

Incapacity utilization rates otien cannot be compared due to the difficulties associated with defining and quantifying available capacity. However, it IS important to note that a major difference in capacity utilization existed and that U.S. producers held significant Idle capacity.

duce costs if they were to compete in the world market. Major changes such as wage and benefit concessions, capital investments in plant and equipment, revised mining plans (including higher cut-off grades and lower stripping ratios), overhead reductions, productivity improvements, and debt restructuring were instrumental in reducing costs (see ch. 10).

After peaking in early 1985, the dollar devalued against the currencies of other developed countries, such as Japan. This brought benefits for domestic smelters in 1986. Initially, the Japanese smelting industry attempted to retain its market share by maintaining dollar prices for treatment and refining charges. By December 1986, Japanese smelters, driven by mounting losses, were forced to raise these charges by as much as 50 to 80 percent to adjust for the weaker dollar. '[11]

[11] D. Maxim, "Exchange Rate Developments and the Primary Copper Industry, " paper presented at the conference on Public Policy and the Competitiveness of U.S. and Canadian Metals Production, Golden, CO, Jan. 27-30, 1987, p. 12.

Copper operations in countries such as Spain, Germany, and Finland also suffered from the devaluation of the dollar. The value of the dollar rose, however, against the currencies of Chile, Peru, Zambia, and Zaire, all major copper producers. This increased their profits in local currency terms.

By the end of 1986, the world copper industry showed signs of a revival. production and consumption reached the highest levels in 10 years and inventories dropped sharply—to less than half the 1983 level. In 1987, the recovery continued. Relatively strong demand (including increased speculation), plus supply disruptions in Canada, Zambia, and Peru, tightened the world copper market. Inventories fell to minimum levels and prices soared, providing a needed boost for both domestic and world producers.

DOMESTIC AND WORLD COPPER SUPPLY

The copper industry is dynamic, with a constantly changing technical, corporate, and market environment. New technologies continue to reduce costs and facilitate mining even very low grade deposits. The nature of the industry–large and capital intensive projects requiring extensive exploration and development—often makes response to change slow, however. Entering and exiting the market are neither simple nor cheap. Exit costs are substantial and discourage closures unless market conditions are severe or reserves are exhausted.

Still, new sources of supply are needed to replace depleted ones. Even if copper demand continues to grow at its recent modest 2 percent annual rate or less, new mines will be needed to keep the market in balance. To examine the world copper supply outlook, and the role of the United States therein, it is essential to identify where supply and demand come from now, and where they are likely to originate in the future.

Capacity

Identifying potential sources of supply (i.e., ore bodies and their developers) is relatively simple, but determining the production capacity is more difficult. Capacity is a function of many factors, including price, technology, costs, ore grade, and demand. Moreover, the definition of capacity varies among analysts. Some reports use the rated engineering capacity of equipment or plants, regardless of actual or potential operating status. Others use actual output for a given period, regardless of underlying economic and other conditions (e.g., labor strikes, bad weather, or temporary fluctuations in ore grade). Furthermore, some analysts do not include a mine's copper output in a country's capacity data if copper is not the primary metal produced (i. e., it is a byproduct or coproduct of other metal mining). As a result, capacity estimates vary widely, and output can be considerably greater or much less than reported capacity.

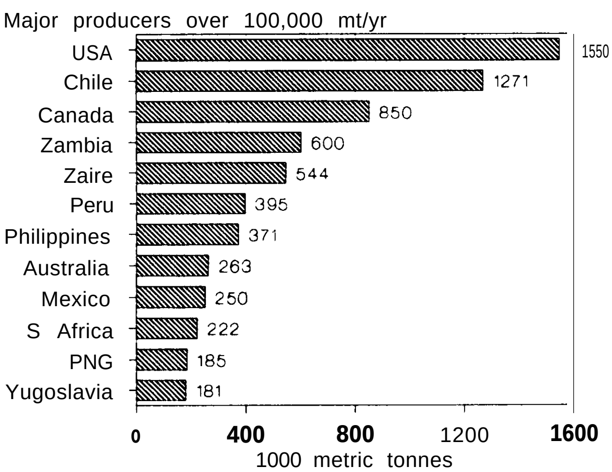
The status of individual operations also is often ambiguous. For example, facilities listed as temporarily shut down may be considered available capacity when, in fact, they are highly unlikely to reopen (e.g., equipment has not been maintained or has been cannibalized). The longer an operation remains idle, the less likely that it will resume production as technological advances increase the capital investment needed to reenter the market. At the same time, corporate strategies postpone the high costs associated with permanent closure, substituting the lower maintenance costs of a "temporary" shut-down.

At the beginning of 1984, the U.S. Bureau of Mines estimated copper mine production capacity in 37 countries at 7.4 million tonnes per year (see figure 4-2).[12] Twelve countries had mine capacity greater than 100,000 tonnes, accounting for 90 percent of the total. The United States had the largest share, with nearly 1.6 million tonnes, followed by Chile with about 1.3 million tonnes. Canada, Zambia, and Zaire also have substantial capacity, with 850,000, 600,000, and 544,000 tonnes, respectively, in 1984.

As of January 1987, annual mine capacity of ***producing*** operations in the United States had dropped slightly to about 1.5 million tonnes.[13] Seventeen mines account for 92 percent of domestic capacity. Phelps Dodge has replaced Kennecott (now BP Minerals America) as the nation's largest copper producer. Phelps Dodge's capacity in four mines amounts to more than 530,000 tonnes (including 75,000 tonnes held by two Japanese partners), or 36 percent of domestic capacity. Also included in the domestic capacity total is nearly 200,000 tonnes from BP Minerals' newly reopened Bingham Canyon mine.

[12] Jolly, supra note 8.

Figure 4-2.-World Copper Mine Capacity (1984)



SOURCE The World Bank

Capacity Utilization

Copper's strong demand growth and high earnings in the 1960s (and much of the 1970s) stimulated exploration and development for new mines as well as expansions at existing facilities. The subsequent downswing resulted in a great deal of this capacity being idled. Very low capacity utilization rates frequently were cited to highlight the industry's distress, especially in the United States. **When prices rose so dramatically in 1987 and domestic production did not increase correspondingly, it became apparent that significant idle capacity was not waiting in the wings for improved market conditions.**

Spot shortages in copper markets during 1987 also imply that industry estimates of available (i.e., economically re-openable) capacity were high. One estimate suggests that "only 45 percent of the 0.9 million tonnes of mine capacity on standby at the end of 1985 was genuinely re-openable."[14] Comparing 1986 Western world production data to an International Wrought Copper Council estimate of available capacity yields utilization rates of 82.6 percent, 86 percent, and 87.5 percent for mines, smelters, and refineries, respectivel y.[15]

Mining

Since 1970, 52 market economy countries have reported copper mine production. In 1986, NSW

[13] Simon Strauss, "Copper: In 1986 the Metal Belied its Reputation for Volatility, " *Engineering and Mining Journal*, March 1987.
[14] P.C. F. Crowson, "Aspects of Copper Supplies for the 1990s, " paper delivered at Copper 87, conference held in Chile, November 1987.
[15] Ibid.

copper mines produced 6.66 million tonnes. **While nearly 40 Western countries reported mine production, eight—Chile, the United States, Canada, Zambia, Zaire, Peru, Australia, and the Philippines—accounted for 78 percent of total mine output (see figure 4-3).** [16]

The U.S. industry led the world in copper mine production for over a century, but lost that position to Chile in 1982. As shown in figure 4-4, Chile's copper industry has been growing rapidly, with mine output nearly doubling from 1970 to 1986. At the same time, U.S. copper production was declining; in 1986 it was 27 percent lower than in 1970. Zaire and Canada show modest growth, while Zambian production has declined slightly. Output from the numerous other producers has increased sharply, due in part to strong growth in countries that already had established mining industries (e.g., Mexico and Peru), and in part to the appearance of new producers such as Papua New Guinea and Indonesia.

Chile mined nearly 1.4 million tonnes in 1986 (21 percent of total output). Corporation del Cobre de Chile (Codelco–Chile's nationalized copper company), announced ambitious plans for expanding mine production, but budget constraints prevented their implementation.

