LIME

By M. Michael Miller

Lime is an important chemical with numerous chemical, industrial, and environmental uses in the United States. Its history probably dates back 4,000 to 6,000 years. The ancient Egyptians used lime as an ingredient in mortar and plaster. The Greeks, Romans, and Chinese used lime for construction, agriculture, bleaching, and tanning. Its uses began expanding with the advent of the industrial revolution, but it remained primarily a construction commodity until the rapid growth of the chemical process industries at the beginning of the 20th century. At the turn of the century, over 80% of lime consumed in the United States went for construction uses, but now over 90% of lime is consumed for chemical and industrial uses.

Lime is a basic chemical that was produced in 33 States and Puerto Rico, and its major uses were in steelmaking, flue gas desulfurization (FGD), pulp and paper manufacturing, construction, water purification, and ore concentration in the mining industry.

Total lime sold or used by domestic producers in 1997, excluding that from Puerto Rico, increased by about 481,000 metric tons (530,000 short tons) to 19.7 million tons (21.7 million short tons) compared with the revised 1996 figures. Production included the commercial sale or captive consumption of quicklime, hydrated lime, and dead-burned refractory dolomite. These products were valued at $1.19 billion. Commercial sales increased by 494,000 tons (545,000 short tons) to a record high of 17.3 million tons (nearly 19.1 million short tons), and captive consumption decreased slightly to about 2.42 million tons (2.66 million short tons). *(See table 1.)*

Production

The term "lime," as used throughout this chapter, refers primarily to six chemicals produced by the calcination of high-purity calcitic or dolomitic limestone followed by hydration where necessary. They are (1) quicklime, calcium oxide (CaO); (2) hydrated lime, calcium hydroxide [$Ca(OH)_2$]; (3) dolomitic quicklime ($CaO \cdot MgO$); two types of dolomitic hydrate, (4) type N [$Ca(OH)_2 \cdot MgO$] and (5) type S [$Ca(OH)_2 \cdot Mg(OH)_2$]; and (6) dead-burned dolomite. Nondolomitic quicklime and hydrated lime are also called high-calcium lime. Lime also can be produced from a variety of calcareous materials such as aragonite, chalk, coral, marble, and shell. Lime is also regenerated; that is, produced as a byproduct, by paper mills, carbide plants, and water treatment plants; however, regenerated lime is beyond the scope of this report.

Domestic production data for lime are developed by the U.S. Geological Survey (USGS) from two separate, voluntary surveys of U.S. operations. The survey used to prepare this report is the annual "Lime" survey. The annual survey form was revised for the 1997 data collection year in cooperation with the lime industry. Major revisions included the elimination of the shipments section and major changes to the end use and value sections. These revisions resulted in the elimination of the shipments table and a reorganization of the end use table. Value data are now collected by type of lime, i.e., high calcium or dolomitic, instead of by market segment as in the past. Value data are not collected by end use, so the value data shown in table 4 are determined by calculating the average value per ton of quicklime sold or used for each respondent and then multiplying it by the quantity of quicklime the respondent reported sold or used for each end use. The same calculation is performed for hydrated lime sold or used. Table 4 displays the total quantity sold or used for an end use and the total value of the quicklime and hydrate sold or used for that end use calculated as described above.

The USGS maintains a list of operations classified as producing or idle; currently there are 117 operations on this list. Six of these operations are not surveyed at the producers request, and estimates are made using reported prior-year production figures or other industry data. Of the 111 operations to which the annual survey request was sent, 106 responded, representing 88% of the total sold or used by producers shown in table 2. Production for five nonrespondents was estimated using reported prior-year production figures.

At the end of 1997, there were 33 commercial lime producers operating 64 lime plants producing quicklime and 7 separate hydrating plants. This takes into account two producers that were idle in 1997, one plant that closed, one plant that was idle except for its hydrator, and a previously captive plant purchased by a commercial producer. There were 4 companies operating 4 plants that combined captive production and commercial sales, and 16 companies operating 39 plants producing quicklime strictly for captive use. The leading producing companies were all commercial producers, with the exception of Martin Marietta Magnesia Specialties Inc., which is a combined captive and commercial producer. In 1997, the top 10 companies were, in descending order of production, (1) Chemical Lime Co., with three lime plants in Alabama, two each in Arizona, Nevada, and Texas, one each in Idaho, Missouri, and Utah, and hydrating plants in California and New Mexico; (2) Dravo Lime Co., with two plants in Kentucky, one plant in Alabama, and a hydrating plant in Louisiana; (3) Mississippi Lime Co., with one plant in Missouri; (4) Marblehead Lime Co., with one plant each in Illinois, Indiana, and Michigan; (5) Continental Lime Inc., with one plant each in Montana, Nevada, Utah, and Washington; (6) Global Stone Corp., with one plant each in Michigan, Oklahoma, Tennessee, and Virginia; (7) APG Lime Co., with two plants in Virginia and one plant in Texas; (8) Martin Marietta Magnesia Specialties Inc., with one plant in Ohio; (9) Carmeuse Pennsylvania Inc., with two plants in Pennsylvania; and (10) Bellefonte Lime Co., with two plants in Pennsylvania. These 10

companies operated 35 lime plants and 5 separate hydrating plants and accounted for 75% of commercial sales of quicklime and hydrated lime combined and 67% of total lime production.

Domestic lime plant capacity is based on 365 days minus the average number of days for maintenance times the average 24-hour capacity of quicklime production, including quicklime converted to hydrated lime, and reported in short tons per year. In 1997, capacity data were available from 34 commercial companies operating 49 plants. The calculations do not include combined commercial and captive producers, hydrating plants, plants that commissioned new kilns during the year, and Puerto Rico. Based on the available data, the U.S. lime industry operated at 81% of capacity in 1997. This is about the same operating rate as 1996. Capacity utilization would be slightly lower if the capacity of several idle or mothballed plants were factored into the calculations.

On a regional basis, capacity utilization ranged from 69% to 90%. In the Middle Atlantic Region (plants in eastern and central Pennsylvania, West Virginia, and northern Virginia), capacity utilization was 83%, based on data from six companies operating eight plants. In the Southeast Region (plants in Alabama, eastern Tennessee, and southern Virginia), capacity utilization was 90%, based on five companies operating seven plants. In the Eastern Midwest Region (plants in Michigan, northern Kentucky, Ohio, and western Pennsylvania), capacity utilization was 89%, based on five companies operating six plants. In the Western Midwest Region (plants in Illinois, Indiana, Iowa, Missouri, and Wisconsin), capacity utilization was 80%, based on seven companies operating nine plants. In the South Central Region (plants in Arkansas, Louisiana, Oklahoma, and Texas), capacity utilization was 82%, based on six companies operating eight plants. In the Western Region (plants in Arizona, Colorado, Idaho, Montana, Nevada, Oregon, South Dakota, Utah, and Washington), capacity utilization was 69%, based on 5 companies operating 11 plants. *(See tables 2 and 3.)*

In regional industry news, in the Southeast Region, the A.P. Green Industries Inc.-SCANA Corp. joint venture to build a new lime plant in Charleston, SC, was delayed, and startup is now scheduled for late 1998. The plant will operate as Palmetto Lime LLC in conjunction with A.P. Green's subsidiary APG Lime. The plant is now expected to have an initial annual capacity of 254,000 tons (280,000 short tons) expandable to 381,000 tons (420,000 short tons) with installation of a second kiln (A.P. Green Industries Inc., 1998). Global Stone Tenn Luttrell Inc.'s Tennessee plant suffered operational delays during the summer due to severe flooding that occurred in late June. The plants new Cimprogetti vertical shaft regenerative kiln came on-line, and the company reported it would boost plant capacity by 30% (Global Stone Corp., 1997). Blue Circle Cement Co. completed most of the modernization and expansion work on its Roberta lime plant at Calera, AL, by yearend 1997. Overall completion was scheduled for early 1998. The project replaced a trio of old kilns with a single Kennedy Van Saun preheater rotary kiln that boosted annual plant capacity to 363,000 tons per year (400,000 short tons per year). Chemical Lime completed startup of its new O'Neal lime plant near Calera, AL. The new plant's annual capacity is about 400,000 tons (445,000 short tons). Dravo Lime purchased a number of land parcels adjacent to its Longview Division quarry in Alabama that doubled its limestone reserves. The facility, which produces lime and aggregates, now has adequate reserves to last 45 years at present rates of extraction. In addition, Dravo Lime secured necessary permits and plans to add a fourth kiln at the Longview Division lime plant in Saginaw, AL. Construction on the new 270,000-ton-per-year (300,000-short-ton-per-year) kiln will commence during the spring of 1998 and increase plant capacity by more than 50% when completed (Dravo Lime Co., 1998). Dravo Lime achieved ISO 9002 certification for the Longview lime operations (Sommer, 1997). Chemical Lime is reassessing plans for its announced processing plants and storage terminals in Charleston, SC, and Tampa, FL, due in part to the evolving rail situation in the southeast and to overall geographic considerations on how to best serve its long-term customers.

