LIME

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Lime is an important chemical with numerous chemical, industrial, and environmental uses in the United States. Some evidence of its use as a lime mortar has been found at a site in what is now eastern Turkey that dates from 7,000 to 14,000 years ago. More definite evidence of its use in mortars in the Near East and in the former Yugoslavia dates from 8,000 years ago. In Tibet, it was used to stabilize clays in the construction of the pyramids of Shersi, which were built 5,000 years ago. The ancient Egyptians used lime as an ingredient in mortar and plaster. The Chinese, Greek, Roman, and other ancient civilizations used lime for construction, agriculture, bleaching, and tanning (Oates, 1998, p. 3-4). 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 20th century, more than 80% of the lime consumed in the United States went for construction uses, but currently more than 90% is being consumed for chemical and industrial uses.

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. Regenerated lime, however, is beyond the scope of this report.

Production

Lime is a basic chemical that was produced as quicklime in 33 States and Puerto Rico (table 2). Hydrated lime was produced in four additional States in which hydrating plants used quicklime shipped in from out of State. Principal producing States were, in descending order of production, Missouri, Alabama, Ohio, Kentucky, Texas, and Pennsylvania.

Domestic production data for lime are derived 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. Quantity data are collected for 28 specific and general end uses, and value data are collected by type of lime, such as high calcium or dolomitic. Because value data are not collected by end use, value data shown in table 4 are determined by calculating the average value per metric ton of quicklime sold or used for each respondent and then multiplying it by the quantity of quicklime that 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; in 1999, there were 115 operations listed. Two of these operations are not surveyed at the producers' request, and estimates are made by using reported prior-year production figures or other industry data. Six operations were idle in 1999. Of the 109 operations to which the 1999 annual survey request was sent, 91 responded, representing 85% of the total sold or used by producers. Production for 3 nonrespondents was estimated based on company production estimates, production for 2 nonrespondents was based on other commodity data, and production for 11 nonrespondents was estimated using reported prior-year production figures.

Total lime sold or used by domestic producers in 1999 decreased by about 500,000 metric tons (t) (551,000 short tons) to 19.6 million metric tons (Mt) (21.6 million short tons) compared with that of 1998 (table 1). Production included the commercial sale or captive consumption of quicklime, hydrated lime, and dead-burned refractory dolomite. These products were valued at $1.18 billion. Commercial sales decreased by 500,000 t (551,000 short tons) to nearly 17.3 Mt (19.1 million short tons), while captive consumption remained essentially unchanged from the 1998 figures at about 2.31 Mt (2.55 million short tons).

Changes continued apace in the lime industry in 1999. The merger of the Carmeuse North America Group and Lafarge S.A.'s North American lime operations was finalized in February (North American Minerals News, 1999a). Later in the year, Carmeuse acquired from parent company Oglebay Norton Co. the stock of Global Stone Detroit Lime Co. in Michigan and Global Stone Ingersoll Ltd. in Ontario, Canada (National Lime Association, 1999a). Carmeuse shut down the lime kiln at its plant at Woodville, OH, but will continue to produce stone at the facility. The Woodville plant had been acquired from Lafarge as part of the merger. The shutdown of the Woodville lime plant was due in part to the startup in October of Carmeuse's newly renovated dolomitic lime plant at Maple Grove, OH, which will have the advantage of being newer, larger, and able to produce the higher purity lime required by Carmeuse's customers (J.M. McKinnon, Toledo Blade, November 4, 1999, Bettsville lime operation thrives, accessed November 18, 1999, at URL http://www.toledoblade.com/editorial/biz/9k04bett.htm). The

project involved the refurbishment of two straight rotary kilns with a combined capacity of 1,090 tons per day (t/d) (1,200 short tons per day). Under a long-term contract with Dow Chemical Co., Carmeuse is committed to supply more than 181,000 tons per year (t/yr) (200,000 short tons per year) to Dow's Ludington, MI, magnesium hydroxide plant (National Lime Association, 1999b).

While divesting itself of lime operations in the Midwest, Oglebay Norton's Global Stone Corp. strengthened its presence in the Mid-Atlantic and Southeast by acquiring the W.S. Frey Co. lime plant at Clearbrook, VA (National Lime Association, 1999c). The plant has been attached to the Global Stone Chemstone, Inc. unit and will be known as the Global Stone Chemstone Winchester plant.

Chemical Lime Co. acquired APG Lime Corp. from parent company Global Industrial Technologies Inc. The acquisition included one lime plant in Texas, two in Virginia, and Chemical Lime replaced APG Lime as co-owner with Scana Corp. in the joint-venture plant in South Carolina (Global Industrial Technologies, Inc., 1999). The South Carolina joint venture, called Palmetto Lime LLC, began lime production in the summer of 1999.

U.S. Lime and Minerals Inc. (USLM) acquired the lime plant, equipment, and inventories of Calco, Inc. in Salida, CO. USLM has received a permit to operate the lime plant and is considering reopening the plant in 2001 (National Lime Association, 1999d). The purchase was judged a logical fit with USLM's Texas Lime Co. operations in Cleburne, TX, in order to better serve customers in the region stretching from Northern Texas to Colorado.

Mississippi Lime Co., headquartered in Alton, IL, announced in June 1999 that it was eliminating 50 to 70 jobs, cutting its nonunion workforce by 20%. The company had made substantial capital investments in recent years and the job cuts were simply another part of its efforts to increase productivity and to expand the company (Rissover, 1999).