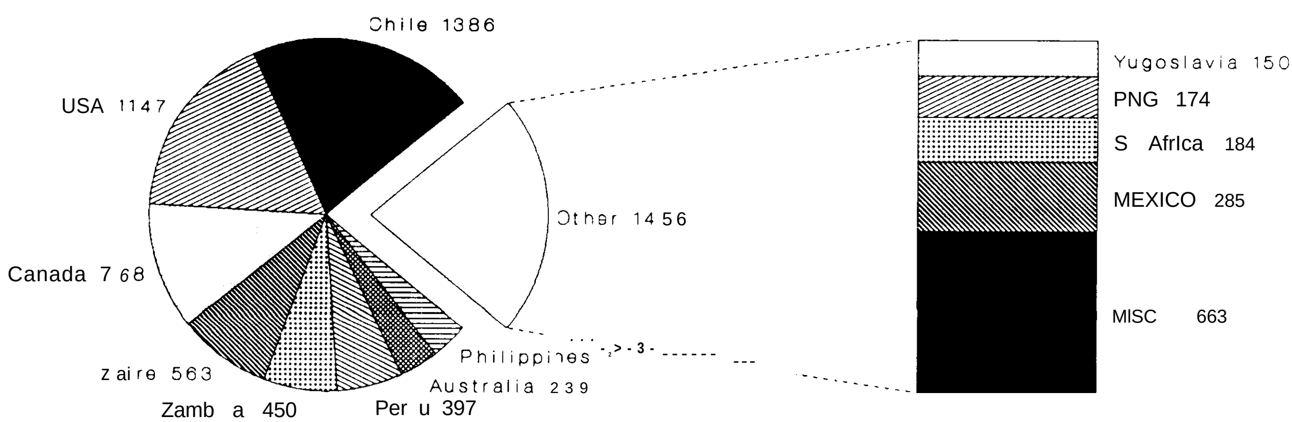
In 1986, the U.S. industry continued to recover from its weak 1983 level, increasing mine production almost 4 percent to around 1.2 million tonnes (17 percent of NSW total). Arizona accounted for nearly 70 percent of U.S. output, with New Mexico and Michigan in second and third places. In total, 87 mines located in twelve States produced copper in 1986; at 61 of these, copper was the primary product, and at 26 it was a byproduct of gold, lead, silver, or zinc mining.[17] Two U.S. mines reopened in the second half of 1986, including Bingham Canyon in Utah and the Continental Mine in Butte, Montana. Earlier that year, things had not been so optimistic when inspiration reduced production by 40 percent and laid off 300 employees.

The improved domestic position resulted from a variety of efforts made by the domestic industry to enhance its competitiveness, including lower labor, energy, and transportation costs; capital investments in plant and equipment; and changes in mining plans (see ch. 10). The impact of these efforts is evidenced by the almost 40 percent increase in productivity in domestic copper

[16] Janice L. W. Jolly and Daniel Edelstein, "Copper," preprint trom *1986 Bureau of Mines Minerals Yearbook* (Washington, DC, U.S. Department of the Interior, Bureau of Mines, 1987).

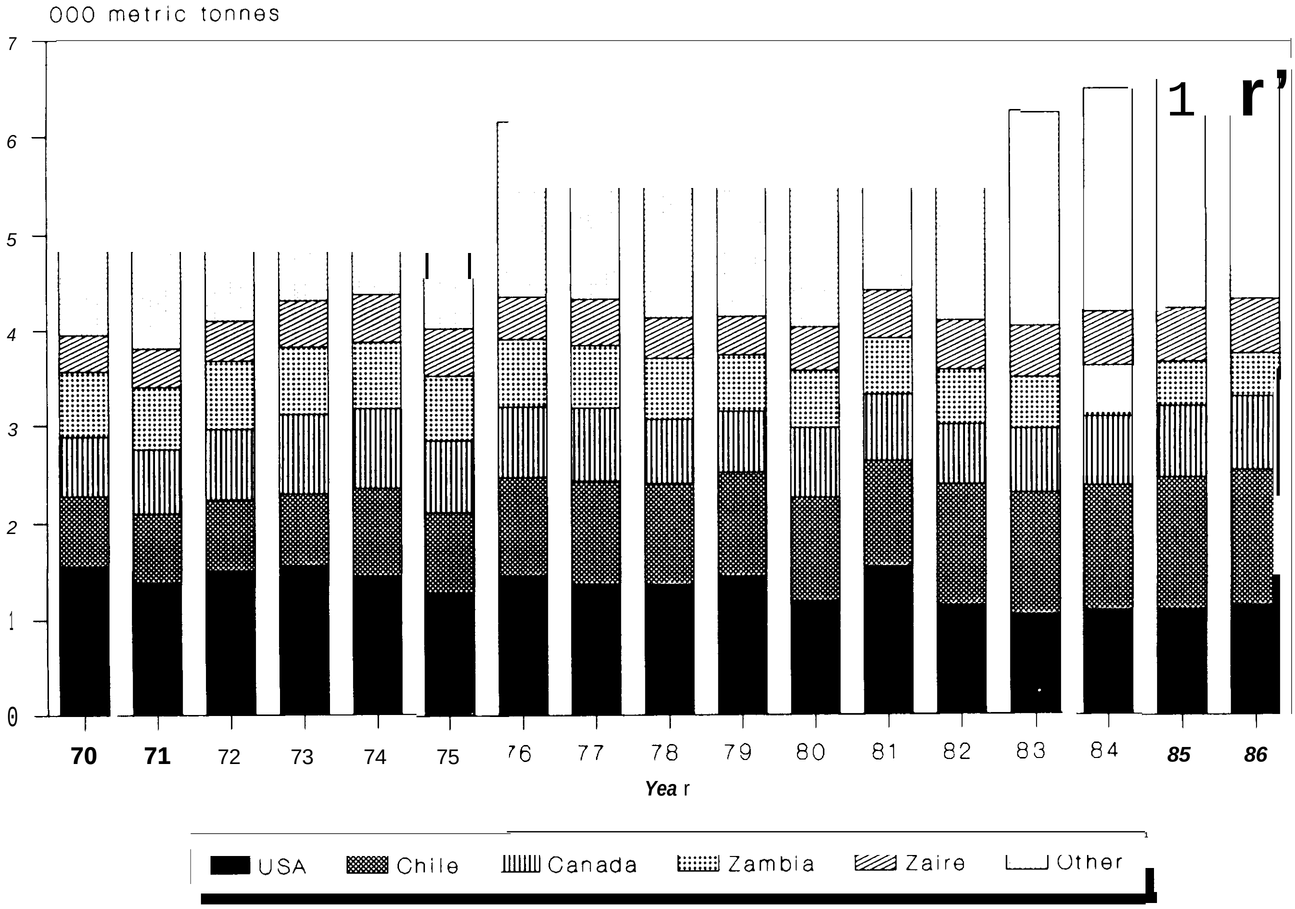
[17] Ibid.

Figure 4-3.-Copper Mine Production in the Market Economy Countries (1986) (1000 metric tonnes)



SOURCE U S Bureau of Mines data

Figure 4-4.-Trends in Mine Production, 1970-86



SOURCE" U S Bureau of Mines data

mining between 1980 and 1984, shown in figure 4-5.

Canada maintained its position as the third largest copper producer in 1986 with output of 768,200 tonnes (1 1.6 percent). A strike during most of November and December at Noranda's Home smelter, which processes ores from several small mines, resulted in slightly reduced aggregate mine production. Three Canadian properties-Highmont, Lornex and Valley–were consolidated during the year and an increase in their total output is expected. Deepening of the Ruttan Mine also increased its output. '8

Zaire, the fourth largest copper producing country, mined 563,000 tonnes in 1986. The State-owned La Generale des Carrieres et des Mines du Zaire (Gecamines) has a 5-year investment program to rehabilitate its industry. The program focuses on maintaining mine production capacity while raising productivity and reducing costs, primarily through worker training, revised mining plans, and capital invest merit. '9

The Zambia Consolidated Copper Mines Ltd. (ZCCM), which accounted for all of Zambia's mine, smelter, and refinery production, mined 450,000 tonnes of copper in 1986. As in Zaire,

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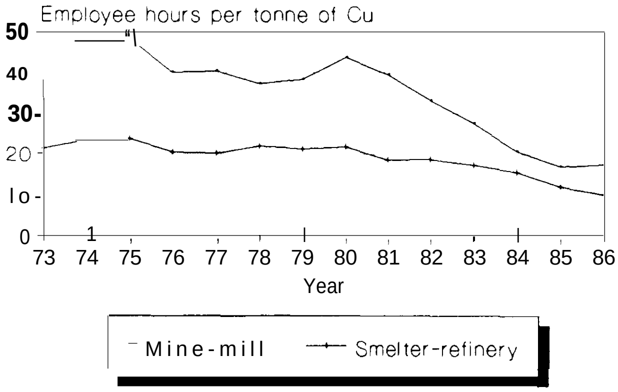
Figure 4-5.-Productivity in the U.S. Copper Industry: 1973-86



SOURCE U S Bureau of Mines

ZCCM announced a 5-year reorganization plan to reverse deterioration of its copper operations. The plan included near-term closure of 50,000 tonnes annual mine capacity as soon as reserves already drilled become exhausted. The Kansanshi and Chambishi copper mines, and one shaft of the Konkola mine closed by mid-1986. The plan reflects a strategy to reduce excess smelter and refinery capacities vis-a-vis mine production and to increase SX-EW production. In total, **20,000 workers** will be affected–3,000 in 1986 alone.[20]

Despite labor problems, Peruvian mine production was up slightly in 1986 to 397,400 tonnes. Three State-owned mining companies (Centromin Peru, Minero Peru, and Tintaya) and one privately-owned company (SPCC) accounted for about 96 percent of Peru's copper production. The two largest companies–SPCC and Centromin—experienced a combined reduction in mine output of around 19 percent.[21]

Approximately thirty other market economy countries reported mine production in 1986, including copper produced as a byproduct of other mining activities. These countries accounted for 29 percent of the NSW total with combined production equal to 1.9 **million tonnes.**

Smelting

Western world primary smelter production was nearly 6 million tonnes in 1986—a 13 percent increase since 1970. Total NSW smelter production (primary and secondary) was 6.8 million tonnes. **While the United States still holds the lead in total smelting (primary and secondary), domestic primary output has dropped almost 40 percent relative to** 1970. **Chilean primary smelter output has increased consistently in the last two decades, passing the United States in 1982 to become the world leader (see** figure 4-6).