In the Middle Atlantic Region, Corson Lime Co. closed its Plymouth Meeting, PA, operations after 175 years in business. Corson Lime's assets were sold by its parent company, U.S. Lime and Minerals Inc., to Highway Materials Inc. (Rock Products, 1997). Medusa Corp., mainly a cement and aggregates company, purchased Lee Lime Corp. of Lee, MA. Lee Lime is a small producer of dolomitic quicklime and dolomitic hydrate (North American Mineral News, 1997a).

In Eastern Midwest Region, Marblehead Lime is beginning a $20 million renovation and construction project at the Maple Grove, OH, plant acquired from American Premier in late 1997. The plant last operated in the early 1980's when its owner, Basic Inc., produced dolomitic lime and dead-burned refractory dolomite. Completion of the current renovation project is expected mid-1999 (North American Mineral News, 1998b). Martin Marietta Magnesia Specialties completed phase II of its capacity expansion project at its Woodville, OH, plant. Phase II increased total lime plant capacity to about 770,000 tons per year (850,000 short tons per year). Phase I, completed in 1996, increased capacity at the Woodville south plant and phase II increased capacity at the north plant. The Ohio plant produces dolomitic quicklime for use at the company's magnesia plant in Manistee, MI, and sells to steel and related markets (North American Mineral News, 1998a). Dravo Lime boosted the annual capacity at its Maysville, KY, plant to 1,270,000 tons per year (1,400,000 short tons per year) by starting up a new kiln during the spring of 1997, and completed a major upgrade of the No. 3 kiln at its Black River plant in Carntown, KY (Dravo Lime Co., 1998b). Dravo achieved ISO 9002 certification for the Maysville lime operations (Sommer, 1997).

In the Western Midwest Region, Marblehead Lime completed kiln and baghouse improvements that boosted capacity by 181,000 tons per year (200,000 short tons per year) to a total of 726,000 tons per year (800,000 short tons per year) at its Buffington, IN, plant (Rock Products, 1998). Vulcan Materials Co. started up its new dolomitic lime plant in Manteno, Kankakee County, IL. Mississippi Lime started construction on a Maerz twin vertical shaft parallel flow regenerative kiln that will produce 120,000 tons per year (132,000 short tons per year). Startup of the new kiln is expected in the third quarter of 1998 (Mississippi Lime Co., press release, accessed February 13, 1998, at URL http://www. mississippilime.com/whatsnew.htm).

In the South Central Region, U.S. Lime & Minerals began a

major modernization and expansion project at its Texas Lime Co. subsidiary in Cleburne, TX. The $22 million project includes the installation of a new stone crushing and handling system, the addition of a preheater to one of the kilns, additional storage, screening and shipping capacity, and a new support building which will house laboratory, administrative, and shop facilities. The new preheater and the crushing system will increase the plant's lime production capacity by about 25% (United States Lime & Minerals Inc., 1998).

In the Western Region, Chemical Lime constructed a hydrating plant in Belen, NM. Chemical Lime also purchased the dolomite quarry, processing equipment, and lime plant in Natividad, CA, from National Refractories and Minerals Inc. (National Lime Association, 1998). Continental Lime installed a 900-ton-per-day (1,000-short-ton-per-day) rotary kiln at its Cricket Mountain plant near Delta, UT. This is the plant's fourth kiln, bringing the plant's total capacity up to 2,500 tons per day (2,750 short tons per day). The new kiln included a 14-ram Fuller-Continental style preheater (World Cement, 1997a).

Environment

At the United Nations Framework Convention on Climate Change held in Kyoto, Japan, representatives from more than 150 countries agreed on measures that would obligate industrial countries to cut emissions of greenhouse gases. The list of greenhouse gases to be controlled include carbon dioxide, methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons, and sulfur hexafluoride. The accord, known as the Kyoto Protocol, would require the United States to reduce emissions of these gases 7% below 1990 levels (1995 levels for hydrofluorocarbons) by the year 2012 (United Nations Climate Change Secretariat, 1998). The protocol, however, does not include an emissions trading system, and major developing countries such as China, India, and Mexico did not sign the accord. Congress voiced its concern over the exclusion of developing countries from the Protocol, and passed resolutions (House Resolution 4761 and Senate Resolution 98) requesting that the President not sign the Protocol or not submit it to Congress unless it is amended to include developing countries. The protocol is an early step in the continuing attempt to deal with the causes of climate change, and any attempt will ultimately require the involvement of all countries.

The lime manufacturing process is heavily energy dependent and generates carbon dioxide as an unavoidable byproduct. Limitations on carbon dioxide emissions or the application of a carbon tax would have a deleterious effect on the lime industry that would affect the steel, pulp and paper, construction, and environmental markets.

Consumption

The breakdown of consumption by major end uses was as follows: 40% for metallurgical uses, 26% for environmental uses, 24% for chemical and industrial uses, 8% for construction uses, and 1% for refractory dolomite. Captive lime accounted for about 12% of consumption and was used mainly in the production of steel in basic oxygen furnaces, in sugar refining, and in magnesia production. Almost all data on captive lime consumption, excluding the sugar industry, are withheld to protect company proprietary information. As a result, table 4, "Lime sold or used by producers in the United States, by use," simply shows the total quantity and value of lime by end use. End uses with captive consumption are listed in footnote 4 of the table.

In steel refining, quicklime was used as a flux to remove impurities such as phosphorus, silica, and sulfur. Dolomitic lime was often substituted for a fraction of the high-calcium lime to extend refractory life. Dead-burned dolomite, also called refractory lime, was used as a component in tar-bonded refractory brick used in basic oxygen furnaces. Lime consumption by the iron and steel industry increased by 5.4% to 6.05 million tons (6.67 million short tons). This continues the recent trend where lime consumption for iron and steel has increased faster than the production of raw steel, which increased by about 3% in 1997. The steel industry accounted for about 31% of all lime consumed in the United States.

In nonferrous metallurgy, lime was used in the beneficiation of copper ores to neutralize the acidic effects of pyrite and other iron sulfides and maintain the proper pH in the flotation process. It was used to process alumina and magnesia, to extract uranium from gold slimes, and to recover nickel by precipitation. It was used in gold and silver recovery operations to control the pH of the sodium cyanide solution used to leach the gold and silver from the ore. Such leaching processes are called dump leaching when large pieces of ore are involved, heap leaching when small pieces of ore are involved, and carbon-in-pulp cyanidation when the ore is leached in agitated tanks. Dump and heap leaching involve crushing the ore, mixing it with lime for pH control and agglomeration, and stacking the ore in heaps for treatment with cyanide solution. Lime is used to maintain the pH of the cyanide solution at a pH level between 10 and 11 to maximize precious-metals recovery and to prevent the creation of hydrogen cyanide gas. Lime consumption for concentration of copper, gold, lead, silver, zinc, and other ores increased by about 5%.