Of the 45 companies manufacturing quicklime at the end of 1999, 27 were primarily commercial producers, 14 were predominantly captive producers, and 4 combined commercial sales with captive production. The 27 commercial producers operated 64 lime plants producing quicklime and 8 separate hydrating plants (including 1 lime plant that was idle but operated its hydrator). The 14 captive producers operated 36 plants producing quicklime primarily for internal company use. At yearend, the top 10 companies were, in descending order of production, (1) Carmeuse North America, (2) Chemical Lime, (3) Continental Lime, Inc., (4) Mississippi Lime, (5) Global Stone, (6) Martin Marietta Magnesia Specialties, Inc., (7) Vulcan Materials Co., (8) U.S. Lime and Minerals, (9) LTV Steel Co., Inc., and (10) Western Lime Corp. These companies operated 48 lime plants and 6 separate hydrating plants and accounted for 86% of commercial sales of quicklime and hydrated lime combined and 78% 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. In 1999, on the basis of capacity data from 38 of the largest commercial plants, the U.S. lime industry operated at about 76% of capacity. The calculations do not include combined commercial and captive producers, hydrating plants, plants that commissioned new kilns during the year, and Puerto Rico. This is slightly lower than the operating rate of 79% calculated for 1998. Capacity utilization would be slightly lower if the capacity of several idle or mothballed plants were factored into the calculations.

Environment

Currently the most common fuel used in lime production is coal. Emissions generated in the combustion of coal and other fuels makes the lime industry subject to regulation under the Clean Air Act. Of immediate concern to the lime industry are the costs and obligations expected for additional monitoring, reporting, and control of hazardous air pollutants, such as mercury and particulate matter. Of longer term concern, but with potentially greater impacts, are the international discussions on the reduction of greenhouse gas emissions, particularly carbon dioxide. Lime production generates carbon dioxide from the combustion of fuels and from the calcination process, which dissociates calcium carbonate into calcium oxide and carbon dioxide. Any program to regulate carbon dioxide emissions would affect lime producers.

Consumption

The breakdown of consumption by major end uses (table 4) was as follows: 39% for metallurgical uses, 25% for chemical and industrial uses, 24% for environmental uses, 11% 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, sugar refining, and 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 lists the total quantity and value of lime by end use. End uses with captive consumption are listed in footnote 4 of the table. Values assigned to specific end uses in table 4 should not be construed as being price specific to that market. The USGS does not collect value data by end use, and the values shown in tables 4 and 5 are derived, in general, from average lime values. The market values shown are simply designed to show the relative value of the market.

In steel refining, quicklime is used as a flux to remove impurities, such as phosphorus, silica, and sulfur. Dolomitic lime is often substituted for a fraction of the high-calcium lime to extend refractory life. Dolomitic quicklime is also used as a flux in the manufacture of glass. The steel industry accounted for about 31% of all lime consumed in the United States. Lime consumption by the iron and steel industry decreased by 2.5% to 5.97 Mt (6.58 million short tons) compared with that of 1998.

In 1998, the steel market was troubled by a 33% increase in imports of steel mill products compared with 1997. In 1999, the beginnings of a recovery were evident as imports decreased by 14% when compared with 1998. However, the 1999 import levels were still 14% higher than in 1997. Total U.S. steel shipments increased by 2.6% in 1999, although production actually decreased by 1.4%. This apparent contradiction is explained by the decrease in imports and the drawdown of

excess inventories that had accumulated in 1998. A better indication of the recovery is evident when comparing the rate of capacity utilization. In the first three quarters of 1999, the utilization rate averaged 79.7%, but in the fourth quarter the utilization rate averaged 88.6%. Steelmaking continues to be the single largest end use for lime.

In nonferrous metallurgy, lime is used in the beneficiation of copper ores to neutralize the acidic effects of pyrite and other iron sulfides and to maintain the proper pH in the flotation process. Lime consumed by the copper industry is included in table 4 under the category "Other nonferrous metallurgy." Lime consumption by the copper industry decreased in 1999 because of a decrease in copper mine production of about 260,000 t (287,000 short tons) in response to lower prices and numerous mine cutbacks. Capacity utilization fell to 79%, down from 90% in 1998. In 1999, Broken Hill Proprietary Ltd. closed the Robinson Mine in Nevada and the San Manuel Mine in Arizona, and Phelps Dodge Corp. closed its Metcalf concentrator at the Morenci Mine in Arizona (Edelstein, 2000).

Lime is used to process alumina and magnesia, to extract uranium from gold slimes, to recover nickel by precipitation, and to control the pH of the sodium cyanide solution used to leach 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 level between 10 and 11 to maximize the recovery of precious metals and to prevent the creation of hydrogen cyanide. Lime sales for gold and silver recovery were down in 1999. Mine production of recoverable gold and silver in the United States decreased by 7% and 6%, respectively. The closure of seven gold mines in the Western United States, two in Alaska, and one in South Carolina was the primary cause for the decrease in gold production.

The tailings that result from the recovery of precious metals may contain elevated levels of cyanides. Lime is used in treatment processes, such as, Cyanisorb, alkaline chlorination, and sulfur dioxide/air, to recover the cyanides.

In the environmental sector, lime is used in the softening and clarification of municipal potable water and to neutralize acid mine and industrial discharges. In sewage treatment, lime's traditional role is to control pH in the sludge digester, which removes dissolved and suspended solids that contain phosphates and nitrogen compounds. It also aids clarification and in destroying harmful bacteria. More recently, the largest use in sewage treatment has been to stabilize the resulting sewage sludges. Sewage sludge stabilization, also called biosolids stabilization, reduces 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. Lime consumption for all sludge treatment decreased by 37% compared with revised 1998 figures. The sewage sludge market decreased by 31%, and the industrial and hazardous waste market decreased by 45%.