Domestic smelters produced nearly 1.2 **million tonnes (17.5 percent of the** NSW total), including 908,100 tonnes of copper from domestic and imported ores and concentrates and 287,800 tonnes from scrap materials. Nine primary smelters and seven secondary smelters operated during 1986, with one of each closing permanently in 1987. The United States imported almost .5,000 tonnes of copper contained in concentrates, versus 174,348 tonnes exported.[22]

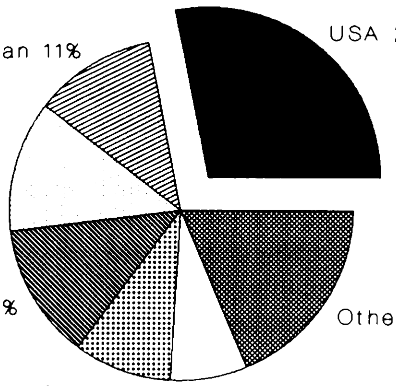
The scheduled reopening of two domestic smelters and the modernization of a third showed evidence of a recovery in the U.S. primary copper smelting industry in 1986. The White Pine smelter in Michigan reopened in 1986 and the Garfield smelter in Utah restarted in 1987. Magma Copper is installing an Outokumpu flash furnace at its San Manuel, Arizona smelter. When it reopens late in 1988, the smelter will be the largest single-furnace smelter in the world, processing about 2,700 tonnes of concentrates daily.

Phelps Dodge's Douglas, Arizona, smelter was permanently closed in January 1987 as part of an agreement reached between the company, the U.S. Environmental Protection Agency, and the State of Arizona. The Douglas smelter was built in 1904, and PD would have had to completely rebuild it to bring it into compliance with air quality standards. Phelps Dodge partially compensated for the loss of the Douglas smelting capacity by buying Kennecott's two-thirds share in the Chino, New Mexico mine and smelter in 1986.

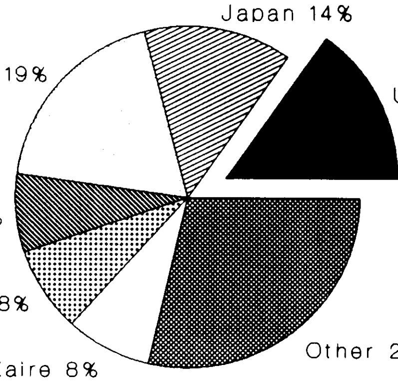
[20] Ibid.
[21] Ibid.

[22] Ibid.

Figure 4-6.-Primary Smelter Production: The U.S. Share Has Declined



1970



1986

SOURCE: U.S. Bureau of Mines data

Chile ranked second in smelting with reported output of 1.113 million tonnes (1 6.2 percent of NSW total), followed by Japan with 951,400 tonnes (1 3.9 percent). Zaire and Zambia are also major players in smelting, reporting outputs of 480,000 and 452,000 tonnes, respectively, Other top smelters included: Canada, 491,000 tonnes; Peru, 297,700 tonnes; Federal Republic of Germany, 246,000 tonnes; and Australia, 176,900 tonnes. The residual total of all other smaller producers amounted to 1.42 million tonnes, or 20.8 percent of total NSW smelter production (see figure 4-7).[23]

Refining

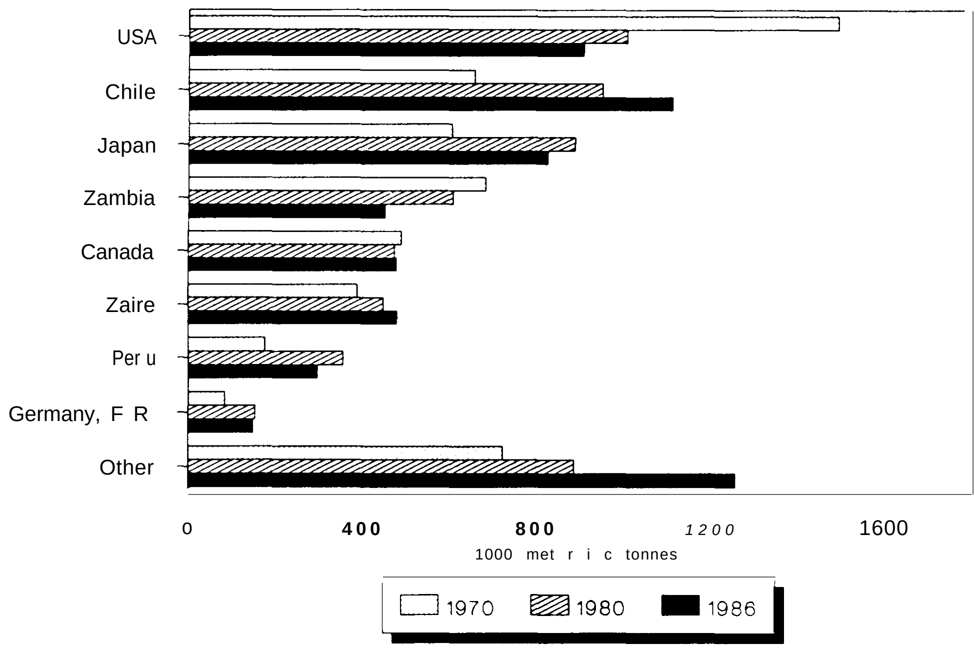
Western world primary copper refineries produced 6.3 million tonnes in 1986–the strongest level since 1982 **and a 2 percent increase over 1985. Western refineries also produced nearly 1.2 million tonnes from scrap. World primary refinery production has increased about 12 percent in the last 10 years, yet domestic production has dropped 23 percent during that time.** The U.S. share of NSW primary refined copper production fell from almost **25 percent in 1976 to only about 17 percent in 1986. Chile has enjoyed the largest growth in refined copper production, increasing 47 percent since 1976.**

Canada, Zambia, the Federal Republic of Germany, and Belgium are also significant producers of refined copper (see figure 4-8). Four of the smaller producers—the Philippines, South Korea, South Africa, and Brazil–have experienced dramatic increases in output. In 1976, aggregate primary production from these four countries was 126,500 **tonnes, or 2.2 percent of the** NSW **to**tal. By 1986, their combined primary refinery output had increased to 564,900 tonnes, or 8.9 percent of the NSW total.

Total domestic refined copper production rose 3 percent in 1986 to 1.48 million tonnes, including **406,000 tonnes from secondary sources (smelter and** refinery scrap). Primary production was 1.07 million tonnes—a 1.5 percent increase over 1985. Virtually all of that increase was attributable to electrowon copper. Primary sources included around 5,000 tonnes imported concentrates and 35,000 tonnes imported blister and anode copper (see figure 4-9). Twenty-four domestic refineries operated during 1986, including 8 electrolytic, 10 electrowinning, and 9 fire-refining facilities (some refineries had more than one type of facility).

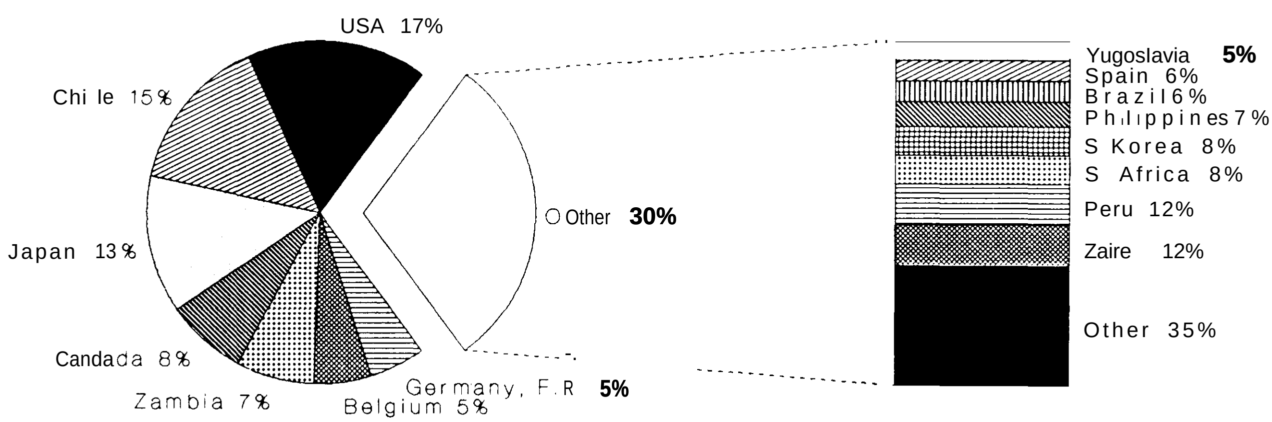
[23]Ibid.