The tailings that result from the recovery of precious metals may contain elevated levels of cyanides. Three of the four major treatment processes (Cyanisorb, alkaline chlorination, and sulfur dioxide/air) used to recover these cyanides use lime in the process.

In the environmental sector, lime was used in the softening and clarification of municipal potable water. Lime was used to neutralize acid mine and industrial discharges. In sewage treatment, lime's traditional role was to control pH in the sludge digester, which removes dissolved and suspended solids that contain phosphates and nitrogen compounds. It also aided clarification and killing of bacteria. More recently, the largest use in sewage treatment has been to stabilize the resulting sewage sludges. Sewage sludge stabilization, also called biosolids stabilization, has as its goal the reduction of odors, pathogens, and putrescibility of the solids. In lime stabilization, the basic process involves mixing quicklime with the sludge to raise the temperature and pH of the sludge to minimum levels for a specified period of time.

In FGD systems serving utility and industrial plants and incinerators, lime was used to react with sulfur oxides in the flue gas and was used to stabilize the resulting sludge before disposal. In 1997, the FGD market exhibited the first drop in demand since

1992, as consumption decreased slightly to 2.75 million tons (3.03 million short tons). Above normal winter temperatures and below normal summer temperatures in the Midwest resulted in lower electricity demand. Lower demand for electricity means lower demand for coal by utility companies and thus lower demand for FGD lime for scrubbing.

Lime is used by the pulp and paper industry in the basic Kraft pulping process, where wood chips and an aqueous solution (called liquor) of sodium hydroxide and sodium sulfide are heated in a digester. The cooked wood chips (pulp) are discharged under pressure along with the spent liquor. The pulp is screened, washed, and sent directly to the paper machine or for bleaching. Lime is sometimes used to produce calcium hypochlorite bleach for bleaching the paper pulp. The spent liquor is processed through a recovery furnace where dissolved organics are burned to recover waste heat and where sodium sulfide and sodium carbonate are recovered. The recovered sodium sulfide and sodium carbonate are diluted with water and then treated with slaked lime to recausticize the sodium carbonate into sodium hydroxide (caustic soda) for reuse.

The paper industry used lime as a coagulant aid in the clarification of plant process water. It was used, generally in conjunction with soda ash, for softening plant process water. This is a precipitation process to remove bivalent soluble calcium and magnesium cations (and to a lesser extent manganese, ferrous iron, zinc, and strontium), which contribute to the hardness of water. This process also reduces carbonate alkalinity and dissolved solids content.

Lime consumption for pulp and paper production, excluding precipitated calcium carbonate production, increased by more than 7% in 1997. This was a partial recovery from the 11% decrease reported in 1996, when consumption dropped to the lowest level since 1983.

Lime was used to make precipitated calcium carbonate (PCC), a specialty filler used in premium-quality coated and uncoated papers, paint, and plastics. The most common PCC production process used in the United States is the carbonation process. Carbon dioxide is bubbled through milk-of-lime, a suspension of hydrated lime in water, to form a precipitate of calcium carbonate and water. The reaction conditions determine the size and shape of the resulting PCC crystals.

The chemical industry used lime in the manufacture of alkalies. Quicklime was combined with coke to produce calcium carbide, which was used to make acetylene and calcium cyanimide. Lime was used to make calcium hypochlorite, citric acid, petrochemicals, and other chemicals.

In sugar refining, milk of lime was used to raise the pH of the product stream, precipitating colloidal impurities. The lime itself was then removed by reaction with carbon dioxide to precipitate calcium carbonate. The carbon dioxide was obtained as a byproduct of lime production.

Dolomitic quicklime was used as a flux in the manufacture of glass. Quicklime was used to make calcium silicate building products such as sand-lime brick. Hydrated lime was used to produce silica refractory brick.

In construction, lime was used for soil stabilization to upgrade clay soils into satisfactory base and subbase materials. Common applications included the construction of roads, airfields, building foundations, earthen dams, and parking areas. Sales for soil stabilization increased by 6% when compared with the revised 1996 sales figures. The latter were revised downward to 1 million tons from the originally reported figure of 1.07 million tons. Quicklime was used in autoclaved aerated concrete to produce building materials that could be cut, drilled, and nailed like wood, but with the advantages of a concrete product. Hydrated lime was used with fly ash to make a base material, in asphalt mixes to act as an antistripping agent, and in plaster, stucco, and mortar to improve durability. *(See table 4.)*

Transportation

Severe flooding along the Ohio and Mississippi Rivers in the spring of 1997 disrupted barge shipments of lime. Particularly hard hit were the barge-loading schedules of Dravo Lime's two Kentucky lime plants at Maysville and Carntown, which resulted in production curtailments and shortfalls in product shipments to major utility customers.

Prices

The average values per ton of lime rounded to three significant figures are discussed in dollars per metric ton with accompanying conversions into dollars per short ton. For accuracy, the conversions were made from the unrounded metric value, and as a result may not be an exact conversion of the rounded values.

Starting with the 1997 data collection year, all value data for lime will now be reported by type of lime produced, rather than by market use as in the past. The average value per ton of high-calcium quicklime, high-calcium hydrate, dolomitic quicklime, dolomitic hydrate, and dead-burned dolomite will be listed. Emphasis will be placed on the average value per ton of lime sold, as in the past.

The average unit value of all lime sold or used by producers, on an f.o.b. plant basis, decreased in 1997 to $60.70 per ton ($55.00 per short ton). Average values per ton were $57.80 ($52.40 per short ton) for quicklime, $80.20 ($72.70 per short ton) for hydrated lime, and $87.70 ($79.60 per short ton) for refractory dolomite.

The average value of quicklime sold was essentially unchanged at $56.60 per ton ($51.40 per short ton). The average value per ton of high-calcium quicklime sold was $56.70 ($51.40 per short ton). The average value per ton of dolomitic quicklime sold was $56.40 ($51.10 per short ton). The average value per ton of refractory dead-burned dolomite sold decreased slightly to $87.30 ($79.20 per short ton).

The average value per ton of hydrated lime sold increased slightly to $80.40 per ton ($73.00 per short ton). The average value per ton of high-calcium hydrate sold was $75.70 ($68.60 per short ton). The average value per ton of dolomitic hydrate sold was $104.60 ($94.90 per short ton). The high dolomitic hydrate value is characteristic of high-value specialty products, such as mason's lime, which is more expensive to manufacture (requires

pressure hydration) and is frequently shipped in bags.

Foreign Trade

The United States imported and exported quicklime, hydrated lime (slaked lime), hydraulic lime, and calcined dolomite (dolomitic lime). Combined exports of lime were 79,800 tons (88,000 short tons) at a total value of $9.55 million, with 63% going to Canada, 21% going to Mexico, 6% going to Suriname, 4% going to Trinidad and Tobago, and 2% each going to Indonesia and Jamaica. Combined imports of lime were 274,000 tons (302,000 short tons) at a total value of $26.5 million, with 94% coming from Canada and 5% coming from Mexico.

World Review

Australia.—Western Australia is undergoing a surge in lime plant construction because of strong demand by the alumina, gold, and synthetic rutile industries. Three of the four Western Australia lime companies are adding capacity.

Cockburn Cement Ltd., part of the Rugby Group PLC, is Australia's largest manufacturer of quicklime from its base in Western Australia. In 1997, Cockburn Cement was involved in major upgrades to its lime production facilities at Munster and Dongara. At Munster, the company installed a 400,000-ton-per-year (440,000-short-ton-per-year) Fuller/FLS calcining system that incorporates a multistage preheater cyclone and flash calcination with a short rotary kiln. Startup of this kiln took place in the spring of 1997. Feedstock for the kiln is dredged shellsand that is screened, washed, and then pumped 7 kilometers from the coast to the Munster facility. At Dongara, the company installed a Krupp-Polysius preheater lime kiln designed to produce 350 tons per day (385 short tons per day). Feedstock will be limesand mined from limesand dunes adjacent to the site. The limesand will be transferred by conveyor belt to a hopper, then dried and beneficiated to reduce silica content, put through the four-stage preheater, and then calcined in the rotary kiln. Startup of the Dongara kiln was expected in the first quarter of 1998 (World Cement, 1997a).

