Lime Production: Industry Profile

Final Report

Prepared for

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EPA Contract Number 68-D-99-024

RTI Project Number 7647-001-020

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SECTION 1

INTRODUCTION

The U.S. Environmental Protection Agency (EPA's) Office of Air Quality Planning and Standards (OAQPS) is compiling information on lime manufacturing plants as part of its responsibility to develop National Emission Standards for Hazardous Air Pollutants (NESHAP) under Section 112 of the 1990 Clean Air Act. The NESHAP is scheduled to be proposed in 2000, and the Innovative Strategies and Economics Group is responsible for developing an economic impact analysis (EIA) in support of the evaluation of impacts associated with the regulatory options considered for this NESHAP. This industry profile of the lime manufacturing industry provides information to be used to support the regulation.

Lime manufacturing falls under the Standard Industrial Classification (SIC) code 3274 (NAICS 32741). According to the 1997 Census of Manufactures, 85 establishments owned by 47 companies manufactured lime in 1997 (U.S. Department of Commerce, 1999b). In 1997, the lime manufacturing industry employed 4,206 people and shipped products valued at $1.2 billion (U.S. Department of Commerce, 1997).

This industry profile report is organized as follows. Section 2 provides a detailed description of the production process for lime, with discussions of individual lime products, limestone inputs, and costs of production. Section 3 describes the characteristics, uses, and consumers of lime as well as substitution possibilities. Section 4 discusses the organization of the industry and provides facility- and company-level data. In addition, small businesses are reported separately for use in evaluating the impact on small businesses to meet the requirements of the Small Business Regulatory Enforcement and Fairness Act (SBREFA).

Section 5 contains market-level data on prices and quantities and discusses trends and projections for the industry.

SECTION 2

THE SUPPLY SIDE

Estimating the economic impacts associated with the regulatory options requires characterizing the lime manufacturing industry. This section describes all steps of the production process, emission controls, and inputs into this process. In addition, characterizing the supply side of the industry involves describing various types of lime products, by-products of the production process, and input substitution possibilities. Finally, this section explains costs of production and economies of scale.

2.1 PRODUCTION PROCESS, INPUTS, AND OUTPUTS

The production of lime begins with the quarrying and crushing of limestone. Limestone is a general term that covers numerous varieties of sedimentary rock. Limestone can be composed of the following four minerals, plus impurities: calcite ($CaCO_3$), aragonite (also $CaCO_3$ but with a different crystal structure from calcite), dolomite ($CaMg(CO_3)_2$), and magnesite ($MgCO_3$) (Boynton, 1980).

Limestone can be categorized as either high calcium or dolomitic. Pure high-calcium limestone is 100 percent calcium carbonate (100 percent calcite or aragonite). Generally, limestone of this purity does not occur naturally. High-quality, high-calcium limestone would actually contain 97 to 99 percent calcium carbonate and 1 to 3 percent impurities. Dolomitic limestone generally contains 40 to 43 percent magnesite, 1 to 3 percent impurities, with the balance made up of calcium carbonate (Boynton, 1980). Section 2.1.6 discusses the various types of limestone in detail.

Deposits of limestone occur in nearly every state of the U.S. and every country in the world. Much of it is not available for commercial use, however, because it is either too deep in the earth, too far from markets, not sufficiently concentrated in a particular area, or not pure enough (Boynton, 1980). Figure 2-1 is a map of the U.S. showing the locations of most high-calcium limestone operations.

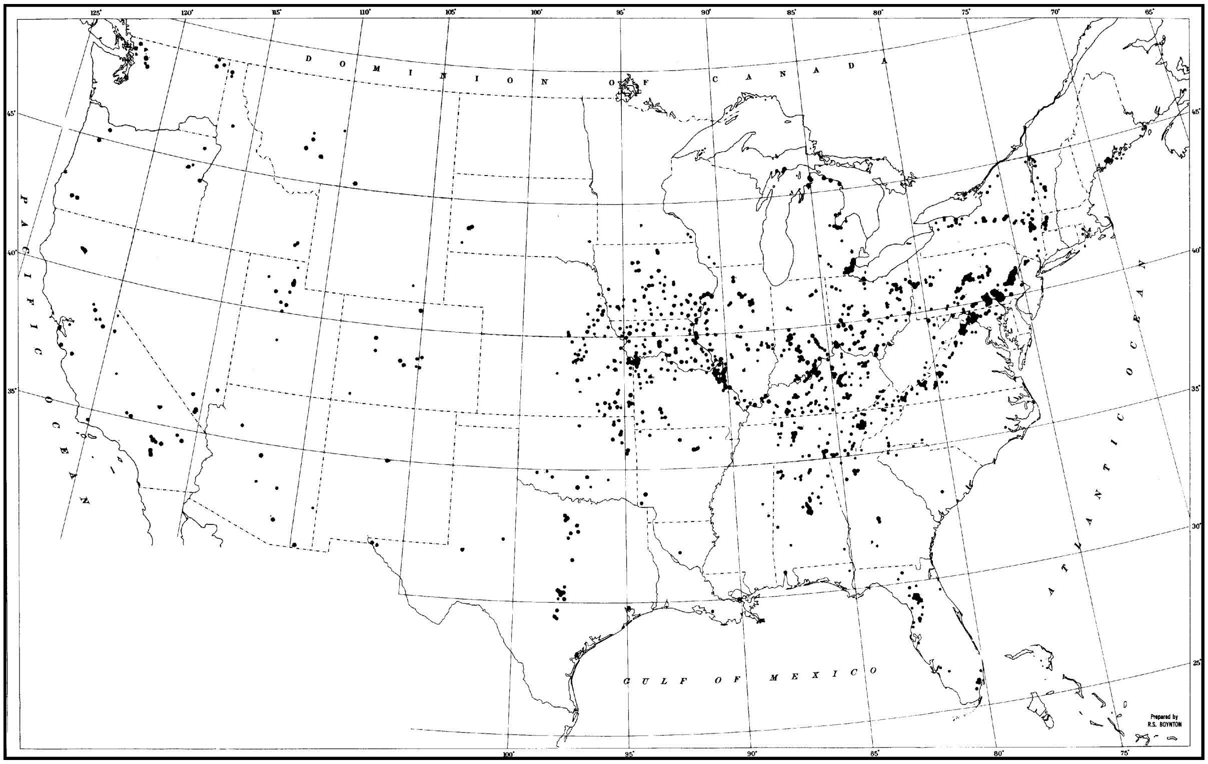

Figure 2-1. Location and concentration of high-calcium limestone deposits in the U.S.