Figure 4-7.-Primary Smelter Production: 1970, 1980, 1986



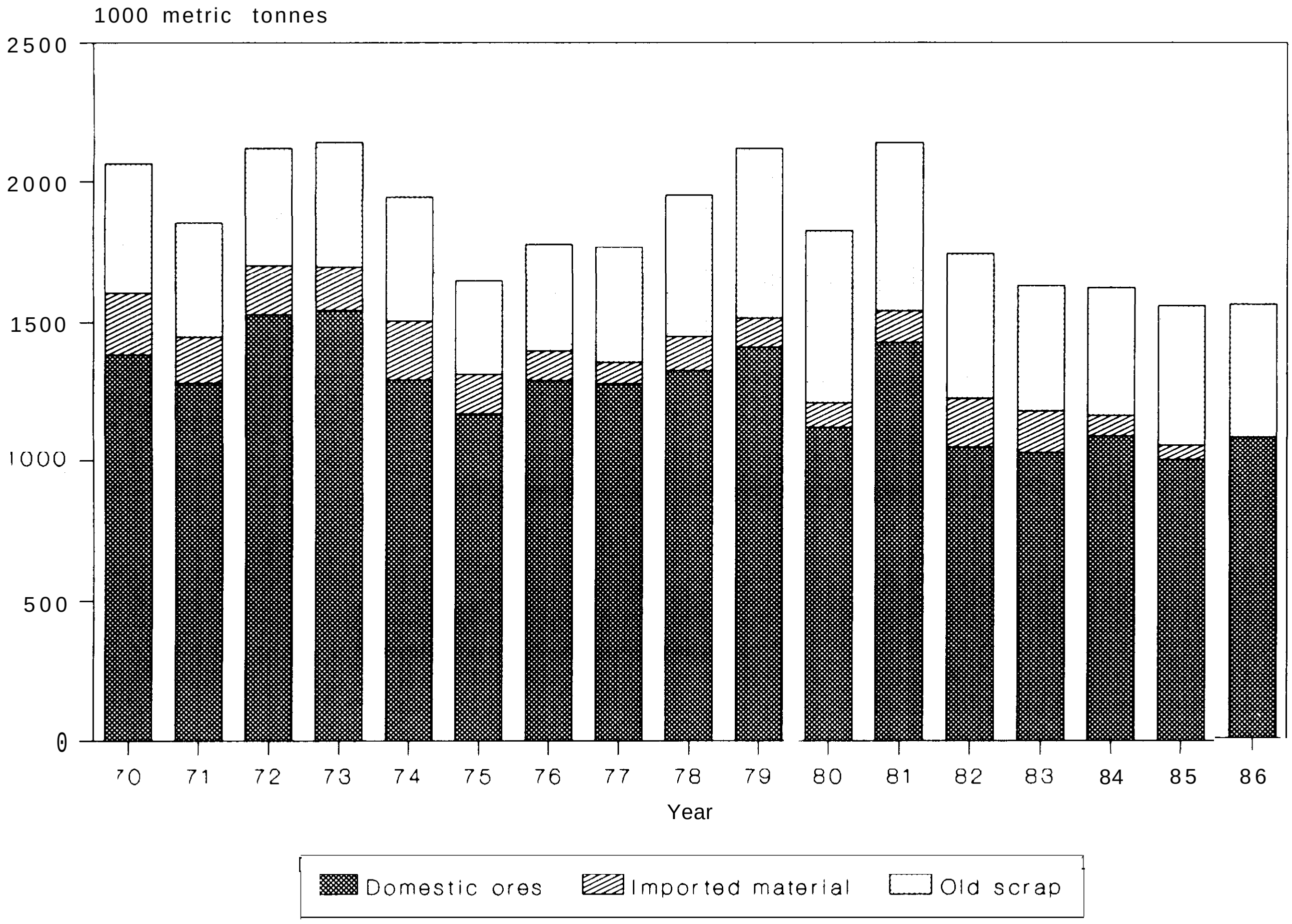
SOURCE U S Bureau of Mines data

Figure 4-8.-Primary Refinery Production, 1986



SOURCE U S Bureau of Mines data

Figure 4-9. -U.S. Production of Refined Copper by Source, 1970-86



NOTES: Old scap only. 1986 data on imports not available
SOURCE' U S. Bureau of Mines data.

Chile (935,000 tonnes) and Japan (827,700 tonnes) followed the United States, providing 14.7 and 13 percent of 1986 NSW refinery output, respectively. Thirty-one other countries reported production for the year, with the top 10 accounting for 80 percent of the total.

Leaching and Solvent Extraction/Electrowinning

The current ability of the U.S. copper industry to produce copper at a price competitive in world markets is due in part to expanded use of solution mining and solvent extraction-electrowinning (SX-EW) technologies. As described in chapter **6, solution mining (or leaching) uses** chemical solutions or water to extract copper from ores. Solution mining can operate on vats or heaps of ore mined specifically for leaching, or the solutions can be applied to old mine workings and mine waste dumps. In the future, solution mining also will be used with undisturbed ore bodies. After leaching, the copper is either precipitated out of the solution, or the copper-Iaden solution goes through solvent extraction and electrowinning plants to produce cathodes, Production of copper cathodes using these techniques is far less complicated than conventional mining/milling/ smelting, and can cost less than 30 cents/lb for old workings and waste dumps.

Photo *credit' Jenifer Robison*

Sprinklers applying leach solution to mine waste dumps. Copper produced by leaching accounted for almost 19 percent of U.S. mine production in 1986.

Leaching/SX-EW of oxide and oxidized sulfide ores is very attractive in today's competitive copper markets because the technology has low capital costs and can be amortized rapidly compared to conventional mining, milling, and smelting. It can be built quickly, is flexible in its applications, and can be run practically at any scale; it has low operating costs, including energy use and environmental control requirements; and it requires minimal supervision compared to conventional copper production .24

As a result, the number of ongoing and planned SX-EW projects in the United States and other major copper producing countries have increased significantly since 1980 as part of copper companies' strategies to reduce costs (see box 4-A). **In 1986, the United States had around 263,000 tonnes of SX-EW capacity. Another 186,500 tonnes are planned, 145,500 by 1990 (see table 4-2).**

U.S. mines leached ore with a recoverable copper content of around almost 215,000 tonnes (including dump leaching) in 1986. Ten electrowinning plants operated in the United States in 1986, producing around 125,400 tonnes of copper (around 12 percent of U.S. primary refinery production).[25] [26]

At least five other Western countries currently produce copper through leaching/SX-EW: Can-

[24] United Nations Industrial Development organization (UNIDO), *Technological Alternatives for Copper, Lead, Zinc and Tin in Developing Countries*, report prepared for the First Consultation on the Non-ferrous Metals Industry, Budapest, Hungary, July 1987.

[25] Jolly and Edelstein, supra note 16.

[26] It should be noted that total electrowinning production reported before 1986 included AMAX's Braithwaite, Louisiana, plant, which processed Imported copper) nickel matte.

Box 4-A. —Phelps Dodge and SX-EW Processing

Phelps Dodge (PD), the nation's largest copper producer, has found the SX-EW facilities at its Tyrone operation to be a major cost-cutter. In 1984, this plant produced around 10,300 tonnes of copper at a total unit cost, including interest and depreciation, of less than 30 cents/lb.1 Leaching plus SX-EW reduced overall Tyrone production costs as much as 11 cents/lb between 1980 and 1985.2 The process was so successful that PD expanded the Tyrone electrowinning plant, increasing its output to about 32,000 tonnes in 1986. Further expansion to a total capacity of 50,000 tonnes/yr is scheduled for 1988 to 1989.3

To further benefit from this strategy, PD is adding two other SX-EW plants–at Morenci and Chino. These will require a capital outlay of $130 million, with approximately the same cost of production as at Tyrone. The 45,000 tonne/yr SX-EW plant at Morenci began operation in 1987; expansion to a total capacity of about 68,000 tonnes/yr is expected within the next few years. A 40,000 tonne/yr plant at Chino is expected to come on line in 1988.4

Phelps Dodge also is evaluating a recently explored ore body near Bisbee, Arizona, for its leaching and SX-EW processing potential. Preliminary drilling results indicate 155 million tonnes of 0.5 percent copper ore amenable to SX-EW. If these results hold true in further exploration, annual production is estimated to be around 40,000 tonnes/yr. S

These facilities, plus increased smelter production at Chino, should compensate for the approaching exhaustion of sulfide reserves at Tyrone. The share of electrowon copper produced by PD using leaching plus SX-EW is expected to rise from its 1986 level of 8.7 percent to 33 percent or more by 1989.[6]

[1]G. Robert Durham, "Remarks," speech given at the Northwest Mining Association, 92nd Annual Meeting, Spokane, Washington, December 4, 1986.
[2]United Nations Industrial Development Organization (UNIDO), *Technological Alternatives for Copper, Lead, Zinc and Tin in Developing Countries*, report prepared for the First Consultation on the Non-ferrous Metals Industry, Budapest, Hungary, July 1987.
[3]"Phelps Dodge Has Something to Smile About," *Engineering and Mining Journal,* August 1987.
[4]Ibid.
[5]"North American SX-EW Copper," *Mine Development Bimonthly*, vol. V, No. 2, Oct. 31, 1987.
[6]*Engineering and Mining Journal*, supra note 3.

ada (5,000 tonnes capacity), Chile (90,000 tonnes capacity), Peru (35,000 tonnes), Mexico (14,000), and Zambia (475,000). Near-term expansions have been announced at Chuquicamata in Chile, and Cananea in Mexico. Reported electrowon copper production in these countries in 1986 **was over 130,000 tonnes.**