Westlime Ltd. also constructed a quicklime plant near Dongara. Construction of the 120,000-ton-per-year (132,000-short-ton-per-year) plant was completed in late 1997 with startup scheduled for the first quarter of 1998 (Department of Resources Development, Commissioned projects, accessed July 21, 1998, at URL http://www.drd.wa.gov.au/pcommiss.htm). Feedstock for the plant will be limesand from dunes near the site.

Swan Cement Ltd. is constructing a 100,000-ton-per-year (110,000-short-ton-per-year) vertical shaft lime kiln near Kwinana (south of Perth). The plant will be supplied by limestone mined at Exmouth on the north coast about 1,000 kilometers north of the plant site. The stone will be transported to the plant by water. The lime plant is scheduled for completion in mid-1998 (Acted Consultants, Lime [Calcium oxide], accessed February 5, 1998, at URL http://www.vianet.net.au/~acted/lime.htm).

Chile.—Annual lime production amounts to about 900,000 to 1,000,000 tons per year. About two-thirds of this is produced captively by, in descending order, the mining industry (mainly gold and copper), pulp mills, and sugar mills. Over 90% of commercial sales go to the mining industry, and the remaining sales go to agriculture, construction, and environmental control. Captive producers are Comisión Chilena del Cobre (the Government copper company), Compañía de Acero del Pacífico, Carbomet, Compañía Manufacturera de Papeles y Cartones, Celulosa Constitución, and Industria Azucarera Nacional. Most commercial sales are from plants operated by Industria Nacional de Cemento S.A. and Sociedad Productora de Cal; these two account for 91% of sales. With major increases in gold and copper mining planned for the next few years, the commercial lime sector is expected to double its capacity to 600,000 tons to meet the increased demand (Gajardo, 1997).

Finland.—Partek Nordkalk AB announced a decision to construct a new kiln at its Tytyri lime plant at Lohja. The new kiln will have a capacity of 140,000 tons per year (154,000 short tons per year) and will cost FIM 70 million (about $13 million). A considerable part of the expanded production will go to the new precipitated calcium carbonate plant at Myllykoski (Partek Corp., press release, accessed July 22, 1998, at URL http://www.partek.fi/). Partek Nordkalk signed an agreement with SSAB Tunnplåt AB to acquire the lime plant that operates at the SSAB Tunnplåt's steel mill at Luleå, Sweden, by yearend 1997. Limestone for the lime plant has been supplied for several years from Partek Nordkalk's quarry in Gotland, Sweden. Most of the plant's future lime production will still go to SSAB Tunnplåt's steel mill, but excess production will be used to supply growing mining and pulp markets (Partek Corp., press release, accessed July 22, 1998, at URL http://www.partek.fi/).

France.—The French materials group, Lafarge SA, acquired the British construction materials company Redland PLC. The takeover included aggregate and lime operations in North America, including the lime plants of Redland Ohio Co. and Redland Stone Products Co. in Texas (Financial Times, UK aggregates, readymix shares up on bid hopes after Lafarge wins Redland, accessed January 22, 1998, at URL http://www.info.FT.com/news/company/company-261197-72.htm).

Italy.—Calcestruzzi Calo Anonio, Manduria, installed a Cimprogetti Cim-Reversy twin shaft kiln at its plant in southern Italy. The project cost $10 million and was scheduled for completion at yearend 1997. Fornaci Crovato SpA, a member of the Carmeuse Group, ordered a Maerz parallel flow regenerative two-shaft kiln with a capacity of 200 tons per day (220 short tons per day). Calce Mori Srl, a member of the Dolomite Colombo Group, installed a 300-ton-per-day (330-short-ton-per-day) Maerz shaft kiln at its Palagiano (Taranto) plant. Sider Calce SpA, also a member of the Dolomite Colombo Group, announced plans to install a 250-ton-per-day (275-short-ton-per-day) Maerz shaft kiln at its Campiglia Marittima (Livorno) plant (World Cement, 1997b).

Japan.—Lime producer Calceed Company Ltd., with lime plants in Chiba and Yamaguchi Prefectures, merged with magnesia producer Ube Chemical Industries Company Ltd. to form a new company called Ube Material Industries Company Ltd. Ube Chemical was a major customer of Calceed and its parent company, Ube Industries Ltd., was a major shareholder in Calceed. The merger is expected to produce efficiencies and benefits in research and development, planning, production, sales and marketing, especially when dealing with steel customers that

consume lime and magnesia products (Industrial Minerals, 1997b).

Turkey.—Carmeuse SA, the Belgian lime and limestone group with operations in Europe and North America, announced a large investment program in Turkish lime and limestone operations. Carmeuse plans to invest in joint ventures with Aster Kimtas AS and the Isiklar Group of companies. Carmeuse, directly or indirectly, owns 50% of each of these firms, which have a combined lime production capacity of 1,450,000 tons per year (1,600,000 short tons per year). Isiklar operates limestone and lime operations at Bartin, Kirsehir, and Silviri; and Aster Kimtas operates facilities at Bergama, Urla, Mugla, and Isparta (Industrial Minerals, 1997a). *(See table 5.)*

Current Research and Technology

Southwest Research Institute, a nonprofit research and development organization located in San Antonio, TX, has developed a lime-based paint designed to exploit lime's biocidal properties. The problem was that calcium hydroxide is incompatible with every known latex compound, resin and plastic solutions, solvent-based paints and coatings, and plastic and elastic film-forming materials. To be effective, the lime has to be exposed and active, but all of the 260 materials tested were either damaged or destroyed by the lime or encapsulated the lime in a plastic or elastic film. The researchers finally found three classes of polymers that are not used in conventional paints. These polymers tolerated all levels of lime indefinitely, provided good adhesion to surfaces, and allowed optimum volumes of various additives (pigments, fillers, surfactants, etc.) to be incorporated. Importantly, they allowed the lime to be active, durable, and effective in killing multiple varieties of viruses, bacteria, fungi, and mildew. This lime-based coating has successfully undergone abrasion and weatherability tests, actual exposures to New York environments and Texas weather, and biocidal tests. The potential applications of this nontoxic coating include floors and walls of nursing homes, hospitals, day-care centers, nurseries, restaurants, and kitchens. Other applications include meat lockers, pantries, air ducts, and any other surface where mold grows and mildew discolors (Paint and Coatings Industry, 1997).

Dravo Lime has introduced a specialized flue gas technology called Sorbalit to North America. The technology is patented by Märker Umwelttechnik of Germany, and combines the neutralization characteristics of lime with surface-activated substances such as activated carbon, lignite, or coke to control acid gas, mercury, and dioxin emissions from a variety of combustion applications. The sorbent is custom formulated with either quicklime (Sorbalime) or hydrated lime (Sorbalit) and includes from 2% to 65% carbon. The technology is versatile enough to be used with a wide variety of wet and semidry scrubbers, as well as duct injection systems (Dravo Lime Co., n.d.).

Canadian firm, Ateba Mines Inc., has developed a patented process to recover phosphate fines from the liquid clay tailings (slimes) that are removed by hydrocyclones during the beneficiation of phosphate rock. These slimes are currently disposed of in ponds and, because these slimes form colloidal suspensions, it takes years for solids to settle out. Ateba's process involves injecting a chemical agent into the slime pond to liquefy the clay in which the phosphate fines are suspended, and the fines can then be recovered using hydrocyclones. The resulting liquid-clay waste stream can then be treated with lime to form solid tailings more suitable for disposal. The company was expecting to sign a deal with a Florida phosphate producer to set up a pilot plant (North American Mineral News, 1997b). If this process proves successful and is widely adopted by Florida phosphate producers, there may be a significant increase in lime demand in Florida.