In flue gas desulfurization (FGD) systems serving electric utility and industrial plants and incinerators, lime is used to react with sulfur oxides in the flue gas and is used to stabilize the resulting sludge before disposal. In 1999, lime sales to the FGD markets decreased by nearly 12% compared with 1998 figures. A number of different factors contributed to the decrease. The new economics that have resulted from power companies having to compete for customers affected the lime FGD market. In attempts to increase their competitiveness, utilities cut operating and maintenance budgets, which resulted in significant outages caused by equipment failures. In addition, mild seasonal temperatures decreased the demand for electricity, and one large powerplant had to reduce its power generation in order to cut emissions of nitrogen oxides.

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 also uses lime as a coagulant aid in the clarification of plant process water. In 1999, lime consumption for pulp and paper production, excluding precipitated calcium carbonate production, increased by more than 5% compared with revised 1998 figures.

Lime is used, generally in conjunction with soda ash, for softening plant process water. This precipitation process removes bivalent soluble calcium and magnesium cations (and, to a lesser extent, ferrous iron, manganese, strontium, and zinc), which contribute to the hardness of water. This process also reduces carbonate alkalinity and dissolved solids content.

Lime is 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. Lime demand for PCC production increased by 19% compared with revised 1998 figures, continuing the strong growth exhibited by this market in the 1990's.

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

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

as a byproduct of lime production.

In construction, hydrated lime and quicklime are used in subgrade stabilization to stabilize fine-grained soils in place (subgrade) or borrow materials that are employed as subbases, such as hydraulic clay fills or otherwise poor-quality clay and silty materials obtained from cuts or borrow pits. Lime is also used in base stabilization, which includes upgrading the strength and consistency properties of aggregates that may be judged unusable or marginal without stabilization. Common applications for lime stabilization included the construction of roads, airfields, building foundations, earthen dams, and parking areas. Lime sales for stabilization were unchanged in 1999, but remain at historic highs.

In road paving, hydrated lime is used in hot mix asphalt to act as an antistripping agent. Stripping is generally defined as a loss of adhesion between the aggregate surface and asphalt cement binder in the presence of moisture. Lime is also used in cold in-place recycling for the rehabilitation of distressed asphalt pavements. Existing asphalt pavement is pulverized by using a milling machine, and a hot lime slurry is added along with asphalt emulsion. The cold recycled mix is placed and compacted by using conventional paving equipment, which produces a smooth base course for the new asphalt surface. In 1999, sales for use in asphalt increased by 13%.

In the traditional building sector, quicklime is used to make calcium silicate building products, such as sand-lime brick and autoclaved aerated concrete (AAC). AAC offers the advantage of producing building materials that can be cut, drilled, and nailed like wood, but with the advantages of a concrete product. Hydrated lime is used in plaster, stucco, and mortars to improve durability. Use of hydrated lime in these traditional building uses increased by 13% in 1999. These figures correlate well with the 11% increase in completions of privately owned housing units (U.S. Bureau of the Census, April 4, 2000, Housing completions—Annual data, accessed April 20, 2000, at URL http://www.census.gov/const/www/c22index.html).

Dead-burned dolomite, also called refractory lime, is used as a component in tar-bonded refractory brick used in basic oxygen furnaces. Hydrated lime is used to produce silica refractory brick used to line industrial furnaces.

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. All value data for lime are reported by type of lime produced—high-calcium quicklime, high-calcium hydrate, dolomitic quicklime, dolomitic hydrate, and dead-burned dolomite. Emphasis is placed on the average value per ton of lime sold.

In 1999, prices decreased for quicklime and refractory dolomite and increased for hydrate. The average unit value per ton of all lime sold or used by producers, on an f.o.b. plant basis, was $60.10 ($54.50 per short ton). The average values per ton of lime sold and used, by type of lime, were $57.20 ($51.90 per short ton) for quicklime, $79.70 ($72.30 per short ton) for hydrated lime, and $83.80 ($76.00 per short ton) for refractory dolomite. The average value for hydrated lime increased $2.00 from the revised 1998 value of $77.70 ($70.50 per short ton).

The average value per ton of quicklime sold was $56.60 ($51.30 per short ton). The average value per ton of high-calcium quicklime sold was $56.90 ($51.70 per short ton). The average value per ton of dolomitic quicklime sold decreased by $2.30 to $55.00 ($49.90 per short ton). The average value per ton of refractory dead-burned dolomite sold decreased by $4.90 to $82.40 ($74.80 per short ton). The decrease in dolomitic quicklime prices is believed to be tied to the difficulties experienced by the domestic steel industry. The steel industry is the largest market for dolomitic quicklime, and lime supply contracts are sometimes tied to the steel producer price index, which was down in 1998 because of the high level of imports.

The average value per ton of hydrated lime sold increased by $1.40 to $79.80 ($72.40 per short ton) from the revised 1998 value of $78.40 ($71.10 per short ton). The average value per ton of high-calcium hydrate sold increased $4.90 to $78.70 ($71.40 per short ton) from the revised 1998 value of $73.80 ($67.00 per short ton). The average value per ton of dolomitic hydrate sold decreased by $12.80 to $87.90 ($79.70 per short ton).