Future Supply Considerations

Overcapacity and low copper prices have existed in the copper industry throughout most of the 1980s. Ambitious development plans prevalent in the 1970s have largely been replaced with strategies aimed at reducing costs at existing facilities. Most recent capacity increases have been new or expanded SX-EW facilities. With the exception of small, relatively high-grade deposits, this trend is expected to continue until in situ solution mining techniques become commercial. Then U.S. producers will begin to exploit large oxide deposits, again with SX-EW technology,

Planned expansions of traditional mining capacity primarily are overseas, where labor costs are lower, ore grades higher, and environmental regulations less stringent. The Ok Tedi Mine in New Guinea began producing copper in 1987, with long range plans for a capacity of 600,000 to 700,000 tonnes/yr of concentrates. However, continuing financing and operational difficulties make the amount produced and the schedule uncertain. During 1988, the Neves Corvo mine in Portugal is projected to come on line with an annual capacity of about 100,000 tonnes of copper in concentrates, and the new Australian operation, Olympic Dam, will add an additional **55,000 tonnes.** The Escondida mine in Chile is tentatively planned to come on line in the early 1990s (perhaps as early as 1991), with Utah international holding a majority share. Initial

Table 4-2.—Solvent Extraction/Electrowinning Capacity

Project	Location	Existing capacity[a] (tonnes/yr)	Operating status	Planned capacity addition (tonnes/yr)	Estimated cost ($/lb)	Comments
Bisbee	Arizona	—		41,000	$0.50	drilling snows 155 million tonnes 0.5°/0 Cu amenable to Sx
Cyprus Bagdad	Arizona	6,800	Open		0.45	Cost includes mining; without mining, cost is 29 cents/lb
Cyprus Casa Grande. . . .	Arizona	18,000	Open	22,000	<0.40	Purchased from Noranda in 1987; ore leached in situ
Cyprus Johnson	Arizona	4,300	Closed		0.50	Closed permanently at end of 1986
Inspiration	Arizona	45,000	Open	13,000	<0.60	All mined ouput for 1986-87 processed by leaching
Miami	Arizona	6,000	Open		0.60	
Morenci	Arizona	45,000	Open	23,000	0.25	Date of expansion uncertain
Pinto Valley	Arizona	8,000	Open	12,000	0.37	Leaching low-grade sulfide ore; leaching of tailings to begin in 1989
Ray	Arizona	36,000	Open		0.50	Leaching 1.25°/0 silicate ore
San Manuel	Arizona	22,500	Open	22,500	0.45	Planned in situ leaching and capacity expansion to begin 1988
Twin Buttes	Arizona	30,000	Closed		0.50	Mine leased by Cyprus in 1988; SX-EW status uncertain
Battle Mountain. , ... , . .	Nevada	6,500	Closed		0.50	
Chino	New Mexico	—		41,000	<0.30	Startup expected late 1988
Tyrone	New Mexico	35,000	Open	15,000	<0.30	Expansion expected 1988-89
Gibraltar	BC, Canada	5,000	Open		0.35	Opened in 1986; first SX-EW in Canada
Chuquicamata	Chile	50,000	Open	40,000	0.45	Current expansion planned for 1990; long-term plans for 250,000 tonnes total
El Teniente.	Chile	5,000	Open		<0.30	
Lo Aguirre	Chile	14,000	Open		0.35	
Las Cascadas	Chile	20,000	Open		0.60	
Cananea	Mexico	14,000	Open	20,000	NA	Startup expected late 1988; leaching low-grade (0.15-0 .45% Cu) dumps
Cerro Verde	Peru	35,000	Open		0.40	
Nkana	Zambia	125,000	Open		0.35	
Nchanaa	Zambia	350.000	Open		NA	Must be re-refined

NA = not available.
aA~t"al production in any year may be less

SOURCE Off Ice of Technology Assessment, from data published by the U S Bureau of Mines, *Mine Development Bimonthly,* and the United Nations Industrial Development Organization

planned output is 200,000 tonnes/yr, increasing to 300,000 tonnes/yr. Other new projects include the Salobo copper-gold deposit in Brazil (1 10,000 tonnes/y r); the Maria mine in Sonora, Mexico; and the Ansil property in Canada (30,000 tonnes/yr) .[27]

These expansions will be balanced to some extent by cutbacks in other regions. Mines that are nearing the exhaustion of their resources include Tyrone in New Mexico and Prieska in South Africa. Operational problems (including disruptions due to weather and labor) continue to trouble Chile, Peru, and several smaller producers. Mine operation and development in Zambia and Zaire have suffered from inadequate capital investment and now are having trouble attracting skilled employees due to the unstable political environment and the threat of **AIDS;** their future output is thus uncertain. Finally, efforts to reduce production costs in recent years, including higher cut-off grades, lower stripping ratios, and abandoning low-grade sections of underground mines, have reduced the life of some mines.[28]

~-Simon D. Strauss, "Copper: Prices Surged Unexpectedly,' " *Engineering and Mining Journal,* April 1 988

[28] Ibid.

DEMAND

Properties and Uses

Copper possesses valuable physical, chemical, and mechanical properties that make the metal and its alloys[29] useful in nearly every sector of the economy. Copper exhibits very high electrical conductivity (second only to silver in volumetric conductivity, and to aluminum in mass conductivity), as well as high thermal conductivity. It also is nonmagnetic and is among the strongest and most durable metals while still being highly malleable. Moreover, copper is especially resistant to corrosion and fatigue, and inhibits the attachment of organisms such as algae, mussels, and slime to submerged structures (biofouling).

Demand for copper in individual sectors of the economy varies with economic conditions and consumer demand for products (e.g., elec-tricity demand growth, housing starts, automobile purchases), **as well as with the price and availability of materials that might be used instead of copper.** Over the last two decades there has been a significant increase in copper use in the electrical and electronics industries due to the growth of electronic devices in computers and telecommunications, consumer products, and automobiles. The combination of all electrical/electronics uses accounted for an average of **50 percent of the semifabricator market during the 1960s, but had risen to around 70 percent of apparent domestic consumption by 1986.**[30]

Construction industry demand ranked second in 1986, with 15 percent. The major non-electrical uses there included plumbing and heating materials, air conditioning and commercial refrigeration equipment, and roof and wall cladding. Next was the industrial machinery and equipment industry, with 6 percent of total domestic demand. in-plant equipment and industrial valves and fittings are the major non-electrical uses in this market.[31]

[29] Including brass, bronze, copper nickel, copper-nickel-zinc alloy and leaded copper; see ch. 1.
[30] Jolly and Edelstein, supra note 16.
[31] Ibid.

The diversity of uses for copper and its alloys is evidenced in the range of consumer goods and general products associated with these materials. Consumer goods containing copper metal or its alloys vary from appliances and cooking utensils to fasteners to jewelry and objets d'art. Other miscellaneous uses include coinage, chemicals, pharmaceuticals, and furnishings. Consumer goods and miscellaneous applications (including non-electrical military uses) represented 5 percent of 1986 total domestic demand for copper mill products.[32]

Virtually all modes of transportation contain copper products. Radiators, bearings, and brake linings are only a few of the many automobile parts made with copper or copper alloys. Resistance to corrosion and biofouling have made copper products invaluable in a number of applications associated with marine transportation, including propeller shafts, steam and water lines, and cladding for hulls. The railroad, aircraft and aerospace, truck; and bus industries also make widespread use of copper products. In total, the transportation industry accounted for the remaining 4 percent of domestic demand for copper mill products in 1986.[33]

The shares of demand for these end-use sectors change substantially when the electrical and electronics applications are distributed among them (e.g., the majority of electrical wiring is included in construction, and copper wire in cars and trucks is included in the transportation sector rather than in electrical/electronics uses; see figure 4-1 O). Again, significant variance over time also is evident. Figure 4-11 compares U.S. copper demand by sector for 3 years: 1979, a year of record consumption; 1982, a recession year; and 1986, a year of recovery.

Using these disaggregate data, the major domestic market for copper in 1986 was the construction industry, accounting for around 41 percent of total demand. The second largest market –23 percent–was in the electrical industry for cable, electric motors, power generators, fans,

[32] Ibid.
[33] Ibid.

Photo credit: Jenifer Robison

Architectural uses of copper have seen a renaissance in the 1980s, in part due to the low price and in part to new coatings that greatly retard formation of the patina caused by exposure to the elements. Here, a copper strip is placed above reflective glass windows.

blowers, lighting, industrial controls, transformers, bus bars, and switchgears. Next was the industrial machinery and equipment industry, with 14 percent of total domestic demand, followed by transportation (almost 13 percent), consumer goods and miscellaneous applications (9 percent).[34]

Copper is a significant critical metal. While only 1 percent of U.S. copper consumption goes to ordnance, per se, copper wire is a critical component of all electrical and electronics needs, including command-communication-control-intelligence ($C^3$1) systems. Military aircraft and vehicles, and tactical, strategic, and advanced weaponry systems also use significant quantities of **copper. Military demand** for electronic equipment and computer components is expanding. Finally, the vast industrial base that supports the national defense requires machinery and goods containing copper.[35] For example, **copper demand doubled within the first year of** WWII, and increased 25 percent within the first year of the Vietnam War.