Outlook

Lime has dozens of end uses in the chemical, industrial, and construction industries, but 70% is consumed in seven clearly defined markets: drinking water treatment, FGD, iron and steel, precipitated calcium carbonate, pulp and paper, ore concentration in the mining industry, and soil stabilization. The forces behind these markets include the health of the economy, metals prices, extreme weather, and Federal funding levels.

Steelmaking remains the largest single end use for lime. The serious economic problems affecting Japan, Russia, Southeast Asia, and the developing countries may eventually have an adverse affect on the U.S. economy. This would affect U.S. steel production because of lower demand or because of increased imports of cheap steel. Steel production is expected to increase in 1998 and 1999, but the extended outlook is less clear. In the near term, demand for lime by the steel industry will follow the trends in domestic steel production, although in the long term, lime consumption by the steel industry may flatten out or decrease because of industry changes in raw materials and flux usage. The latter includes greater use of flux pellets and hot metal desulfurization.

The FGD market decreased slightly in 1997 because of a mild winter and summer in the Midwest, but despite this downturn in consumption the future continues to look promising for this market. Major FGD lime suppliers, such as Dravo Lime, are counting on the conversion of utilities in the Ohio River Valley to lime scrubbing from competing reagents, and feel that shipments to current customers could increase if the utilities decide to operate their scrubbers at higher levels prompted by an increase in the sulfur content of their fuel or a decision to overscrub to earn additional emission allowances. Phase II of the Clean Air Act Amendments, which takes effect January 1, 2000, and regulates small utility generating units, will probably provide an additional boost to lime sales after 1999. Lime scrubbers display favorable efficiencies and economics for these small units. Regulations covering small municipal incinerators and waste to energy incinerators also favor the use of lime scrubbers. Quantifying the increased demand generated by Phase II and other emissions regulations is difficult (note the unexpected dip in demand in 1997), but some industry projections have forecast FGD demand at 5 million tons (5.5 million short tons) by 2002. Major FGD lime producers are investing in research and development to lower the capital and operating costs associated with lime scrubbing and to produce salable byproducts. The goal of such research ultimately is to provide environmentally sound and economic technologies designed to attract customers from

powerplants currently utilizing limestone scrubbers or low-sulfur coal.

Soil stabilization sales remained strong and topped the 1-million-ton mark for the second year in a row. The soil stabilization market is affected by the level of funding for highway construction, the weather, and competition from products like cement. The use of lime in asphalt paving increased dramatically by 73% in 1997 after the decrease of 35% in 1996. This only brings sales up to the same level they were in 1994, and suggests the large decrease reported in 1996 may have been a reporting error. Stabilization and asphalt markets are expected to be boosted significantly by passage of new transportation legislation (Transportation Equity Act for the 21st Century). This legislation budgets $167 billion over 6 years for highway construction, which is a 44% increase, compared with the previous 6 years. Healthy increases in lime sales for stabilization and asphalt are expected during this period. The legislation was not signed into law until the summer of 1998, so evidence of such increases probably won't show up until 1999.

Demand in lime's traditional pulp and paper market rebounded somewhat in 1997, but no long-term growth is expected in this market. Current environmental controls make it expeditious for pulp mills to regenerate as much lime from their carbonate sludge as possible, which lessens the need to purchase makeup lime. The PCC market increased by 12% in 1997, and will probably continue to grow as PCC attempts to expand into the groundwood paper and paper coating markets. Anticipated growth in the PCC market is expected to be particularly strong in the Southeastern United States.

Overall, commercial lime sales are expected to grow at about 3% per year over the next several years. Barring any greenhouse gas emissions legislation, the only major market force on the horizon is Phase II of the Clean Air Act Amendments, which may boost FGD sales after the year 2000.

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TABLE 1
SALIENT LIME STATISTICS 1/

(Thousand metric tons unless otherwise specified) 2/

	1993	1994	1995	1996	1997
United States: 3/					
Number of plants	112	108 r/	106 r/	107 r/	105
Sold or used by producers					
High-calcium quicklime	NA	NA	NA	NA	14,300
Dolomitic quicklime	NA	NA	NA	NA	2,900
Total quicklime	14,200	14,800	15,800	17,000 r/	17,200
High-calcium hydrated lime	NA	NA	NA	NA	1,800
Dolomitic hydrated lime	NA	NA	NA	NA	352
Total hydrated lime	2,250	2,290	2,390	2,150 r/	2,150
Dead-burned dolomite	315	300	308	W	W
Grand total	16,700	17,400	18,500	19,200 r/	19,700
Value 4/ thousands	$965,000	$1,020,000	$1,100,000	$1,170,000 r/	$1,190,000
Average value per ton	$57.60	$58.80	$59.20	$60.80 r/	$60.70
Lime sold	14,900	15,500	16,400	16,800 r/	17,300
Lime used	1,870	1,910	2,180	2,430 r/	2,420
Exports 5/ 6/	69	74	72	50	80
Value thousands	$7,830	$7,800	$8,490	$5,600	$9,550
Imports for consumption 5/ 6/	201	204	289	262	274
Value thousands	$13,300	$13,100	$20,200	$19,400	$26,500
Consumption, apparent 7/	16,900	17,500	18,700	19,300	19,800
World: Production	123,000	120,000	121,000	121,000	120,000

r/ Revised. NA Not available. W Withheld to avoid disclosing company proprietary data.

1/ Data are rounded to three significant digits; may not add to totals shown.

2/ To convert metric tons to short tons multiply metric tons by 1.10231.

3/ Excludes regenerated lime. Excludes Puerto Rico.

4/ Selling value, f.o.b. plant, excluding cost of containers.

5/ Bureau of the Census.

6/ For 1993 through 1996 data include quicklime, slaked lime, and hydraulic lime; data for 1997 also include calcined dolomite.

7/ Defined as sold or used plus imports minus exports.

TABLE 2
LIME SOLD OR USED BY PRODUCERS IN THE UNITED STATES, BY STATE 1/ 2/

State	1996 Plants	1996 Hydrated (thousand metric tons)	1996 Quicklime (thousand metric tons)	1996 Total (thousand metric tons)	1996 Value (thousands)	1997 Plants	1997 Hydrated (thousand metric tons)	1997 Quicklime (thousand metric tons)	1997 Total (thousand metric tons)	1997 Value (thousands)
Alabama	4	196	1,660	1,860	$116,000	5	131	1,700	1,830	$115,000
Arizona, California, Nevada, Utah	15	205	2,060	2,260	142,000	14	215	2,130	2,340	142,000
Colorado, Montana, Wyoming	10	18	321	340	33,000	9	22	327	348	21,400
Idaho, Oregon, Washington	7	11	596	606	47,600 r/	7	23	646	669	53,400
Illinois, Indiana, Missouri	9	364 r/	3,330 r/	3,700	207,000 r/	8	350	3,380	3,730	217,000
Iowa, Nebraska, South Dakota	4	W	W	246 r/	16,100 r/	4	W	W	277	18,500
Kentucky, Tennessee, West Virginia	5	135	2,360	2,490	137,000	5	123	2,390	2,510	139,000
Michigan	9	3	782 r/	785 r/	42,700 r/	8	--	802	802	42,600
Ohio	8	W	W	1,950 r/	105,000 r/	8	W	W	1,960	111,000
Pennsylvania	8	276	1,250	1,530	105,000	8	212	1,300	1,510	103,000
Texas	7	462	894	1,360	87,100	7	508	957	1,470	91,500
Virginia	5	124	642	766	45,700	5	125	693	818	49,300
Wisconsin	4	121	430	551	32,000	4	132	464	597	35,100
Other 3/	13	276	2,700 r/	788	50,500	14	332	2,720	817	55,400
Total	108	2,190 r/	17,000 r/	19,200 r/	1,170,000 r/	106	2,170	17,500	19,700	1,190,000

r/ Revised. W Withheld to avoid disclosing company proprietary data; included with "Other."