Despite competition, the low inflation rate, and stable coal prices (coal prices are forecast to decline in 2000 according to the U.S. Energy Information Administration), “delivered” lime prices may increase in 2000 because of increased transportation costs resulting from higher gasoline and diesel fuel prices.

Foreign Trade

The United States exported and imported quicklime, hydrated lime (slaked lime), hydraulic lime, and calcined dolomite (dolomitic lime). Combined exports of lime (table 6) were 58,500 t (64,500 short tons) at a total value of $8.02 million, with nearly 80% going to Canada, 13% going to Mexico, and the remaining 7% going to various other countries. Combined imports of lime (table 7) were 152,000 t (168,000 short tons) at a total value of $15.4 million, with 89% coming from Canada and 11% coming from Mexico.

No tariffs are placed on imports of hydraulic lime, quicklime, and slaked lime from countries with normal trade relations (NTR) with the United States. There is a 3.0% ad valorem (percentage of value) tariff on imports of calcined dolomite from NTR countries.

World Review

With the exception of industrialized nations with good data collection, accurate lime data for many countries are frequently difficult to acquire. The variations in quality, types of lime, production technologies, and industries manufacturing lime and the frequent confusion with limestone data make accurate reporting of world lime data (table 8) extremely difficult and certainly incomplete. The following is a brief discussion of acquisitions or new construction in specific countries.

Canada.—On December 31, Graymont Inc. announced that it entered into an agreement to purchase Havelock Lime in New Brunswick, Canada. Havelock Lime has one rotary kiln and one

shaft kiln with a combined capacity of about 163,000 t/yr (180,000 short tons per year). It will join Graymont's Eastern Division, which currently includes Graybec, Inc. of Montreal, Quebec, and Graybec Lime, Inc. of Bellefonte, PA (National Lime Association, 2000).

Chile.—South American Gold and Copper Ltd. announced the terms of a joint venture with Cia. Minera Quelon Ltda. for the construction and operation of a new lime plant approximately 300 kilometers north of Santiago. The plant will utilize an unspecified vertical shaft kiln with a capacity of 150 t/d (165 short tons per day). The new plant will have a substantial transportation advantage in serving the gold and copper mines in Chile's Regions IV and V compared with existing private sector lime companies (North American Minerals News, 1999b).

Poland.—The Gorazdze Lime plant at Gorazdze in Poland was privatized by the state in 1993, when it was purchased by the CBR Group of Belgium, which itself was subsequently acquired by Heidelberger Zement AG of Germany. Heidelberger poured investment into the company, and construction of a new lime plant 1.5 kilometers south of Gorazdze was completed in 1998. The new plant is adjacent to the quarry and preexisting limestone preparation facilities. The new plant has a 600-t/d Maerz parallel-flow regenerative double-shaft kiln and a 300-t/d Fercalx Gopex single-shaft kiln (Global Lime Magazine, 2000).

United Kingdom.—Both the technology and acceptance of lime stabilization as a cost effective and flexible treatment method for sewage sludge has progressed dramatically since the banning of ocean dumping in December 1998. By the summer of 1999, there were 14 full-scale permanent installations using lime stabilization technology for treatment of wastewater sludge. At least 5 full-scale technology demonstrations have been successfully completed resulting in 2 major water companies standardizing the technology at more that 12 sites. These demonstrations have been instrumental in proving lime stabilization's effectiveness in killing pathogens, and that an excellent biosolids product is produced that is desired by the agricultural community (J.D. Robinson, Senior Executive Marketing and Corporate Development, Singleton Birch, written commun., August 13, 1999).

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, PCC, pulp and paper, ore concentration in the mining industry, and soil stabilization. The forces behind these markets include the health of the economy, imports, metals prices, weather conditions, and Federal funding levels.

Environmental markets are driven more by regulatory requirements; for example, Phase II of the Clean Air Act Amendments (CAAA), which went into effect January 1, 2000, is expected to provide a boost to FGD demand. Despite the unexpected decrease in FGD sales in 1999, the future of the FGD market still looks promising. Although, this increase in demand may not materialize for a few years. An excess of emissions allowances accumulated during Phase I of the CAAA and the current low price of allowances makes it likely that installation of new FGD scrubbers will be delayed. The basic arguments, however, remain the same. The sulfur dioxide removal processes with the longest proven track record are calcium-based scrubbers. To comply with Phase I of the CAAA, most utilities relied on fuel switching or purchased emission allowances. The U.S. Department of Energy forecasts that scrubbers will be more cost competitive during Phase II of the CAAA because the cost of lime-based scrubbers has decreased from about $400 to $900 per short ton of sulfur dioxide removed to about $300 per short ton. Lime will compete primarily against limestone for this increased scrubber market. Lime scrubbers display favorable efficiencies and economics for small units. Regulations covering emissions from 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, but the Department of Energy estimates that about 23 gigawatts of coal-fired capacity will be retrofitted with scrubbers by 2010 (Los Alamos National Laboratory, [no date], Clean coal technology compendium, accessed July 23, 1999, at URL http://www.lanl.gov/projects/cctc/projects/ projects_fs.html).

Overall, the construction markets, boosted by the healthy economy and the 1998 passage of the Transportation Equity Act for the 21st Century, should remain strong. The traditional building markets (masonry and finishing lime) may experience a slow down. The U.S. Bureau of the Census reported only a 3% increase in housing units started in 1999 (as compared with an 11% increase in 1998), which will translate into fewer completed in 2000.