World Consumption

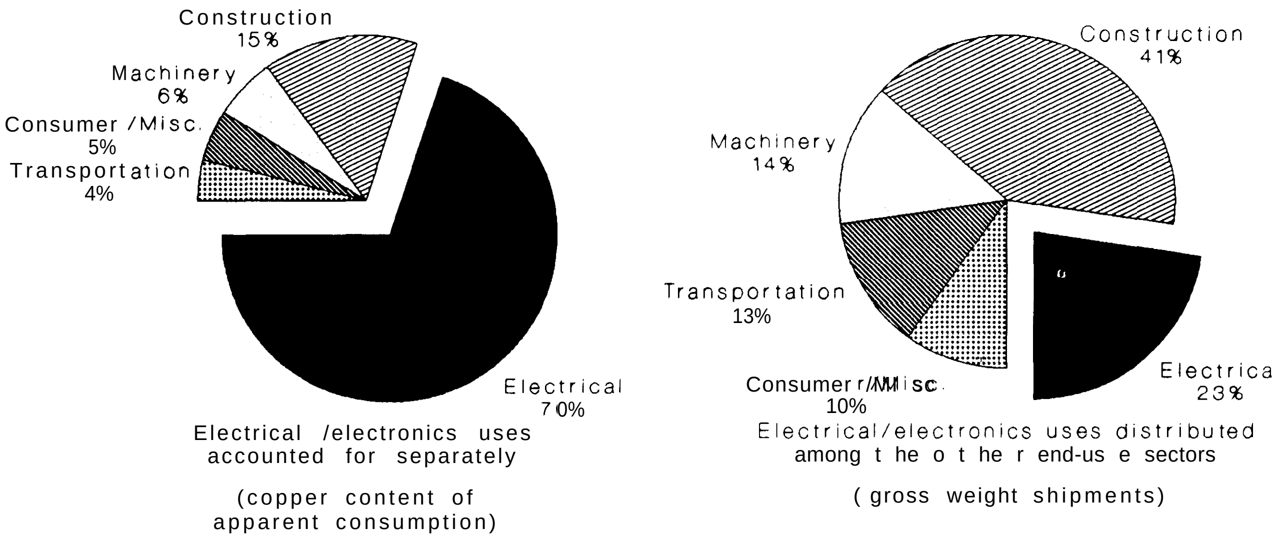
Total NSW demand for refined copper[36] was 7.67 million tonnes in 1986. **The United States is the largest user of refined copper,** with con-

[34] Copper Development Association, "Copper and Copper Alloy Mill Products to U.S. Markets– 1986,' *CDA Market Data,* May 10, 1987.

[35] Louis Sousa, *The U.S. Copper Industry, Problems, Issues, and Outlook* (Washington, DC: U.S. Department of the Interior, Bureau of Mines, October 1981).

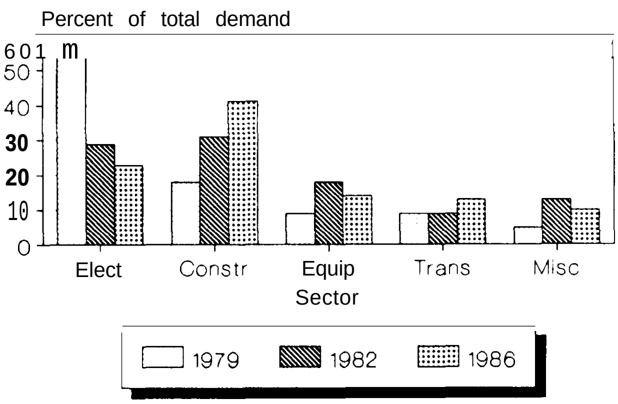
[36] Consumption of unwrought refined copper, whether refined from primary or secondary materials, except the direct use of copper in scrap.

Figure 4-10.-Distribution of Electrical and Electronics Uses in Copper Demand



SOURCE: US. Bureau of Mines, Copper Development Association

Figure 4-11. -U.S. Copper Demand by Sector: 1979, 1982, 1986



NOTE: In this figure, demand is measured by the gross weight of shipments
SOURCE: US Bureau of Mines data.

sumption of 2.1 million tonnes. Demand in Japan, the second largest consumer, was around 1.2 **million tonnes. European consumption of refined copper was 2.8 million tonnes in 1986, with five countries–the Federal Republic of Germany, France, Italy, the United Kingdom and Belgium–accounting** for almost **80** percent of European demand. Although Chile, Zaire, and Zambia are major copper producing countries, their consumption of the metal is low. Combined demand for the three of 45,000 tonnes in 1986 represented less than 1 percent of NSW refined copper demand.

Remelting of unrefined copper scrap by semifabricators amounted to 2.5 million tonnes in 1986. Brass mills and other fabricators in the United States and Japan were the primary consumers of scrap. Domestic consumption of copper scrap by brass mills declined 8 percent in 1986 due to supply shortages resulting from increased scrap exports and narrow profit margins for scrap dealers. At some times, #l scrap was actually more expensive than refined copper. Because of the scrap shortage, primary refined copper consumption at brass mills increased **26** percent during 1986.[37]

[37] Jolly and Edelstein, supra note 16.

Technology and Future Demand[38]

In the last forty years, transistors and subsequent microelectronic technologies have had far-reaching effects. A host of derivative technologies **have evolved,** such as advanced global communications and the array of services and products introduced by the computer. The copper industry experienced both positive and negative impacts from this transition. The electronics industry provided a sizable market for copper, representing nearly a quarter of domestic consumption in 1986. However, the evolution of microelectronics also brought more efficient technologies that decreased the intensity of copper use in some applications, including reducing wire size and replacing the metal with optical fibers. In electronics, high-temperature fabrication and performance needs also have led to a shift from pure copper to specialty alloys such as beryllium copper. Copper alloy consumption in electronics has grown fivefold since 1975.[39]

Other recent technological developments having a negative impact on copper demand include low-cost brazing methods, which allowed aluminum to replace copper in large portions of the automotive radiator market; temperature-resistant plastics that have replaced copper in many plumbing tube applications; and aluminum alloys that made aluminum wire and cable more competitive with their copper counterparts.

In balance, though, **domestic copper consumption has grown at a modest rate of about 2 percent annually since 1970. over the same period, consumption in the rest of the market economy countries has averaged 3 percent annual growth, for** an NSW average of around 2.4 percent.

Predicting future growth is difficult for a number of reasons. First, as noted above, **technological changes have both positive and negative impacts on copper demand.** This is evident even in individual products. For example, the Copper Development Association estimates that increased electric and electronic applications in automobiles since 1980 have more than offset reduced copper use due to downsizing of cars and the one-third market share currently enjoyed by aluminum radiators. A passenger car contained around 41 pounds of copper in 1975, 36 pounds in 1980, and 48 pounds in 1986. This increase is projected to continue through at least 1990.[40]

A second major difficulty in predicting short-term future demand is the inability to foresee general economic conditions. For instance, a 1980 Resources for the Future study suggested that demand surges between 1980 and 1985 would lead to copper shortages.[41] Instead, there was a major recession accompanied by capacity increases and substantial oversupply. Although domestic demand grew at an average of 2 percent during 1970-1986, those years saw two recessions, two periods of double-digit growth, and several unusual market shifts (e. g., the rise of personal computers and the effects of the oil crisis).

Even more difficult to predict are demand surges caused by new technologies. Much of the technological research affecting copper consumption goes on outside the industry that produces the metal, making forecasting even more difficult. Estimates for the next 10 years made by the Copper Development Association include an enormous short-term growth in demand for consumer electronics, telecommunications, information services, and copper-dependent electronics such as heat pumps and devices in automobiles.

Copper-based marine antifouling paints will increase rapidly through the early 1990s. Existing paints use tributyltin (TBT), which is being banned for environmental reasons. Copper paints may only provide one year's protection, compared to 3-7 years for TBT paints. Thus they will have to be applied more often. Over the long term, cop-

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[38] Unless otherwise noted, the information in this section is from a presentation given by William Dresher, International Copper Research Association, at Copper 87, in Chile, November 1987.

[39] Jolly and Edelstein, supra note 16.

[40] Copper Development Association, "Use in Autos Rises as Cars Increase Electrical/Electronic Systems," *Copper Topics, No.* 61, Winter 1987.

[41] Leonard L. Fischman, *World Mineral Trends and U.S. Supply Problems* (Washington, DC: Resources for the Future, Research Paper R-20, 1980).

per paints probably will be replaced by non-stick coatings similar to Teflon. [42]

Further down the road–perhaps 10 **to** 20 years —the effects of new technologies, including superconductors (which use copper), might vary from a major expansion in copper-consuming applications to drastic reductions from substitution and obsolescence. Technological forecasting becomes completely opaque when it comes to radically new inventions, however. Something totally unforeseen could be invented tomorrow that dramatically increases or decreases the demand for copper.

[42]H ugh McKellar, "Good Substitutes Will Lessen Impact of Ban on TBT Paints, " *National Fisherman,* December 1987, p. 5.

Photo credit: Argonne National Laboratory

Superconducting wire, ready for testing.