Source: Boynton, Robert S. Chemistry and Technology of Lime and Limestone. 2nd Ed. New York, John Wiley & Sons. 1980.

Figure 2-2 illustrates the lime production process. Air pollutant emission points are indicated in the diagram by Source Classification Code. Several steps are involved in the production of lime.

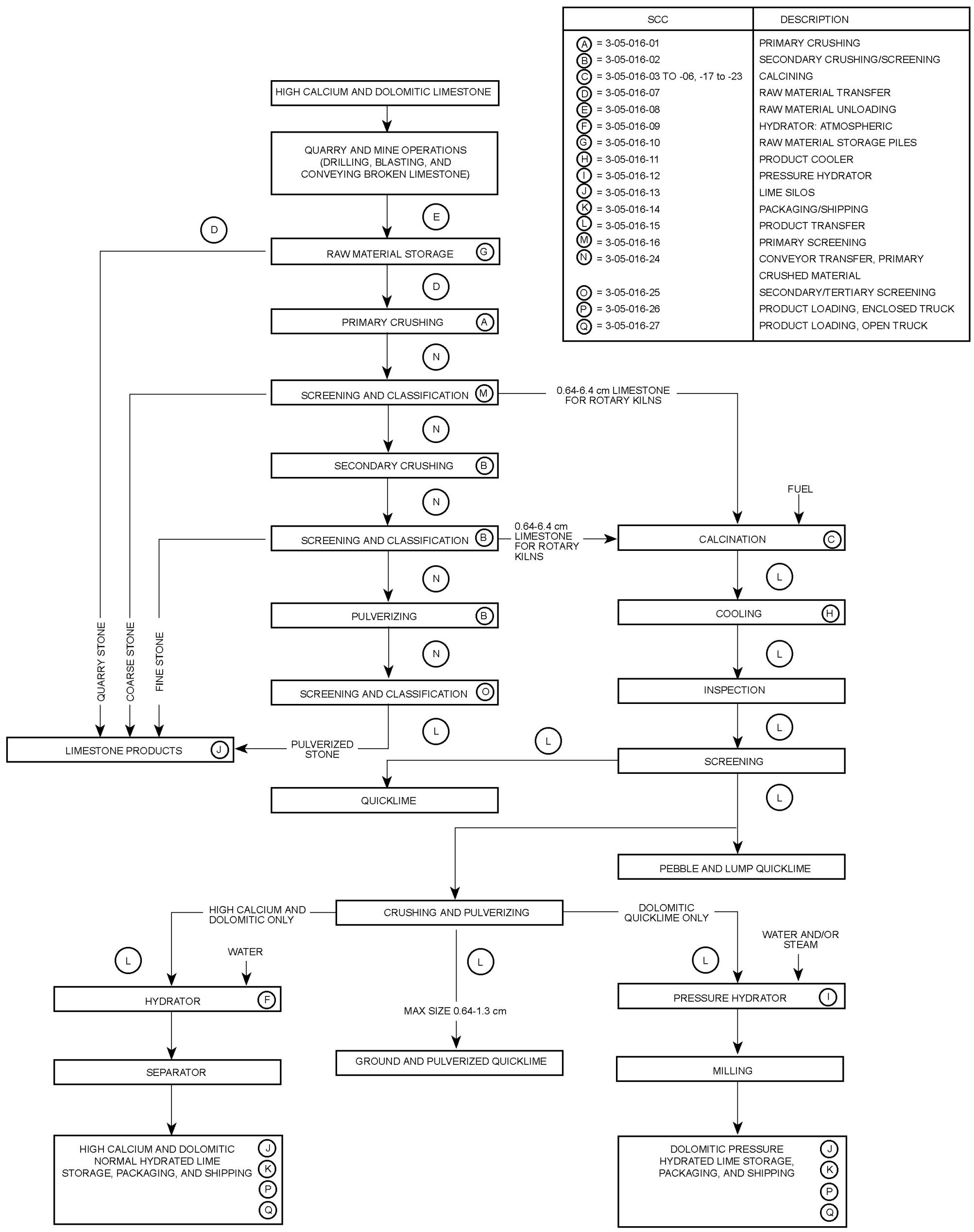

Figure 2-2. General process flow diagram for the manufacturing and processing of lime.

Source: Midwest Research Institute. Emission Factor Documentation for AP-42, Section 11.15, Lime Manufacturing. Prepared for U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards, Emission Inventory Branch. Cary, NC, Midwest Research Institute. April 28, 1994.

2.1.1 Crushing

The first step in the manufacturing of lime is to crush the pieces of limestone to make them smaller. There are two basic types of primary crushers: compression and impact. Compression crushers use slow, steady amounts of pressure to reduce the size of the rock, whereas impact crushers rely on intense, repeated blows. Compression crushers are used mainly for larger stones, impact crushers for smaller sizes. In some plants, stones undergo secondary crushing as well. The crushed stone is screened to provide the desired stone size and then conveyed to storage in conical stockpiles (Gutschick, 1994).