The continued strength of the economy aids markets in general, and although it is not reflected in the preliminary steel production figures for 1999, the domestic steel industry is recovering from the negative effects of high levels of steel imports in 1998. Lime suppliers to the steel market are, however, faced with a steel industry that because of price pressures is seeking to cut production costs. One change that may adversely affect lime sales is the partial replacement of dolomitic lime with MgO. USX Corp.'s U.S. Steel Group conducted flux reduction trials using pure MgO to partially replace dolomitic lime during the initial fluxing stage. The result required 5% less high-calcium lime per ton of steel and 27% less dolomitic lime per ton of steel. The test also showed improved protection of the furnace lining to slag attack and improved high-calcium lime dissolution. As a result, less flux is required because of more efficient slag formation (Xio Dong Zhang, 1999).

Sales of paper fillers are forecast to grow by 3% in 2000 thanks to the paper industry's continued push to cut costs and a modest recovery in the paper market. PCC is expected to be the leader, and its sales are forecast to grow by 7% per year through 2003 (Chemical Week, 2000).

In the ore concentration market, U.S. copper producers are under financial pressures because of low copper prices and excess world capacity. U.S. production of copper from concentrate is expected to decrease from 1,015,000 t to 870,000 t or about 15% in 2000 (D.L. Edelstein, Copper Commodity Specialist, U.S. Geological Survey, written commun., April 26, 2000).

As a result of low inflation and stable prices for coal (the

major fuel used in U.S. lime kilns), production costs have not risen appreciably in the 1990's. Partly as a result of this, but mainly because of strong competition between producers, the average value per ton of quicklime on an f.o.b. plant basis increased since 1990 by an annual rate that has not kept up with the rate of inflation. If not addressed, this will result in shrinking margins and an obviously lower return on investment. The larger lime companies, possessing the backing to finance construction and acquisitions, have responded by adding or replacing kilns at existing plants, by building greenfield plants, and by buying out smaller companies. In the long term, this results in lower production costs through the introduction of larger, more efficient kilns and through economies of scale. In the short term, reductions in production costs at a new plant or recently expanded plant may be lost to increased charges for capital and depreciation. Buying competitors has the advantage of decreasing competition, increasing demand for the acquiring company's product, and may offer the opportunity to raise prices. An acquisition can also create synergies within a large company that allows for the reduction in operating expenses for transportation, storage, etc.

References Cited

Chemical Week, 2000, PCC expands its share as kaolin and TiO_2 fade: Chemical Week, v. 162, no. 5, February 2, p. 40-41.

Edelstein, D.L., 2000, Copper in December 1999: U.S. Geological Survey Mineral Industry Surveys, March, 12 p.

Global Industrial Technologies, Inc., 1999, Global Industrial Technologies reports first quarter results; completes sale of APG Lime: Dallas, TX, Global Industrial Technologies press release, April 14, 4 p.

Global Lime Magazine, 2000, New developments at Gorazdze Lime: Global Lime Magazine, February, p. 12-13.

National Lime Association, 1999a, Carmeuse buys two Global Stone lime plants: Limelites, v. 65, no. 4, April-June, p. 5-6.

———1999b, Carmeuse enters long-term supply contract with Dow Chemical: Limelites, v. 65, no. 3, January-March, p. 2.

———1999c, Global Stone acquires assets of W.S. Frey: Limelites, v. 65, no. 4, April-June, p. 6.

———1999d, U.S. Lime & Minerals purchases Calco, Inc.: Limelites, v. 65, no. 4, April-June, p. 5.

———2000, Graymont adds Havelock Lime to Eastern Division: Limelites, v. 66, no. 3, January-March 2000, p. 1.

North American Minerals News, 1999a, North American lime industry: North American Minerals News, no. 53, October, p. 8-10.

———1999b, SAGC announces Chilean lime JV: North American Minerals News, no. 50, July, p. 4.

Oates, J.A.H., 1998, Lime and limestone—Chemistry and technology, production and uses: Weinem, Germany, Wiley–VCH, 455 p.

Rissover, J.F., 1999, MLC plans cut back of 50 to 70 non-union jobs, companywide: Ste. Genevieve, MO, Ste. Genevieve Herald, June 16, p. 1.

Xio Dong Zhang, 1999, Flux reduction trials at the U.S. Steel Edgar Thomson BOP shop *in* Lime & Carbonates—Market Strength in Diversity, The 4th North American Industrial Minerals Annual Meeting, San Francisco, CA, 1999, Proceedings: London, Industrial Minerals magazine, [unpaginated].

GENERAL SOURCES OF INFORMATION

U.S. Geological Survey Publications

Lime. Ch. in Mineral Commodity Summaries, annual.[1]

Lime. Ch. in Minerals Yearbook, annual.[1]

Limestone and dolomite. Ch. in United States Mineral Resources, Professional Paper 820, 1973.

Other

Chemical Economics Handbook, SRI International.

Chemical Market Reporter.

Chemistry and Technology of Lime and Limestone, John Wiley & Sons, 1980.

Industrial Minerals (London).

Industrial Minerals and Rocks, 6th ed., AIME, 1994.

Industrial Specialty News.

Lime. Ch. in Mineral Facts and Problems, U.S. Bureau of Mines Bulletin 675, 1985.

Lime and Limestone: Chemistry and Technology, Production and Uses, Wiley-VCH, 1998.

Lime Facts, National Lime Association, 1999.

North American Minerals News.

[1]Prior to January 1996, published by the U.S. Bureau of Mines.