1/ Excludes regenerated lime. Includes Puerto Rico.

2/ Data are rounded to three significant digits; may not add to totals shown.

3/ Includes Arkansas, Louisiana, Massachusetts, Minnesota, North Dakota, Oklahoma, Puerto Rico, and data indicated by the symbol W.

TABLE 3
LIME SOLD OR USED BY PRODUCERS IN THE UNITED STATES, BY RANGE OF PRODUCTION 1/ 2/

	1996			1997		
Range of production	Plants	Quantity (thousand metric tons)	Percent of total	Plants	Quantity (thousand metric tons)	Percent of total
Less than 25,000 tons	26	293	2	22	258	1
25,000 to 100,000 tons	23	1,240	6	24	1,200	6
100,000 to 200,000 tons	23	2,920	15	21	2,700	14
200,000 to 300,000 tons	16	3,820	21	19	4,360	22
300,000 to 400,000 tons	7	2,170	11	6	1,850	9
400,000 to 600,000 tons	7	3,120	16	8	3,750	19
More than 600,000 tons	6	5,670	29	6	5,560	28
Total	108	19,200 r/	100	106	19,700	100

r/ Revised.

1/ Excludes regenerated lime. Includes Puerto Rico.

2/ Data are rounded to three significant digits; may not add to totals shown.

TABLE 4
LIME SOLD OR USED BY PRODUCERS IN THE UNITED STATES, BY USE 1/ 2/

(Thousand metric tons and thousand dollars) 3/

Use	1996		1997	
	Quanitity 4/	Value	Quantity 4/	Value
Chemical and industrial:				
Fertilizer (aglime and fertilizer)	26	2,190	24	1,790
Glass	159	8,930	141	9,130
Paper and pulp	908	56,700 r/	976	60,200
Precipitated calcium carbonate	774 r/	43,800 r/	868	51,800
Sugar refining	655	47,100 r/	748	55,100
Other chemical and industrial 5/	1,950 r/	116,000 r/	2,080	126,000
Total	4,480	275,000	4,840	304,000
Metallurgical:				
Steel and iron:				
Basic oxygen furnaces	4,000 r/	227,000 r/	4,380	249,000
Electric arc furnaces	1,160 r/	67,300 r/	1,330	82,300
Other steel and iron	578	37,000	348	21,300
Total	5,740 r/	331,000	6,050	353,000
Nonferrous metals:				
Aluminum and bauxite	237	14,800	216	13,200
Other nonferrous metallurgy 6/	1,550	86,900	1,620	89,700
Total nonferrous metals	1,790	102,000	1,840	103,000
Total metallurgical	7,530	433,000	7,890	456,000
Construction:				
Asphalt	137	11,000 r/	237	18,900
Soil stabilization	1,000 r/	63,300 r/	1,060	65,000
Building uses 7/	298	27,600	314	33,700
Other construction 8/	71	9,790 r/	18	1,310
Total	1,510 r/	112,000 r/	1,630	119,000
Environmental:				
Flue gas sulfur removal:				
Utility powerplants	2,660	150,000	2,590	133,000
Incinerators	121	7,200	108	6,630
Other	32	1,960	56	3,560
Total	2,810 r/	159,000 r/	2,750	143,000
Sludge treatment:				
Sewage	NA	NA	335	23,000
Other (industrial, hazardous, etc.)	NA	NA	96	6,310
Total	NA	NA	430	29,300
Water treatment:				
Acid mine drainage	NA	NA	172	11,500
Drinking water	NA	NA	895	56,600
Wastewater	NA	NA	485	30,700
Total	NA	NA	1,550	98,800
Other enviromental: 8/	2,630	163,000	309	20,100
Total environmental	5,440	323,000 r/	5,040	291,000
Refractories (deadburned dolomite)	W	W	W	W
Grand total	19,200 r/	1,170,000 r/	19,700	1,190,000

r/ Revised. NA Not available. W Withheld to avoid disclosing company proprietary data.

1/ Excludes regenerated lime. Includes Puerto Rico.

2/ Data are rounded to three significant digits; may not add to totals shown.

3/ To convert metric tons to short tons multiply metric tons by 1.10231.

4/ Quantity includes lime sold and used, where "used" denotes lime produced for internal company use for copper ore concentration, magnesia, paper and pulp, precipitated calcium carbonate, basic oxygen furnaces, mason's lime, and refractories.

5/ The 1996 and 1997 data are not directly comparable, in 1996 "Other chemical and industrial" included metallurgical uses.

6/ Includes ore concentration (copper, gold, etc.), magnesium, and other.

7/ The 1996 and 1997 data may not be directly comparable, because the 1996 data only included mason's lime and finishing lime.

8/ The 1996 and 1997 data may not be directly comparable.

TABLE 5
QUICKLIME AND HYDRATED LIME, INCLUDING DEAD-BURNED DOLOMITE: WORLD PRODUCTION, BY COUNTRY 1/ 2/

(Thousand metric tons)

Country 3/	1993	1994	1995	1996	1997 e/
Australia e/	1,500	1,500	1,500	1,500	1,500
Austria	1,811	1,850	1,908 r/	1,990 r/	1,900
Belgium e/	1,750	1,750	1,800	1,800	1,800
Brazil e/	5,700	5,700	5,700	5,700	5,700
Bulgaria	531	665	952	1,000 e/	1,200
Canada	2,380	2,390 e/	2,398	2,402 r/	2,447 p/
Chile (hydraulic) e/	1,300	1,300 r/	1,006 4/	1,050	1,050
China e/	19,500	19,500	20,000	20,000	20,500
Colombia e/	1,300	1,300	1,300	1,300	1,300
Czech Republic	1,147	1,206	1,186	1,176 r/	1,200
France	3,000 e/	3,015	2,940	2,714 r/	2,800
Germany	7,483	8,511	8,000 e/	8,000 e/	8,000
Italy e/ 5/	3,600	3,500	3,500	3,500	3,500
Japan (quicklime only)	7,958	7,712	7,871 r/	7,744 r/	7,850
Mexico e/	6,500	6,500	6,580 4/	6,600	6,600
Poland	2,584	2,516	2,526	2,500 e/	2,500
Romania	1,738	1,621	1,763 r/	1,712 r/	1,750
South Africa (sales)	1,599	1,597	1,743	1,691	1,585 4/
U.S.S.R., Former e/ 6/	20,000	16,000	16,000	15,000	14,000
United Kingdom e/	2,500	2,500	2,500	2,500	2,500
United States, including Puerto Rico (sold or used by producers)	16,800	17,400	18,500	19,100	19,700 4/
Other e/	12,300 r/	12,000 r/	11,600 r/	11,700 r/	11,700
Total	123,000	120,000	121,000	121,000	120,000

e/ Estimated. p/ Preliminary. r/ Revised.

1/ World totals, U.S. data, and estimated data are rounded to three significant digits; may not add to totals shown.

2/ Table includes data available through June 3, 1998.

3/ Lime is produced in many other countries besides those included in the total. Argentina, Iraq, Pakistan, and Syria are among the more important countries for which official data are not available.