Of known technologies, superconducting materials and their applications probably have the greatest potential to impact future copper demand. A possibility exists for tremendous growth in copper usage arising from several feasible developments in superconductor technologies, including: 1) the need for copper oxide in all high temperature superconductors as part of the chemical makeup; 2) the use of a predominantly high purity, oxygen-free copper stabilizer in state-of-the-art superconductors; 3) the development of "electricity pipelines" where electrical power would be transmitted in copper-clad superconductors cooled by liquid nitrogen;[43] and 4) a significant decrease in the cost of generating and transmitting electricity could increase electricity consumption and the demand for copper in wire and cable applications would grow as well.

While the potential for expansion in copper usage exists with the introduction of superconductor technologies, negative impacts also could be realized. The development of a superconductor requiring no coolant or stabilizer could be devastating, possibly replacing copper in all major electrical conduction applications. In addition, superconducting electrical generators have several advantages over copper-wound generators and require significantly less copper per megawatt. The new superconductor generators are especially useful where space is a consideration and are already replacing conventional **wire-wound generators in icebreakers and submarines.**

[43]Only a few "electricity pipelines" wou Id be needed to Service an entire continent, However, aluminum would be displaced from high voltage transmission lines.

TRADE

Until the 1960s, most major copper operations were integrated in the sense that ore was mined, milled, and smelted within the same region— often at the same site. Many operations were further integrated to include refineries and wire **mills; in other cases, blister copper or anodes were** shipped to refineries located **closer to fabri**caters. This pattern evolved in part due to the transportation costs for copper contained in concentrates (20-30 percent Cu) **versus copper in blis-**

ter (98.5 percent) and anodes (99.5 percent). Nearly all trade occurred in the form of refined copper. As a result, much of the value added accrued to the country or region where the ore was mined, or at least to the mining company.

In the early 1960s, the rapid growth of Japan and **West** Germany, both deficient in copper resources, greatly increased the proportion of copper trade in concentrates. As part of their raw materials strategies for postwar industrialization, these countries built smelters at home, financed mine development abroad, and arranged long-term contracts for trade between the two.[44] The trend toward increased trade in concentrates continued in the 1970s **and 1980s, as financing and operating smelters became increasingly difficult, and as the Clean Air Act compliance deadlines neared for U.S. smelters. Over the last 20-25 years, many major new mines developed around the world were not paired with local smelters.**

In Japan, this strategy was based on the reasoning that, by importing copper concentrate and smelting and refining it themselves, they could gain the value added in processing. Over time, increased Japanese smelter capacity would encourage the development of new copper mines in the Philippines, Papua New Guinea, and elsewhere around the Pacific Rim. This would mean security of concentrate supply by making mines dependent on Japan to buy their concentrates.[45]

producing sulfuric acid from the smelters' sulfur dioxide-laden gases meant even more value added, as this byproduct could be sold profitably to the growing Japanese chemical industry.[4G] Japanese smelters were also given an advantageous pricing system, whereby Japanese industries paid higher than world market prices for copper and sulfuric acid. This system was supported by high tariffs on refined copper and sulfuric acid, and essentially provided an indirect subsidy to the smelters. The smelting companies were then able to offer foreign mines terms well below what it would cost to finance, build, and operate smelters and refineries.[47] These generous terms drew a great deal of concentrate to Japan, and have been controversial among U.S. smelting companies since the 1960s. Most recently, they came under fire during the tight concentrate market in the early to mid-1980s.

The world concentrate market has been characterized by an increasing group of players and supply shortages in the last few years. The demand for concentrates has risen as new and modernized smelters have come on line in Chile, the Philippines, and elsewhere. As a result, concentrate supplies available to Japan have declined. High energy costs and the increased valuation of the yen relative to the currencies of other smelting countries also reduced Japan's ability to compete for input for its smelters.

As a result, **Japan has moved to secure their supply of concentrates by investing directly in overseas mining capacity.** In the United States, Phelps Dodge (PD) sold a 15 percent interest in its Morenci properties (excluding the smelter but including SX/EW output) to a partnership subsidiary of Sumitomo Metal Mining Company and Sumitomo Corporation in 1986.48 For PD, this sale provided much-needed cash flow, and reduced the operating imbalance that resulted from closure of the Morenci smelter.[49] For Japan, the sale was linked to an agreement that Sumitomo would obtain their share of the concentrate at cost.[50]

Japan's overall strategy dovetailed neatly with two other trends affecting smelter and refinery capacity in the United States. The first was simply the age of U.S. operations. Of the major copper-producing countries, the United States has the oldest industry, with many facilities operating since the early 1900s and before. Modernization often is not simply a matter of exchang-

[44] Some of the financing came from official government lending institutions such as the Export-Import Bank of Japan and the German Kreditanstalt fur Wiederaufbau.

[45] "Asset Restructuring in the U.S. Copper Industry, Part I: U.S. Industry Responds to Dramatic Changes in World Role," *CRU Copper Studies*, vol. 14, No. 4, October 1986.

[46] Japan a 1₅₀ produces elemental sulfur and gypsum with the sulfur dioxide (see ch. 8). They export both sulfuric acid and sulfur.

[47] *CRU Copper Studies*, supra note 45.

[48] Previously, Kennecott had sold a one-third interest in all of the output of Chino Mines to MC Minerals, a joint venture between Mitsubishi Corp. and Mitsubishi Metal Corp. PD purchased the remaining two-thirds from Kennecott in 1986.

[49] G. Robert Durham, "Remarks," speech given at the Northwest Mining Association, 92nd Annual Meeting, Spokane, Washington, Dec. 4, 1986.

[50] *CRU Copper Studies*, supra note 45.

ing outdated equipment, but replacing the whole plant, and the cost frequently is prohibitive. Thus, in the mid-1980s, PD closed their 100-year old refinery at Laurel Hill, New jersey. **The** second, and more significant, trend was the combination of slow demand growth, smelter age, and Clean Air Act deadlines for smelter sulfur dioxide controls. Of 16 domestic copper smelters operating in the late 1970s, eight have been closed permanently.

The net result of all these events is that **the United States has reversed its early 1970s position as a net exporter of refined copper products and a net importer of concentrates, to become a net importer of refined products and a net exporter of concentrates (see** table 4-3). In 1986, the United States exported 15 percent of its concentrate production, while net import reliance for refined copper, measured as a percent of apparent consumption, was 24 percent. **imports for consumption of refined copper reached a record high level in 1986, up** 33 percent over 1985. The ratio of net imports to consumption exceeded 20 percent for the third successive year.

Canada and Chile were the principal sources of U.S. imports of refined products. Canadian copper accounted for almost 50 **percent of the increase in total refined imports since 1985.** In terms of economic significance, the value of U.S. trade in copper concentrates has gone from roughly equivalent exports and imports in 1970, to net exports valued at $184.6 million in 1986. Refined products have shifted from net exports of $72.4 million in 1970, to net imports of $540.6 million in 1986.[51]

[51] Jolly and Edelstein, supra note 16.

While the balance of mining/smelting and trade probably has shifted in the United States more than in other major copper mining countries, trading patterns have changed worldwide. The following sections present data on exports and imports of copper concentrates, blister/anode, and refined products for the major producing and consuming countries.

While OTA is able to report quantities of exports and imports, despite our best efforts at sorting out the available data, it was not possible to determine which trade went where. No single U.S. or international organization tracks such interchanges unless they are reported by the countries involved. Discrepancies between exports claimed by mining country A destined for consuming country B, and imports reported by country B allegedly originating in country A, confound any attempts to map trade among mining, smelting/refining, and consuming countries.

Trade in copper contained in manufactured goods (e.g., automobiles, television sets) is virtually impossible to determine, because it is not reported. Moreover, the copper content of such goods varies among models and manufacturers, and over time, and thus is extremely difficult to calculate. This is part of a broader problem affecting the analysis of changes in materials intensity of goods and the balance of trade in raw materials. It could be alleviated by reporting requirements for the copper content of goods imported to (and exported from) the United States. Such reporting could, however, be quite burdensome and may mean disclosure of what is currently considered proprietary information for some products.

Table 4-3.—U.S. Copper Trade, 1970 and 1986 (thousand tonnes and million nominal $U.S.)

	1970				1986			
	Exports		Imports		Exports		Imports	
Product	Tonnes	Value	Tonnes	Value	Tonnes	Value	Tonnes	Value
Concentrates[a] . . .	55.81	$58.4	58.76	$77.7	174.35	$187.8	4.93	$ 3.2
Blister[b]	7.10	7.5	203.43	224.3	15.96	17.4	34.55	60.2
Refined	200.64	221.6	119.85	149.2	12.45	136.4	501.98	677.0
Scrap[c]	—[d]		2.09	2.0	134.30	123.1	27.22	31.6

[a]Includes matte

[b]For 1988, exports include precipitate, Imports include anode.

[c]Unalloyed.

[d]Not available; probably 16,000 to 18,000 metric tonnes.

SOURCE: Off Ice of Technology Assessment, from Bureau of Mines data.

Concentrates

In 1986, **1.4** million tonnes of concentrates were exported from Western countries for processing elsewhere (see table 4-4). Canada was the largest exporter that year, shipping out 341,400 tonnes. Chile was second with exports totaling 281,300 tonnes, followed by Papua New Guinea and the United States with concentrate exports of 178,800 and 174,400 tonnes, respectively.