2.1.2 Calcination

Limestone is converted into lime through heating in a kiln, a process known as calcination. When limestone is subjected to high temperatures, it undergoes a chemical decomposition resulting in the formation of lime (CaO) and the emission of carbon dioxide gas (CO_2).

High-Calcium Lime

$$CaCO_3 + \text{heat} \leftrightarrow CO_2 + CaO$$

Dolomitic Lime

$$CaCO_3 \bullet MgCO_3 + \text{heat} \leftrightarrow 2CO_2 + CaO \bullet MgO$$

To complete the thermal decomposition of limestone into lime, the stone must be heated to the dissociation temperature of the carbonates, and this temperature must be maintained for a certain period of time. The dissociation temperature varies depending on the type of limestone being burned. For example, calcite dissociates at 898°C (1,648°F) while magnesium carbonate dissociates at 402 to 480°C (756 to 896°F).

Because this is a reversible chemical reaction, the carbon dioxide emitted as a result of calcination must be removed to prevent recarbonation. Recarbonation occurs when carbon dioxide is reabsorbed by the cooling lime, diminishing the quality of the finished product (Boynton, 1980).

Lime kilns can be categorized into three groups: rotary kilns, vertical kilns, and miscellaneous. About 90 percent of commercial lime capacity in the U.S. is calcined in rotary kilns. Most of the remaining capacity is processed with vertical kilns (vertical kilns are more common in captive supply facilities), and small quantities are processed in other miscellaneous types of kilns (Gutschick, 1994).

Rotary Kilns. Figure 2-3 illustrates a rotary kiln system with a preheater. A rotary kiln is a long cylinder, ranging in length from 75 to 500 feet, with a diameter between 4 and 11 feet. This cylinder is set at an incline of 3 to 5 degrees and rotates at a rate of 35 to 80 revolutions per hour. The inner surface of the cylinder is lined with refractory brick. Surrounding the brick is a layer of insulation, then an outer casing of steel boiler plate.

Before entering the kiln, the limestone passes through the preheater, where it is heated with hot exhaust gases from the kiln. Preheaters improve thermal efficiency by using

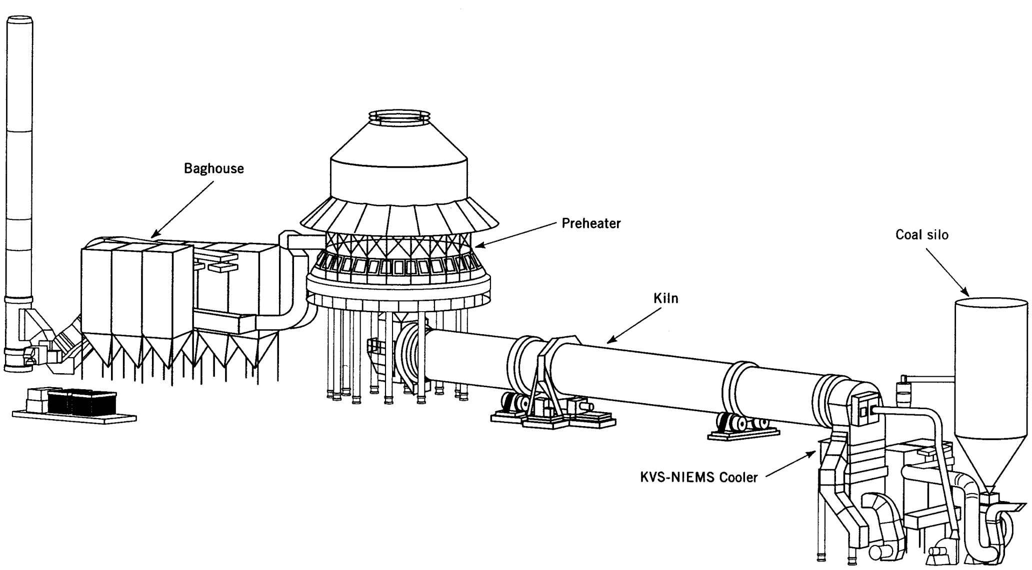

Figure 2-3. Preheater rotary kiln system for lime production.

Source: Gutschick, K.A. Lime and Limestone. Kirk-Othmer Encyclopedia of Chemical Technology. 4th Ed. Vol. 15. New York, John Wiley & Sons. 1994. p. 319-359.

heat from the kiln that might otherwise be lost (Boynton, 1980). Burning fuel enters the cylinder from the lower end, and pre-heated limestone is delivered into the upper end. As the limestone passes through the cylinder that is filled with flame and hot combustion gases, it calcines into lime, which is discharged at the lower end of the cylinder (Boynton, 1980).

Lime must be cooled after exiting the rotary kiln. Various types of coolers are used, including contact coolers, satellite coolers, rotary coolers, and grate coolers. These coolers operate under different principles, but they serve the same two purposes: to cool the lime for further handling and to recapture heat. The first two types listed are the most commonly used because they are the most effective at heat recuperation (Boynton, 1980). Most rotary kilns are fired by coal; however, with the correct adaptations, coke, oil, and natural gas can also be used (Gutschick, 1994).

The refractory brick linings in all kilns must be replaced periodically, because heat, abrasion, and temperature changes cause them to disintegrate. Plants try to avoid cooling and reheating lime kilns as much as possible because this hastens disintegration. When plants need to stop production, they will often slow-fire the kilns, or maintain their heat until production resumes. It is generally less costly to keep the kilns hot than it is to replace the linings or to restart the kilns (Boynton, 1980).

Vertical Kilns. The vertical kiln has many different variations, but all operate under the same general premise. Figure 2-4 is a diagram of a vertical kiln. Vertical kilns are large vertical cylinders that are completely filled from the top with large chunks of limestone. These kilns have four zones, or sections: the preheating zone, the calcining zone, the finishing zone, and the cooling zone. These zones are not physically separated from one another. They are terms used to indicate areas within the kiln, which is a continuous cylinder.