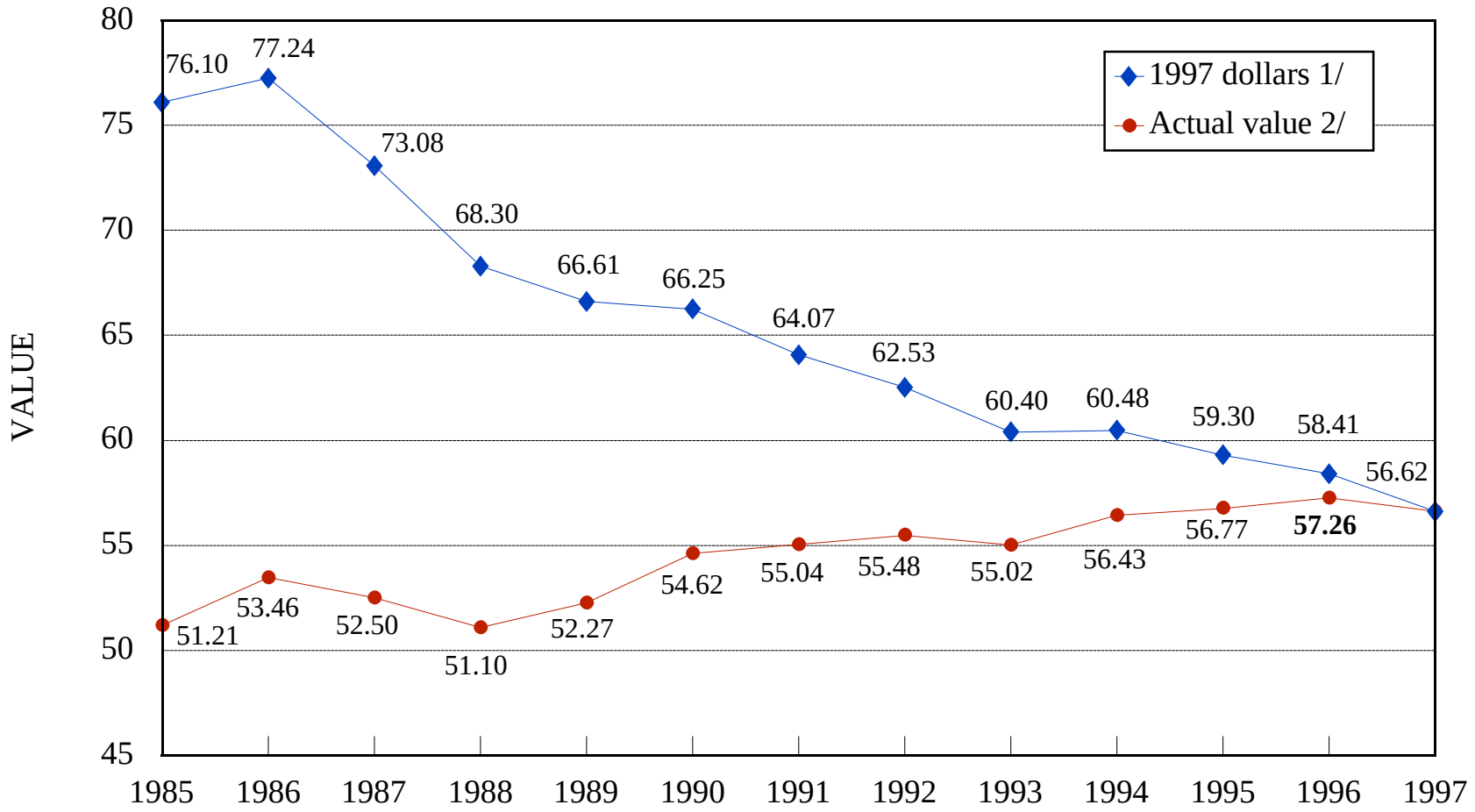
4/ Reported figure.

5/ Includes hydraulic lime.

6/ Information is inadequate to formulate reliable estimates for individual countries of the former U.S.S.R.

FIGURE 1

TIME-VALUE RELATIONSHIPS FOR QUICKLIME SOLD
(Dollars per metric ton)



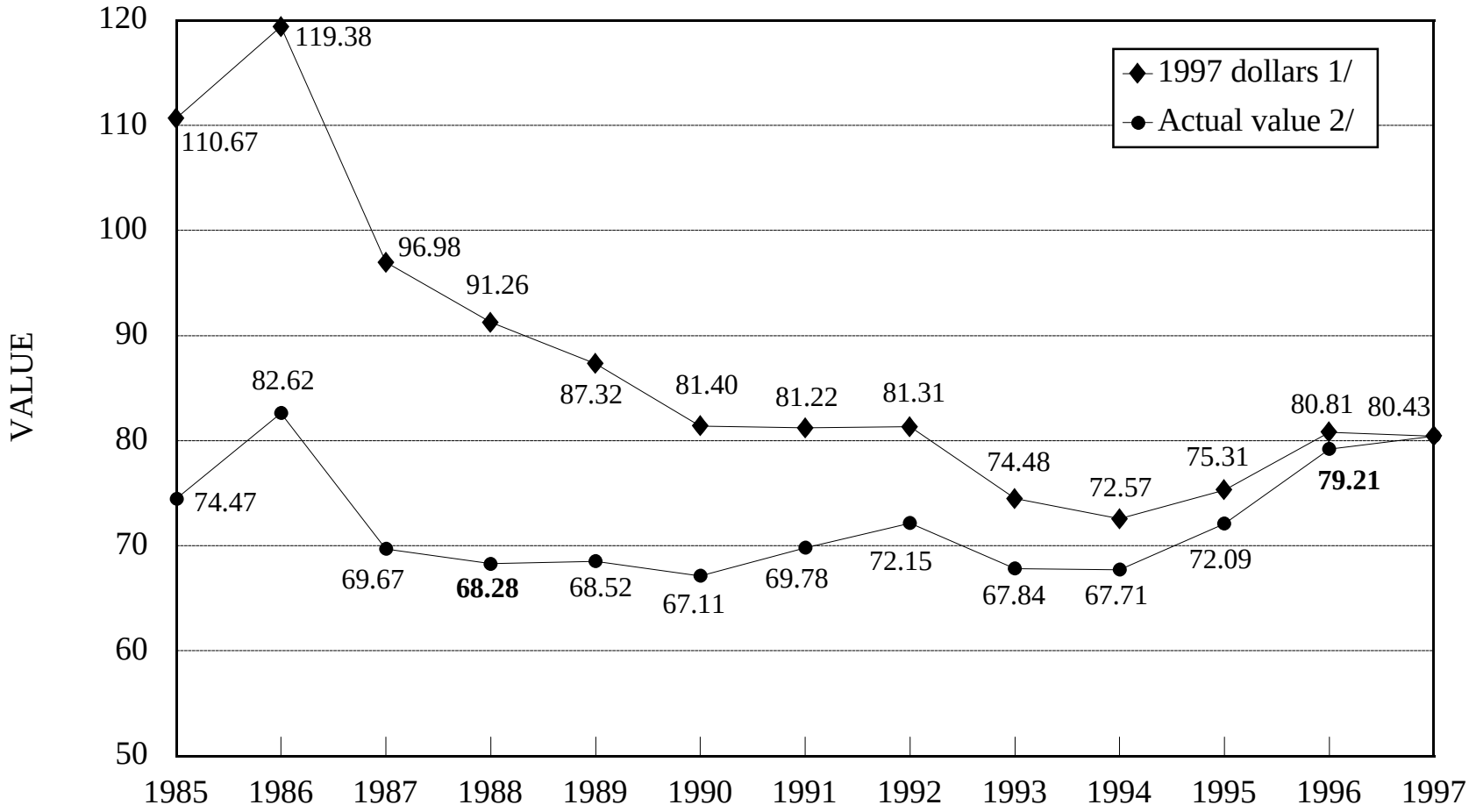
Values in bold indicate revisions.

1/ Based on implicit price deflator for gross domestic product; base year is 1997.

2/ Value of lime sold as prepared for shipment, f.o.b. plant.