TABLE 1
SALIENT LIME STATISTICS 1/

(Thousand metric tons, unless otherwise specified) 2/

	1995	1996	1997	1998	1999
United States: 3/					
Number of plants	106 4/	108	106	107	108
Sold or used by producers:					
High-calcium quicklime	NA	NA	14,300	14,800	14,100
Dolomitic quicklime	NA	NA	2,900	2,740	3,010
Total quicklime	15,800	16,800	17,300	17,500 r/	17,100
High-calcium hydrated lime	NA	NA	1,820	1,950 r/	1,910
Dolomitic hydrated lime	NA	NA	352	383	298
Total hydrated lime	2,390 4/	2,190	2,170	2,340 r/	2,210
Dead-burned dolomite	308	300 5/	300 5/	300 5/	300 5/
Grand total	18,500 4/	19,200	19,700	20,100	19,600
Value 6/ thousands	$1,100,000	$1,180,000	$1,200,000	$1,210,000	$1,180,000
Average value per ton	$59.20	$61.50	$61.00	$60.40 r/	$60.10
Lime sold	16,400 4/	16,800	17,300	17,800	17,300
Lime used	2,180	2,430	2,400	2,310 r/	2,310
Exports 7/ 8/:					
Quantity	72	50	80	56	59
Value thousands	$8,490	$5,600	$9,550	$9,110	$8,020
Imports for consumption 7/ 8/:					
Quantity	289	262	274	231	152
Value thousands	$20,200	$19,400	$26,500	$22,700	$15,400
Consumption, apparent 9/	18,700	19,400	19,900	20,300	19,700
World, production	115,000	113,000	114,000 r/	114,000 r/	114,000 e/

e/ Estimated. r/ Revised. NA Not available.

1/ Data are rounded to no more than 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.

4/ Excludes Puerto Rico.

5/ Data rounded to no more than one significant digit to protect company proprietary data.

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

7/ Bureau of the Census.

8/ For 1995 and 1996, data include quicklime, slaked lime, and hydraulic lime; data for 1997 through 1999 also include calcined dolomite.

9/ 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	1998 Plants	1998 Hydrated (thousand metric tons)	1998 Quicklime (thousand metric tons)	1998 Total (thousand metric tons)	1998 Value (thousands)	1999 Plants	1999 Hydrated (thousand metric tons)	1999 Quicklime (thousand metric tons)	1999 Total (thousand metric tons)	1999 Value (thousands)
Alabama	5	121	1,840	1,960	$119,000	5	102	1,830	1,930	$114,000
Arizona, California, Nevada, Utah	14	261	2,100	2,360	150,000 r/	14	289	1,930	2,220	136,000
Colorado, Montana, Wyoming	9	27	365	392	24,700	8	21	358	379	22,400
Idaho, Oregon, Washington	8	27	586	613	42,500	8	25	519	544	39,000
Illinois, Indiana, Missouri	8	326 r/	3,610	3,930 r/	220,000 r/	9	329	3,770	4,100	231,000
Iowa, Nebraska, South Dakota	4	W	W	277	19,000	4	W	W	260	17,500
Kentucky, Tennessee, West Virginia	5	134	2,460	2,590	143,000	5	132	2,170	2,300	124,000
Michigan	8	--	761	761	40,300	8	1	781	781	43,900
Ohio	8	W	W	1,870	109,000	8	W	W	1,820	105,000
Pennsylvania	7	199	1,200	1,390	97,800	7	176	1,170	1,340	94,300
Texas	7	548	1,070	1,620	101,000	7	496	1,080	1,580	105,000
Virginia	5	137	723	860	51,700	5	135	672	807	48,400
Wisconsin	4	148	434	582	35,400	4	149	469	618	37,000
Other 3/	15	407	2,640	902	59,900	16	166	723	890	57,000
Total	107	2,340 r/	17,800	20,100	1,210,000 r/	108	2,210	17,400	19,600	1,180,000

r/ Revised. W Withheld to avoid disclosing company proprietary data; included with "Other." -- Zero.
1/ Excludes regenerated lime.
2/ Data are rounded to no more than three significant digits; may not add to totals shown.
3/ Includes Arkansas, Georgia, 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/

Range of production	1998 Plants	1998 Quantity (thousand metric tons)	1998 Percent of total	1999 Plants	1999 Quantity (thousand metric tons)	1999 Percent of total
Less than 25,000 tons	21	269	1	21	320	2
25,000 to 100,000 tons	24	1,180	6	27	1,330	7
100,000 to 200,000 tons	24	3,200	16	21	2,840	15
200,000 to 300,000 tons	15	3,290	16	18	3,760	19
300,000 to 400,000 tons	8	2,410	12	9	2,820	14
400,000 to 600,000 tons	8	3,580	18	4	1,950	10
More than 600,000 tons	7	6,180	31	8	6,540	33
Total	107	20,100	100	108	19,600	100