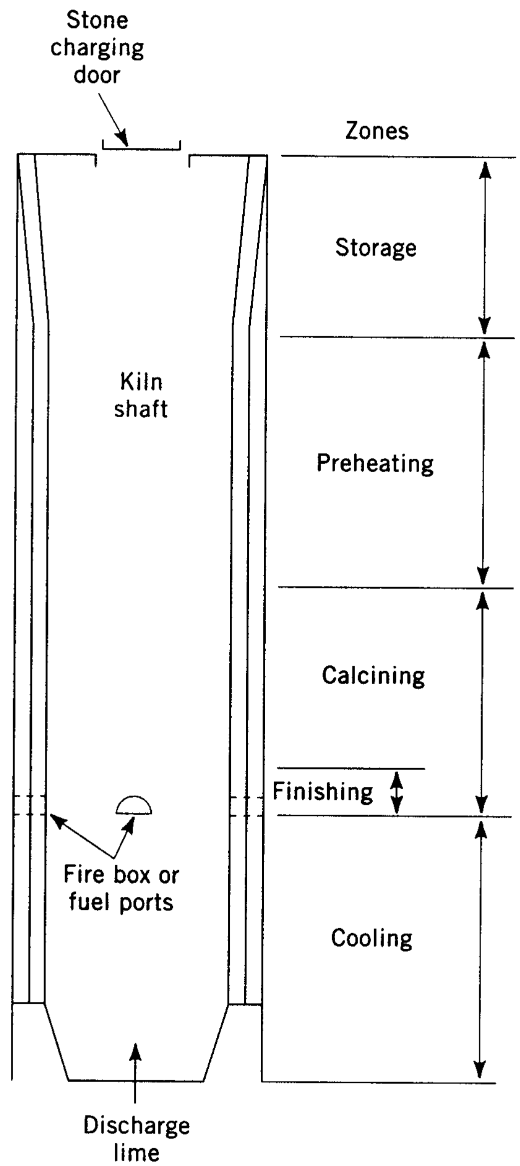

Figure 2-4. Vertical kiln system for lime production.

Source: Gutschick, K.A. Lime and Limestone. Kirk-Othmer Encyclopedia of Chemical Technology. 4th Ed. Vol. 15. New York, John Wiley & Sons. 1994. p. 319-359.

Burning fuel is injected into the cylinder just beneath the calcining zone, causing the limestone in this zone to calcine. Hot gasses from the calcining zone migrate upward, warming the stone in the preheating zone. Finished lime drops into the cooling zone, where cool air is blown through it. Air blown into the cooling zone carries recovered heat upward into the calcining zone, where it also provides air for combustion. Cooled lime is removed from the bottom, making room for the limestone and lime in the upper levels to descend. Some vertical kilns require an attendant to determine when calcining is complete. The attendant must open “poke holes” in the kiln and dislodge the mass of hot lime with a long iron bar, allowing it to drop down into the cooling zone (Boynton, 1980). The predominant fuels for vertical kilns are natural gas and fuel oil (Boynton, 1980).

Vertical kilns require large stones (6 to 8 inches in diameter) to allow for the circulation of combustion gases. Stones that are too small to be used are called “spalls.” Large quantities of spalls can accumulate at plants with vertical kilns and can be difficult or impossible to dispose of profitably. Depending on the source of limestone, spalls can constitute from 30 to 70 percent of the limestone intended for use as kiln feed. Rotary kilns can use small stones that calcine faster and lead to fewer spalls. To solve the problem of spalls, some plants have installed rotary kilns in addition to vertical kilns. European researchers have developed vertical kilns that can use small stones, but this technology has not been implemented in the U.S. (Boynton, 1980).

For a number of reasons, rotary kilns have largely replaced vertical kilns in the U.S. They dominate the industry because they can be fired with coal, require less labor, lead to fewer spalls, and have the highest output and quality of all kilns (Boynton, 1980; Gutschick, 1994). In contrast, vertical kilns are preferred in many other parts of the world. They require smaller capital investment and have greater fuel efficiency than rotary kilns.

<u>Miscellaneous Kiln Types</u>. Parallel-flow kilns are beginning to gain acceptance in the U.S. These kilns are made up of two side-by-side vertical shafts that are similar to vertical kilns (see Figure 2-5). The two shafts are connected in the middle, allowing gases to

flow from one shaft to the other. The shafts alternate functions: while one is acting as the calcining shaft, the other serves as the preheating shaft. Limestone fills the shafts from the top. Hot combustion gases are fired down the first shaft, calcining the lime. The exhaust then flows across and up through the second shaft, preheating the lime. Every 12 to 14 minutes, the flow is reversed. The lime is cooled in the bottom section of each shaft with a countercurrent flow of air. Finished lime exits from the bottom of each shaft. Parallel-flow kilns can be fired with natural gas or oil. They are energy-efficient and produce high-quality lime (Wood, 1996; Sauers, Beige, and Smith, 1993b).

The Fluo-Solids kiln, which is a fluidized-bed system, looks like a vertical kiln on the outside but operates on a different principle (see Figure 2-6). It calcines tiny (0.23 to 2.38 μm) particles of limestone. These tiny particles are "fluidized," or suspended in air in the preheating and calcining zones of the kiln. These kilns require external cooling equipment, as described in the section on rotary kilns. Because small particles will burn at lower temperatures, these kilns have relatively low fuel consumption. They also produce consistently high-quality lime. However, the cost of providing such finely ground limestone as kiln feed prohibits the use of these kilns in most areas (Boynton, 1980).

The calcimatic kiln (also called a rotary hearth kiln) consists of a circular hearth that rotates through a kiln (see Figure 2-7). Preheated limestone is loaded onto the hearth. It rotates through the kiln, and finished lime is removed from the hearth after one complete rotation. External cooling equipment is also used. These kilns have not been widely accepted because they can only operate with gas and oil and have poor fuel efficiency (Boynton, 1980).