FIGURE 2

TIME-VALUE RELATIONSHIPS FOR HYDRATED LIME SOLD
(Dollars per metric ton)



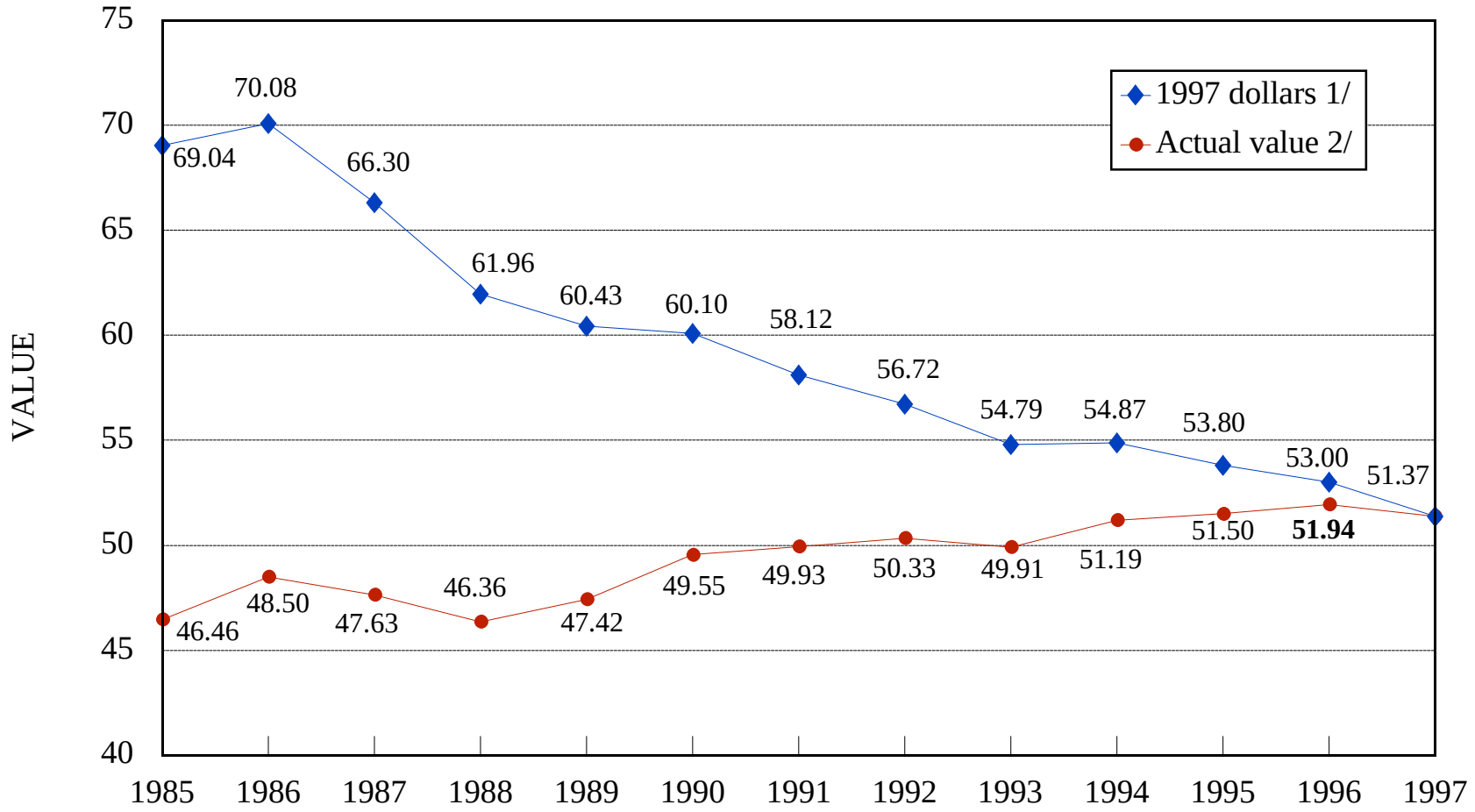
Values in bold indicate revisions.

1/ Based on implicit price deflator for gross domestic product; base year is 1997.

2/ Value of lime sold as prepared for shipment, f.o.b. plant.

FIGURE 3

TIME-VALUE RELATIONSHIPS FOR QUICKLIME SOLD
(Dollars per short ton)



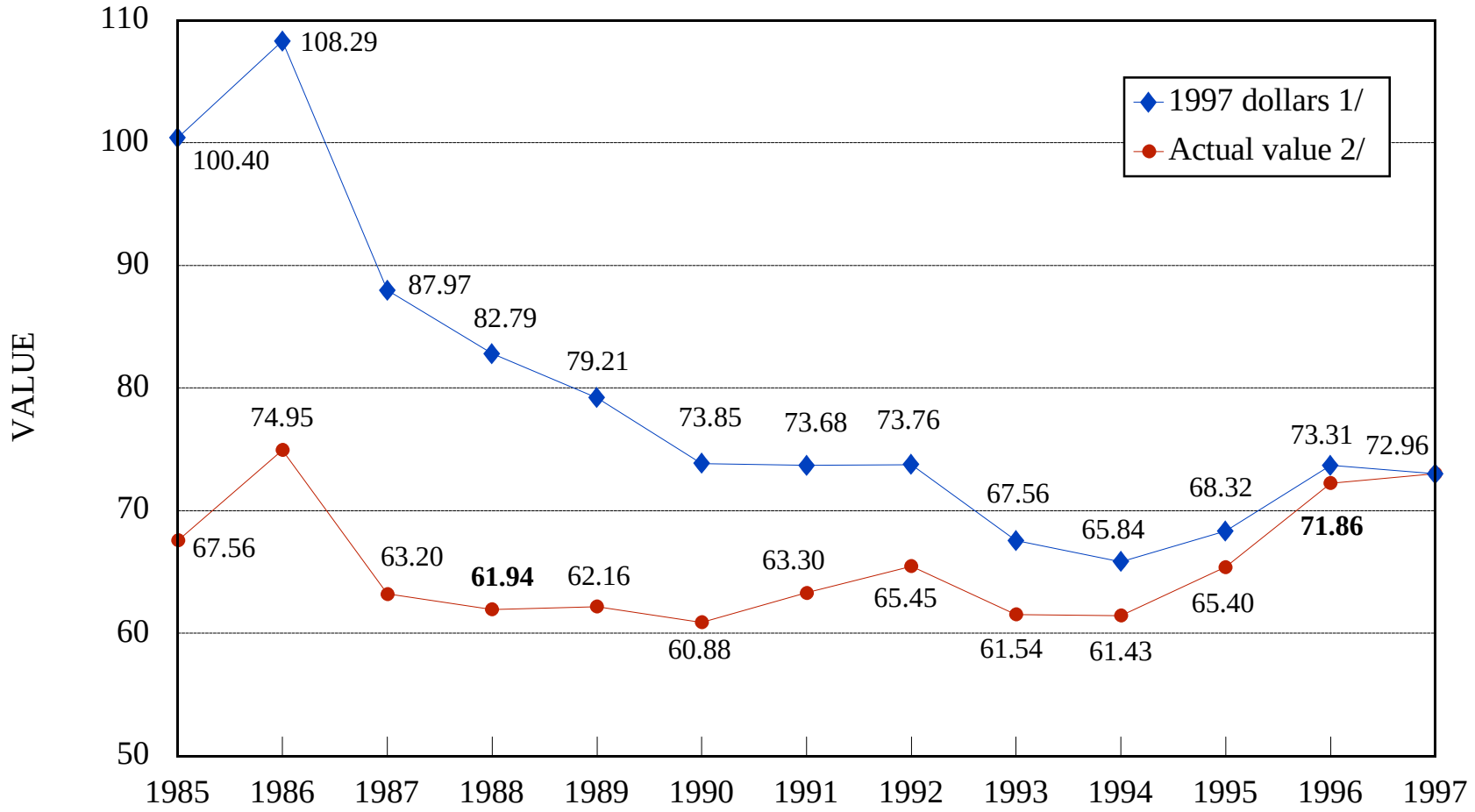
Values in bold indicate revisions.

1/ Based on implicit price deflator for gross domestic product; base year is 1997.

2/ Value of lime sold as prepared for shipment, f.o.b. plant.

FIGURE 4

TIME-VALUE RELATIONSHIPS FOR HYDRATED LIME SOLD
(Dollars per short ton)



Values in bold indicate revisions.

1/ Based on implicit price deflator for gross domestic product; base year is 1997.

2/ Value of lime sold as prepared for shipment, f.o.b. plant.