1/ Excludes regenerated lime. Includes Puerto Rico.
2/ Data are rounded to no more than 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	1998		1999	
	Quantity 4/	Value	Quantity 4/	Value
Chemical and industrial:				
Fertilizer (aglime and fertilizer)	33	2,480	23	1,900
Glass	141 r/	8,120 r/	98	5,650
Paper and pulp	921 r/	55,800 r/	971	57,700
Precipitated calcium carbonate	1,010 r/	59,900 r/	1,200	71,100
Sugar refining	796	49,000	783	45,800
Other chemical and industrial	1,950 r/	123,000 r/	1,920	121,000
Total	4,840 r/	298,000 r/	5,000	303,000
Metallurgical:				
Steel and iron:				
Basic oxygen furnaces	4,280 r/	245,000 r/	3,930	220,000
Electric arc furnaces	1,650 r/	102,000 r/	1,810	107,000
Other steel and iron	206	13,000	239	14,700
Total	6,130 r/	359,000 r/	5,970	342,000
Nonferrous metals:				
Aluminum and bauxite	239	14,800	303	17,800
Other nonferrous metallurgy 5/	1,480 r/	83,700 r/	1,270	73,200
Total nonferrous metals	1,710 r/	98,500 r/	1,570	91,000
Total metallurgical	7,840 r/	458,000 r/	7,550	433,000
Construction:				
Asphalt	319	24,800	362	26,500
Soil stabilization	1,280 r/	78,500 r/	1,280	82,700
Other construction	376 r/	37,700 r/	427	42,500
Total	1,980 r/	141,000 r/	2,070	152,000
Environmental:				
Flue gas sulfur removal:				
Utility powerplants	2,950	153,000	2,580	131,000
Incinerators	99	6,370	134	8,580
Other	56	3,540	34	2,150
Total	3,110	163,000	2,750	142,000
Sludge treatment:				
Sewage	213 r/	14,700 r/	147	9,350
Other (industrial, hazardous, etc.)	178	11,500	98	6,130
Total	391 r/	26,200 r/	245	15,500
Water treatment:				
Acid mine drainage	135	9,370	90	5,870
Drinking water	785 r/	49,200 r/	904	56,000
Wastewater	388	25,600	410	26,600
Total	1,310 r/	84,100 r/	1,400	88,600
Other environmental	308 r/	19,600 r/	297	18,600
Total environmental	5,120 r/	293,000 r/	4,690	265,000
Refractories (dead-burned dolomite) 6/	300	26,400	300	24,400
Grand total	20,100	1,210,000	19,600	1,180,000

r/ Revised.

1/ Excludes regenerated lime. Includes Puerto Rico.

2/ Data are rounded to no more than 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/ Includes ore concentration (copper, gold, etc.), magnesium, and other.

6/ Data rounded to one significant digit to protect company proprietary data, values are estimated based on average value per ton for 1998 and 1999.

TABLE 5
HYDRATED LIME SOLD OR USED IN THE UNITED STATES, BY END USE 1/ 2/

(Thousand metric tons and thousand dollars) 3/

Use	1998		1999	
	Quantity 4/	Value	Quantity 4/	Value
Chemical and industrial	549	43,700	476	37,300
Construction:				
Asphalt paving	308	24,200	348	25,900
Building uses	349 r/	35,900 r/	394	40,200
Soil stabilization	485 r/	31,500 r/	438	32,900
Other construction	22 r/	1,620 r/	16	1,080
Total	1,160 r/	93,200 r/	1,200	100,000
Environmental:				
Flue gas treatment (FGT):				
Incinerators	13	996	17	1,270
Industrial boilers and other FGT	31	2,100	11	740
Utility powerplants	41	2,960	37	2,480
Total	85	6,060	65	4,490
Sludge treatment:				
Sewage	38 r/	3,010 r/	15	1,240
Other sludge treatment	11	1,080	20	1,690
Total	49 r/	4,090 r/	34	2,930
Water treatment:				
Acid mine drainage	86	6,170	54	3,590
Drinking water	199 r/	15,200 r/	199	15,200
Wastewater	111	8,390	106	7,730
Total	396 r/	29,800 r/	360	26,500
Other environmental	46 r/	3,660 r/	57	4,420
Metallurgy	46 r/	3,810 r/	22	1,530
Grand total	2,340 r/	185,000 r/	2,210	177,000

r/ Revised.
1/ Excludes regenerated lime. Includes Puerto Rico.
2/ Data are rounded to no more than 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 hydrated lime sold or used, where "used" denotes lime produced for internal company use in building, chemical and industrial, and metallurgical sectors.

TABLE 6
U.S. EXPORTS FOR CONSUMPTION OF LIME, BY TYPE 1/

Type	1998		1999	
	Quantity (metric tons) 2/	Value 3/	Quantity (metric tons) 2/	Value 3/
Calcined dolomite:				
Brazil	113	$28,200	--	--
Canada	1,990	407,000	1,850	$428,000
Israel	--	--	20	25,500
Japan	568	149,000	1,400	326,000
Mexico	7,080	1,200,000	245	37,600
Netherlands	--	--	25	33,400
New Zealand	--	--	36	17,900
Taiwan	656	154,000	498	110,000
United Kingdom	517	86,800	--	--
Venezuela	1,310	327,000	--	--
Total	12,200	2,350,000	4,080	979,000
Hydraulic lime:				
Bahamas, The	64	11,700	31	3,730
Canada	5,130	835,000	10,600	1,280,000
Chile	956	185,000	--	--
Mexico	--	--	35	13,000
New Zealand	116	80,200	269	99,800
United Kingdom	--	--	45	8,180
Other 4/	79	662,000	100	37,700
Total	6,350	1,770,000	11,100	1,440,000

See footntoes at end of table.