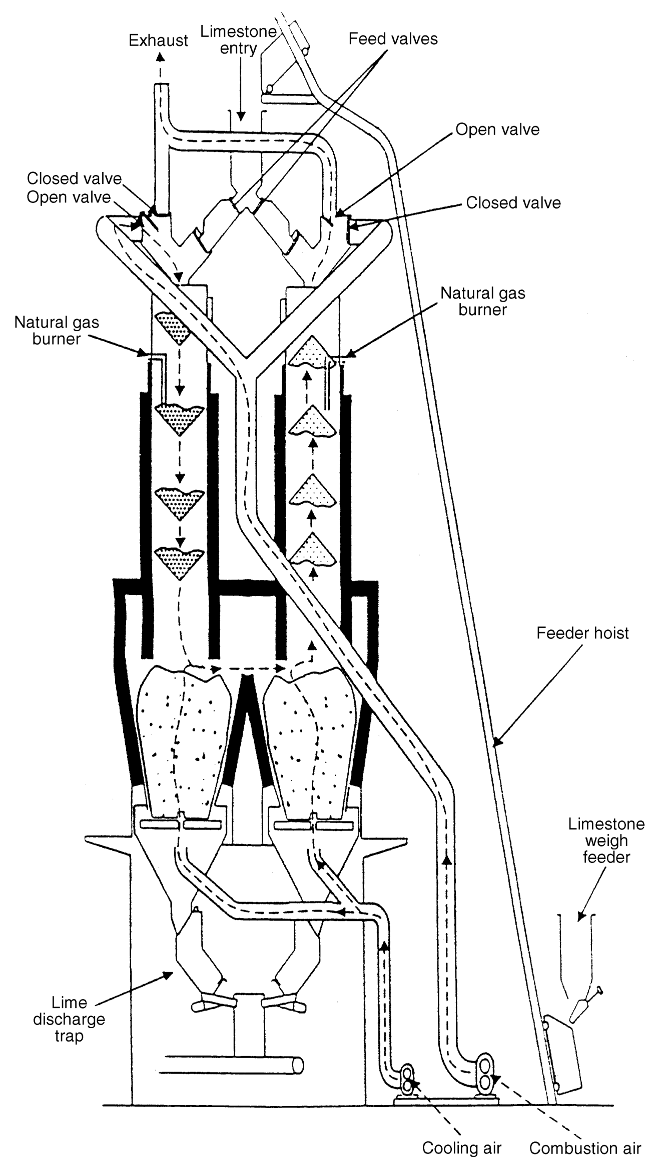

Figure 2-5. Parallel flow kiln with left shaft calcining and right shaft preheating.

Source: Memorandum from Wood, Joseph P., U.S. Environmental Protection Agency, to Chappell, Linda M., U.S. Environmental Protection Agency. November 6, 1996. Engineering industry profile for the economic analysis.

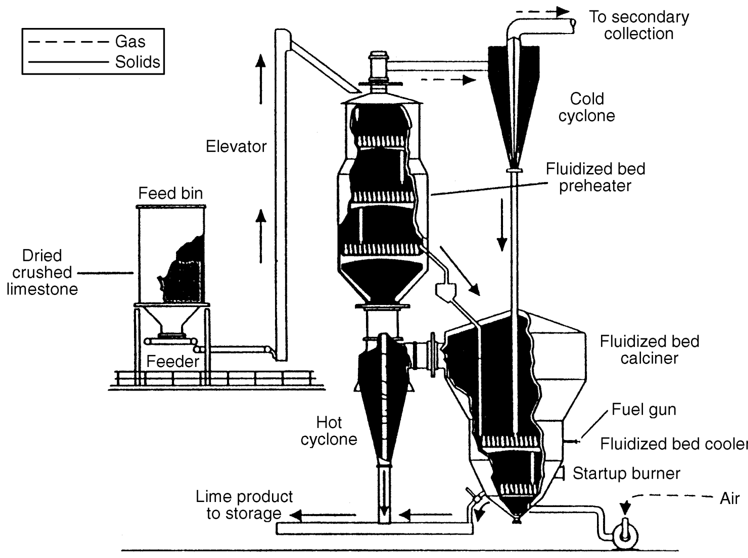

Figure 2-6. Fluidized bed kiln.

Source: Memorandum from Wood, Joseph P., U.S. Environmental Protection Agency, to Chappell, Linda M., U.S. Environmental Protection Agency. November 6, 1996. Engineering industry profile for the economic analysis.

2.1.3 Final Commodities

Briefly described here, quicklime, hydrated lime, and dead-burned dolomite are the three broad categories of lime produced. Section 2.2 contains a more detailed discussion of the many types of lime and lime products.

Quicklime. Lime as it exits the kiln is known as quicklime. As mentioned previously, it can be either high calcium or dolomitic, depending on the type of limestone that was calcined. Pure quicklime is white, and impurities can cause off-colors. After the quicklime leaves the kiln, it is screened to remove fines and undersized particles. Depending on particle size, quicklime may be sold in the following forms: lump (6.35 cm to 30.5 cm pieces), pebble (6.35 mm to 6.35 cm pieces), ground (particles less than 2.38 mm), pulverized (particles less than 0.84 mm), or briquette (fines that are molded into lumps)