Japan was by far the largest recipient of trade in concentrates, importing 837,400 tonnes in 1986 (60 percent of all concentrates destined for market economy countries). In contrast, 1986 mine production in Japan was 35,000 tonnes—around 4 percent of smelter production. As noted previously, Japan is experiencing increasing competition for this low value added material, and their relative share of the market is expected to decline gradually. On a much smaller scale, twelve other countries imported concentrates in 1986.

Blister and Anode

Eleven countries reported exports of blister and anode copper in 1986; eleven also reported imports (table 4-s). Five countries reported both imports and exports of these products (France, the Federal Republic of Germany, Italy, Spain, and the United States); all were net importers.[52]

Zaire and Chile were the largest exporters of blister and anode copper, providing around 60 percent of market economy country exports. Zaire exports about 50 percent of its total smelter output, while Chile exported almost 18 percent of its smelter production in 1986. Peru's shipping 94,700 tonnes blister and anode copper represented nearly one-third of its smelter production. The United States imported 46,300 tonnes of blister and anode copper in 1986, and exported 16,000 tonnes. Belgium, the United Kingdom, and the Federal Republic of Germany were the

[52]WBMS, supra note 5.

Table 4-4.—1986 Concentrate Trade (1,000 metric tonnes)

Importers		Exporters	
Japan	**837.4**	**Canada**	**341.4**
Germany, F.R.	**161.3**	**Chile**	**281.3**
South Korea	**116.7**	**PNG**	**178.8**
Spain	**72.3**	**USA**	**174.4**
Canada	**70.7**	**Philippines**	**93.3**
Taiwan	**44.8'**	**Mexico**	**90.0'**
Finland	43.2	Australia	72.9
Other	51.7	Other	173.6
Total	1,398.1	Total	1,405.7

aJanuaV to September.

SOURCE World Bureau of Metal Statistics data

Table 4-5.—1986 Blister and Anode Copper Trade (1,000 metric tonnes)

Importers		Exporters	
Belgium	240.0	Zaire	236.3[b]
United Kingdom	79.5	Chile	199.4
Germany, F.R.	69.8	Peru	94.7
USA	46.3	Sweden	18.5
South Korea	34.6	USA	16.0
Japan	27.8	Finland	15.7
France	22.3	Germany, F.R.	14.0
Other	28.9	Other	12.9
Total	549.2	Total	607.5

a,985 figure

SOURCE World Bureau of Metal Statistics data largest recipients of blister and anode copper with imports of 240,000, 79,500, and 69,800 tonnes, respectively.[53]

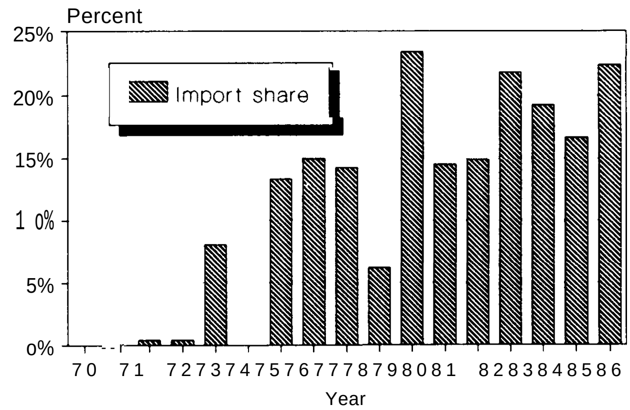
Refined

More than 30 countries were involved in trade of refined copper in 1986. Major players in the market (table 4-6) included Chile and Zambia, with respective exports of 895,700 and 466,300 tonnes. The United States and the Federal Republic of Germany led imports with 491,700 and **447,900 tonnes, respectively.**

U.S. imports of refined copper rose to 24 percent of domestic consumption in 1986. The United States has been a net importer of refined copper since 1976 and has experienced net exports in only 3 years since 1970. The penetration of imported refined copper products in the domestic market in 1986 was only 1 percent lower than the 17-year high level of 1980 (see figure 4-1 2).

[53] Ibid.

Figure 4-12.-Refined Copper Imports as Percent of Domestic Refined Consumption



NOTE The United States was a net exporter of refined copper in 1970, 1971, and 1975

SOURCE Copper Development Association

Table 4-6.—1986 Refined Copper Trade (1,000 metric tonnes)

Importers		Exporters	
USA	491.7	Chile	895.7
Germany, F.R.	447.9	Zambia	466.3
Italy	349.1	Canada	304.8
France	334.5	Belgium	232.5
Japan	272.4	Peru	193.0
United Kingdom	263.5	Philippines	124.6
Belgium	215.2	South Africa	68.4
China	103.5[a]	Germany, F.R.	67.8
Taiwan	84.7[b]	Australia	66.8
South Korea	83.9	Spain	62.3
Other	292.8	Other	243.8
Total	2,939.2	Total	2,726.0

[a]January to September
[b]January to October
SOURCE: World Bureau of Metal Statistics data

COPPER MARKETS IN CENTRALLY PLANNED COUNTRIES[54]

Under central planning, the State determines prices, the level of production, the amount of consumption, and the purposes for which minerals are used. The major priorities in mineral policy are first to attain maximum self-sufficiency in supply, and second to conserve scarce foreign exchange. If a mineral must be imported, the source is most likely to be another centrally-planned trading partner. Detailed official statistics of mineral production and consumption are not published by most centrally planned coun-

[54] Unless otherwise noted, the material in this section is from Simon D. Strauss, *Trouble in the Third Kingdom* (London: Mining Journal Books Ltd., 1986).

tries, including the Soviet Union and China. informed (but differing) estimates for the post-World War II period are available from the U.S. Bureau of Mines and the World Bureau of Metal Statistics (see table 4-7).

Soviet production of copper between the two world wars was small by world standards. Following World War II, production was expanded to reduce import dependency and rebuild the industrial base. Between 1950 and 1986, production of copper contained in ore increased from 218,000 tons to 620,000 tonnes, and the Soviets are now essentially self-sufficient in copper. In order to achieve self-sufficiency, however, the Soviets have had to develop copper deposits that would not be considered economically viable in market-economy countries. For example, a 1985 report of the Kazakhstan Academy of Science noted that "nationally ore containing 0.2 percent copper is now considered economic."

After centuries of orientation on agricultural rather than industrial production, the extent of China's mineral resources were largely unknown. Since 1949, efforts have been made to explore and map the country's minerals, but the full potential is far from being determined. Large low-grade copper deposits have been discovered that will require enormous investments if they are to become producers. However, this cost creates severe problems given the government policy to avoid incurring substantial external debt. Plans for joint venture arrangements between the Chinese Government and foreign corporations are proceeding very slowly. With roughly 25 percent of the world's population, China accounted for only about 5 percent of the global consumption of most minerals—390,000 metric tons of copper in 1985.

The current copper producing status of the other centrally-planned countries is estimated to be as follows:

- Albania is self-sufficient;
- Bulgaria has export surpluses;
- Cuba has a modest output, exported as concentrate, but the mineral content of finished goods supplied by the Soviet Union and other countries is significant;
- Czechoslovakia is heavily industrialized but has a small non-fuel minerals industry, and is a net importer;
- The German Democratic Republic produces only a small fraction of its own needs;
- Hungary also is heavily import dependent;
- Korea D.P. R. is close to self-sufficiency;
- Poland is a large producer, with a well-established industry developed over the last 20 years with capital and technology from the market-economy countries, and substantial exports to Western Europe; and
- Romania has some production, but is a net importer.

Table 4-7.—Copper Production in Centrally Planned Countries
(1,000 metric tonnes)

	1970[a]		1978			1986		
Country	Mine	Smelter[b]	Mine	Smelter	Refinery[c]	Mine	Smelter[c]	Refinery[c]
Albania[d]	NA	5.6	11.5	9.5	**7.0**	17.6	**13.7**	11.7
Bulgaria	43.2	43.8	58.0	64.0	**62.0**	80.0	**90.0**	95.0
China	100.0	100.0	200.0	200.0	**270.0**	185.0	**225.0**[e]	400.0
Cuba	3.0	—	2.8	—	—	3.3	—	—
Czechoslovakia	4.4	**4.0**	4.7	**10.0**	23.8	10.0	**12.4**	26.5
German D.R.	10.0	**10.0**	16.0	**17.0**[e]	49.0	10.0	**12.0**[e]	63.0
Hungary	1.0	**1.0**	0.5	**0.3**	13.1	—	**0.1**[f]	12.8
Mongolia	NA	NA	4.0	—	—	128.0	—	—
North Korea	12.7	12.7	15.0	**20.0**	25.0	15.0	**18.0**	22.0
Poland	72.2	72,4	321.0	**337.0**	332.2	431.0	**400.0**	388.0[e]
Romania	13.0	10.0	27.0	**42.9**	40.5	27.0	**39.0**	43.0
U.S.S.R.	572.7	572.7	865.0	**955.0**	980.0	620.0	**915.0**	965.0
Total	832.2	832.2	1,525.5	1,655,7	1,802.6	1,526.9	1,725.2	2,027.0

[a] Refinery data not available
[b] Primary only
[c] Primary and secondary unless noted otherwise
[d] Primary smelter and refinery production.
[e] Primary
[f] Secondary only

SOURCE U S Bureau of Mines data