TABLE 6--Continued
U.S. EXPORTS FOR CONSUMPTION OF LIME, BY TYPE 1/

Type	1998		1999	
	Quantity (metric tons) 2/	Value 3/	Quantity (metric tons) 2/	Value 3/
Quicklime:				
Argentina	--	--	150	$36,400
Canada	22,900	$2,250,000	28,300	3,140,000
Costa Rica	322	61,000	739	124,000
Guyana	1,920	506,000	--	--
Mexico	5,160	921,000	7,540	1,240,000
Suriname	922	106,000	--	--
Other 5/	137	59,000	58	19,980
Total	31,400	3,900,000	36,600	4,520,000
Slaked lime (hydrate):				
Canada	5,380	845,000	5,820	840,000
Mexico	62	19,500	40	7,400
Philippines	658	161,000	372	81,800
South Africa	28	8,460	--	--
Other 6/	139	53,400	527	146,000
Total	6,260	1,090,000	6,760	1,080,000
Grand total	56,200	9,110,000	58,500	8,020,000

-- Zero.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ To convert metric tons to short tons, multiply metric tons by 1.10231.
3/ Declared " Free alongside ship" (f.a.s.) valuation.
4/ Includes Australia, Ecuador, Germany, Haiti, India, the Republic of Korea, Taiwan, the United Kingdom, and Venezuela.
5/ Includes The Bahamas, Guadeloupe, Guatemala, and Haiti.
6/ Includes The Bahamas, France, the Republic of Korea, Ireland, Taiwan, Trinidad and Tobago, and the United Kingdom.

TABLE 7
U.S. IMPORTS FOR CONSUMPTION OF LIME, BY TYPE 1/

Type	1998		1999	
	Quantity (metric tons) 2/	Value 3/	Quantity (metric tons) 2/	Value 3/
Quicklime:				
Canada	144,000	$12,300,000	87,200	$7,570,000
Mexico	40	2,870	--	--
Other 4/	54	71,200	99	138,000
Total	144,000	12,400,000	87,300	7,700,000
Calcined dolomite:				
Canada	32,500	4,370,000	30,100	4,200,000
Mexico	112	17,000	--	--
Other 5/	11,200	1,510,000	9	5,760
Total	43,800	5,900,000	30,100	4,210,000
Slaked lime (hydrate):				
Canada	27,700	2,570,000	18,700	1,590,000
Mexico	9,400	1,260,000	13,000	1,490,000
Other 6/	48	130,000	96	198,000
Total	37,100	3,960,000	31,800	3,270,000
Hydraulic lime:				
Canada	136	8,850	28	2,750
Mexico	6,380	496,000	3,160	189,000
Total	6,520	505,000	3,190	192,000
Grand total	231,000	22,700,000	152,000	15,400,000

-- Zero.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ To convert metric tons to short tons, multiply metric tons by 1.10231.
3/ Declared c.i.f. valuation.
4/ Includes Australia, China, Finland, Germany, Japan, and Thailand.
5/ Includes Austria, China, and the Republic of Korea.
6/ Includes Ecuador, Germany, Italy, Japan, Taiwan, Thailand, and the United Kingdom.

TABLE 8
QUICKLIME AND HYDRATED LIME, INCLUDING DEAD-BURNED DOLOMITE: WORLD PRODUCTION, BY COUNTRY 1/ 2/

(Thousand metric tons)

Country 3/	1995	1996	1997	1998	1999 e/
Australia e/	1,500	1,500	1,500	1,500	1,500
Austria	1,908	1,990	1,900 e/	2,000 r/ e/	2,000
Belgium e/	1,800	1,800	1,750	1,750	1,750
Brazil e/	5,700	5,700	5,700	5,700	5,700
Bulgaria e/	952 4/	1,000	1,200	1,100	1,100
Canada	2,398	2,402	2,477	2,514	2,585 p/
Chile e/	1,006 4/	1,050	1,000	1,000	1,000
China e/	20,000	20,000	20,500	21,000	21,500
Colombia e/	1,300	1,300	1,300	1,300	1,300
Czech Republic	1,186	1,176	1,217 r/	1,151 r/	1,200
France	2,940	2,714	2,360 r/ e/	2,400 r/ e/	2,400
Germany e/	8,000	7,570 4/	7,600	7,600	7,600
Italy e/ 5/	3,500	3,500	3,500	3,500	3,500
Japan (quicklime only)	7,871	7,744	8,104	7,646 r/	7,750
Mexico e/	6,580 4/	6,600	6,600	6,600	6,600
Poland	2,526	2,461 r/	2,516 r/	2,406 r/	2,500
Romania	1,763	1,712	1,750	1,700	1,700
Russia 6/	9,263	7,822	7,626	7,000 e/	7,000
South Africa (sales)	1,743	1,650	1,585 r/	1,523 r/	1,500
Spain e/	1,000	1,000	1,000	1,000	1,000
Turkey 7/	897	1,023	1,170 r/	1,066 r/	1,100
United Kingdom e/	2,500	2,500	2,500	2,500	2,500
United States (sold or used by producers)	18,500 8/	19,200 r/ 9/	19,700 9/	20,100 9/	19,600 4/ 9/
Other e/	9,710 r/	9,840 r/	9,820 r/	9,930 r/	9,840
Total	115,000	113,000	114,000 r/	114,000 r/	114,000

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

1/ World totals, U.S. data, and estimated data are rounded to no more than three significant digits; may not add to totals shown.

2/ Table includes data available through April 6, 2000.

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

4/ Reported figure.

5/ Includes hydraulic lime.

6/ Total industrial and construction production as reported by Russia.

7/ Lime produced for steel production; does not include the widespread artisanal production of lime for whitewash and sanitation purposes.

8/ Excludes Puerto Rico.

9/ Includes Puerto Rico.