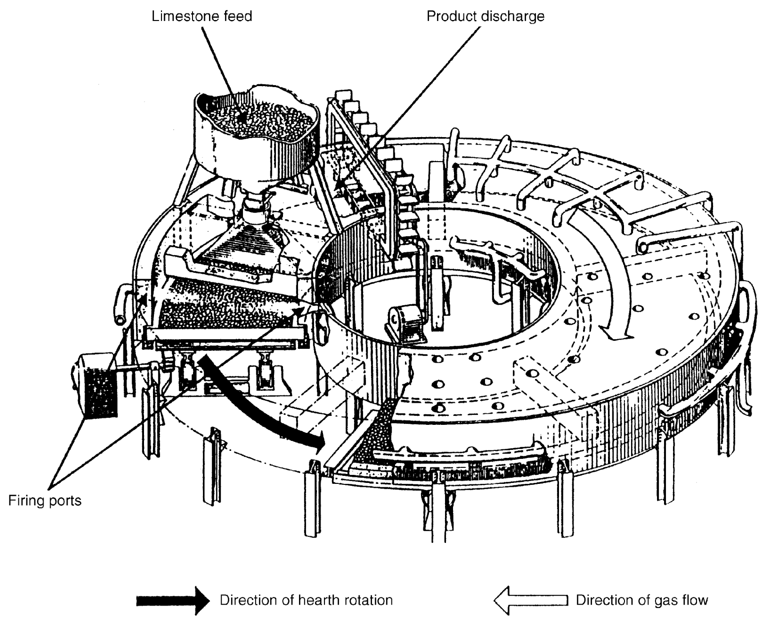

Figure 2-7. Rotary hearth kiln with cross sectional view of one firing zone.

Source: Memorandum from Wood, Joseph P., U.S. Environmental Protection Agency, to Chappell, Linda M., U.S. Environmental Protection Agency. November 6, 1996. Engineering industry profile for the economic analysis.

(Boynton, 1980).

Hydrated Lime. Large quantities of quicklime are converted into hydrated lime. The process of hydration, also known as slaking, is one of the following chemical reactions between lime and water (Boynton, 1980):

High-calcium hydrate

$$CaO \text{ (h.c. quicklime)} + H_2O \rightleftarrows Ca(OH)_2 \text{ (h.c. hydrate)} + \text{heat} \uparrow \qquad (2.1)$$

$$Ca(OH)_2 \text{ (h.c. hydrate)} + \text{heat} \rightleftarrows$$

$$CaO \text{ (h.c. quicklime)} + H_2O\text{(vapor)} \uparrow$$

Normal dolomitic hydrate

$$CaO \bullet MgO \text{ (dol. quicklime)} + H_2O \rightleftharpoons \tag{2.2}$$
$$Ca(OH)_2 \bullet MgO \text{ (dol. hydrate)} + \text{heat} \uparrow$$

Highly hydrated dolomitic lime

$$CaO \bullet MgO \text{ (dol. quicklime)} + 2H_2O + \text{pressure} \rightleftharpoons \tag{2.3}$$
$$Ca(OH)_2 \bullet Mg\,(OH)_2 \text{ (dol. hydrate)} + \text{heat} \uparrow$$

These equations show that this process is used for both high-calcium and dolomitic lime (first and second equations). Dolomitic lime does not fully hydrate, however, without additional processing under pressure (third equation) (Gutschick, 1994). These are highly exothermic reactions. The heat released by the hydration of one pound of pure quicklime can heat 3.4 pounds of water from room temperature to boiling (Boynton, 1980). Because of the powerful nature of this reaction, quicklime must be handled with extreme care to avoid contact with water. When quicklime is exposed to high humidity, it slowly reacts with the moisture in the air and becomes "air-slaked" (Boynton, 1980).

Hydrated lime is produced in a vessel called a hydrator, where a precise amount of water is slowly added to crushed or ground quicklime and the mixture is stirred and agitated. The resulting hydrated lime is a fluffy, dry, white powder, which is conveyed to an air separator where most coarse particles are removed. Next, it may undergo further refining or proceed directly to bagging, shipment, and/or storage. The gas resulting from the hydration process contains steam and lime particles. This gas may be vented back into the kiln or sent to a control device where it is cleaned and then released (Wood, 1996).

Dead-Burned Dolomite. Dead burned dolomite, also called refractory lime, is a sintered or double-burned form of dolomitic lime. It is used for lining open hearth or electric arc steel furnaces or as an input in the refractory bricks that line basic oxygen steel furnaces. Dead-burned dolomite represented less than 2 percent of total U.S. lime production in 1995 (Wood, 1996).

2.1.4 Emissions and Controls in Lime Manufacturing

Lime production leads to emissions of particulate matter (PM); metals; and gaseous pollutants, including carbon monoxide (CO), carbon dioxide, sulfur dioxide (SO_2), and nitrogen oxides (NO_x) (Midwest Research Institute, 1994; Wood, 1996). Emission points are indicated by Source Classification Code in Figure 2-2.

PM and Metals Emissions. The kiln is the largest ducted source of PM and metals emissions from lime production. PM and metals emissions can also occur from coolers, but only in plants where exhaust gases are not recycled back through the kiln. Emissions from ordinary hydrators are generally readily controlled, whereas emissions from pressure hydrators are somewhat more difficult to control. In addition to these sources, PM and metals emissions can also occur at primary and secondary crushers, mills, screens, transfer points, storage piles, and roads. Drilling and blasting at the quarry also create PM and metals emissions.

Rotary lime kilns constructed or modified after May 3, 1977, are required by law to limit their emissions of filterable PM to 0.30 kg/Mg (0.60 lb/ton) of stone feed. Devices used to control PM emissions from kilns are fallout chambers and cyclone separators for large particles and fabric or gravel bed filters, wet scrubbers, and electrostatic precipitators for smaller particles. Cyclones, fabric filters, and wet scrubbers are also used to control PM emissions from coolers, crushers, and loaders (Midwest Research Institute, 1994).

Rotary kilns have high potential PM and metals emissions relative to other types of kilns, because they calcine small pieces of stone using high air velocities and a rotating chamber. Vertical kilns have very low PM and metals emissions because they process large chunks of stone using low air velocities, and the material moves slowly through the kiln. Fluidized bed kilns can potentially produce large amounts of PM and metals emissions, because they process fine particles in large volumes of air. But emissions from these kilns are generally well controlled. Calcimatic kilns have relatively low PM and metals emissions

(Midwest Research Institute, 1994). The characteristics of the kiln feed and, if coal is used, the ash content of the coal can also influence PM and metals emissions (EPA, 1995).

Gaseous Pollutants. As previously mentioned, carbon monoxide, carbon dioxide, sulfur dioxide, and nitrogen oxides are produced along with lime. The source of most sulfur dioxide emissions is the fuel used to fire the kiln. The composition of the kiln feed, the quality of the lime being manufactured, and the type of kiln affect the amount of sulfur dioxide produced. Most of the sulfur dioxide from the kiln fuel is never released because it reacts with the lime within the kiln. Pollution control equipment can further limit sulfur dioxide emissions (Midwest Research Institute, 1994).

In addition to the gaseous pollutants created by burning fossil fuels, the chemical reaction that occurs during calcination produces a large volume of carbon dioxide. Limestone is approximately 44 percent carbon dioxide by weight, and this carbon dioxide is released during calcination (Miller, 1997d).

2.1.5 Inputs

The inputs in the production process for lime are general inputs such as labor, capital, and water. The inputs that are specific to this industry are the type of fuel and the limestone or other calcareous material used. These two specific inputs are discussed below.

Fuel. Lime production is extremely energy intensive. Assuming perfect efficiency, producing a ton of lime from pure calcium carbonate requires 2.77 million Btu. In practice, the process is considerably less efficient. Lime producers are concerned about the quality of fuel used in the process because the quality of the resulting lime depends directly on fuel quality. A change in fuel source can lead to a noticeable change in the characteristics of the lime produced. For this reason, lime producers do not always choose the cheapest fuel available (Boynton, 1980). The fuels most widely used in lime production in the U.S. are coal, coke, natural gas, and fuel oil (Sauers, Beige, and Smith, 1993a). A brief discussion of each fuel follows.

Coal. During the energy crisis of the 1970s, when fuel oil and natural gas prices soared and supplies were limited, many lime producers switched from vertical kilns to rotary kilns that operate with cheaper, more plentiful coal (Gutschick, 1994). To produce the highest quality lime, coal must be of moderate to low reactivity. (Reactivity refers to how freely the coal burns.) Coal used to fire lime kilns should also have a low ash content, since ash provides no heat value, can damage kiln linings, and may contaminate the lime. A low sulphur content is also desirable. Sulfur in the fuel volatilizes at calcining temperatures and might contaminate the lime (Boynton, 1980).

Coke. Coke can be produced from either coal or petroleum. Coke is the solid material that remains after coal has been heated in coke ovens until volatile components are driven off and collected as coal tar. It is also the solid material remaining after the various fractions of crude oil have been distilled off during the process of refining petroleum (Caldwell, 1998).

Coke is lower in both ash and volatiles than coal. Fuels that are high in volatiles create a stable flame, which is required by rotary kilns. Because coke is low in volatiles, it cannot be used exclusively in rotary kilns but can be mixed with coal to reduce ash. Kilns that do not require a stable flame formation, such as the parallel flow kiln, can burn 100 percent coke (Sauers, Beige, and Smith, 1993a).

Natural gas. Natural gas is relatively clean burning and is consistent in quality; therefore, it produces the highest quality lime. Natural gas-fired kilns require about 10 percent more energy than coal-fired kilns, however, and the cost per million Btu is generally much higher for natural gas than for coal. Kilns operating with natural gas also require more combustion air and larger vent capacity (Sauers, Beige, and Smith, 1993a).

Fuel oil. Because fuel oil generally costs more per million Btu than coal or natural gas, it is seldom used as the primary source of fuel in lime kilns, but it is sometimes combined with other fuels. It is low in ash and produces high-quality lime (Sauers, Beige, and Smith, 1993a).

Fuel oils, which are used mostly in nonrotary kilns, are usually Bunker C grade. Fuel oil has a greater potential for heat generation than solid fuels. When fuel oil is used, the kiln operation must be closely monitored to avoid excessive temperatures and overburning (Boynton, 1980).

Limestone. As previously mentioned, limestone is a general term that refers to a variety of sedimentary rocks. Limestone can be either high calcium or dolomitic, depending on its magnesium content. Table 2-1 provides descriptions of the various types of limestone that can be used to produce lime. The type of limestone used by a particular facility is determined by the type of limestone that is available in nearby quarries.

TABLE 2-1. CHARACTERISTICS OF LIMESTONE TYPES USED IN THE PRODUCTION OF LIME

Limestone Type	Characteristics
Argillaceous limestone	Contains considerable amounts of clay or shale and has a high content of silica and alumina
Calcitic limestone	Contains a high calcium content, though it does not necessarily signify pure calcite
Carbonaceous limestone	Contains impurities in the form of organic materials such as peat, natural asphalt, and oil shale
Cementstone	Produces a hydraulic cementing material when it is calcined; contains the correct balance of silica, alumina, and calcium carbonate for Portland cement
Chalk	A fossiliferous form of calcium carbonate with varying color, hardness, and purity
Chemical-grade limestone	A pure type of high-calcium or dolomitic limestone containing a minimum of 95 percent total carbonate. Used by the chemical-process industry.
Compact limestone	A dense, fine, often hard stone
Dolomitic limestone	Used to describe stone with a magnesium carbonate content between 20 percent and 45 percent
Ferruginous limestone	Red or yellow in color due to considerable amounts of iron as an impurity
Fluxstone	A pure form of limestone containing at least 95 percent carbonate; used either as flux or as purifier in metallurgical furnaces
Fossilferous limestone	The fossil structure of the stone is visually apparent
High calcium limestone	Has varying degrees of purity, but contains mostly calcium carbonate and less than 5 percent magnesite
Hydraulic limestone	Similar to cementstone but may contain more magnesite; the cement-like materials produced with hydraulic limestone usually also have a lower hydraulicity
Iceland spar	Also known as optical calcite; rare, extremely pure limestone, consisting of approximately 99.9 percent calcium carbonate
Magnesian limestone	Contains between 5 percent and 20 percent magnesite, the intermediate between high-calcium and dolomitic limestone
Marble	Varies in purity and may be a high calcium or dolomitic limestone. Occurs in many colors, is very hard, and can be polished to create a very smooth surface
Marl	An impure, carbonate rock, containing varying amounts of clay and sand
Oyster shell	A highly calcitic form of fossiliferous limestone
Phosphatic limestone	A high calcium variety of limestone, containing phosphorous and is created through invertebrate marine creatures

(continued)

TABLE 2-1. CHARACTERISTICS OF LIMESTONE TYPES USED IN THE PRODUCTION OF LIME (CONTINUED)

Limestone Type	Characteristics
Marble	Varies in purity and may be a high calcium or dolomitic limestone. Occurs in many colors, is very hard, and can be polished to create a very smooth surface
Marl	An impure, carbonate rock, containing varying amounts of clay and sand
Oyster shell	A highly calcitic form of fossiliferous limestone
Phosphatic limestone	A high calcium variety of limestone, containing phosphorous and is created through invertebrate marine creatures
Stalactites and stalagmites	Icicle-like structures found in caverns that are formed by cold groundwater that drips from limestone crevices
Travertine	Calcium carbonate similar in appearance to marble that is formed by hot-water mineral springs
Whiting	All finely divided carbonates derived from highly calcitic and dolomitic limestone, chemically precipitated calcium carbonate, marble, or shell; not a natural form of limestone

Source: Gutschick, K.A. Lime and Limestone. Kirk-Othmer Encyclopedia of Chemical Technology. 4th Ed. Vol. 15. New York, John Wiley & Sons. 1994. p. 319-359.

2.2 TYPES OF PRODUCTS

Table 2-2 lists the different forms of lime and describes them briefly. As previously mentioned, most types of lime are included under the three major categories: quicklime, hydrated lime, and dead-burned dolomite.

2.3 MAJOR BY-PRODUCTS AND SUBSTITUTION POSSIBILITIES

This section describes by-products and substitution possibilities for lime production.

TABLE 2-2. TYPES AND DESCRIPTIONS OF LIME PRODUCED

Grouping	Type of Lime	Description
Quicklime (unslaked lime)	Air-slaked lime	Partially decomposed quicklime resulting from excessive exposure to air
	Fluxing lime	Chemical type of quicklime used in steel manufacturing and in the fluxing of metals and glass
	Ground burned lime	Quicklime used for agricultural liming
	Hard-burned lime	Quicklime with low chemical reactivity and high density that is calcined at relatively high temperatures
	Lump lime	Form of quicklime calcined in a vertical kiln
	Pebble lime	Form of quicklime
	Soft-burned lime	Quicklime identified by high porosity and chemical reactivity
Hydrated lime	Autoclaved lime	Highly hydrated dolomitic lime used for structural purposes
	Building lime	Hydrated lime whose physical qualities are suitable for ordinary structural purposes
	Finishing lime	Refined hydrated lime used for plastering
	Hydraulic hydrated lime	Chemically impure lime containing silica, alumina, and iron used in structural applications
	Lime putty	Lime hydrate in the form of a wet, plastic paste containing free water
	Lime slurry	Contains more free water than lime putty and is found in a more liquid state
	Mason's lime	Hydrated lime used for masonry purposes
	Milk-of-lime	Dilute lime hydrate with the consistency of milk
	Slaked lime	Hydrated lime that occurs as either a powder or a putty or in a state of aqueous suspension
	Type S hydrated lime	Special hydrated lime distinguished from normal hydrated lime (type N) by the American Society for Testing and Materials because it meets specified plasticity and gradation requirements; commonly used in mortar
Dead-burned dolomite	Dead-burned dolomite	Special form of dolomitic quicklime, which is stabilized by adding iron oxides; also referred to as refractory lime
Other lime	Chemical lime	Quicklime or hydrated lime with high chemical purity
	Fat lime	Pure lime used to yield a plastic putty used in structural applications

Source: Gutschick, K.A. Lime and Limestone. Kirk-Othmer Encyclopedia of Chemical Technology. 4th Ed. Vol. 15. New York, John Wiley & Sons. 1994. p. 319-359.

2.3.1 Major By-Products

A major by-product of the lime industry is stone spalls, or pieces of limestone that do not meet the size requirements for kiln feed. Sometimes limestone spalls can be further processed and sold as limestone pebbles, granules, and fines, but where no market exists, spalls may accumulate into huge piles, creating a disposal problem (Boynton, 1980).

Another by-product is kiln dust. The composition of kiln dust varies depending on the nature of the kiln feed and fuel used. In the past, lime producers generally disposed of kiln dust in abandoned quarries or landfills. In the early 1970s, a shortage of lime caused by a combination of high demand and labor strikes at lime plants forced consumers to try using kiln dust to meet their needs. Since then, the use of kiln dust for agricultural and industrial purposes has increased (Boynton, 1980).

Carbon dioxide, which was discussed as an emission in Section 2.1.5, is collected as a valuable by-product and used by some captive lime producers (see Section 3.2).

2.3.2 Input Substitution Possibilities

Kiln Feed. Most commercial lime plants worldwide are integrated lime producers and extract their own kiln feed from an adjoining limestone quarry or mine (Gutschick, 1994). Transportation costs make it generally infeasible for producers to substitute kiln feed from alternate sources (Boynton, 1980).

Fuel. Because most kilns are able to accommodate several different fuel types, producers can substitute fuels based on price and availability. As previously mentioned, the most widely used fuels are coal, coke, natural gas, and fuel oil. Producers must consider quality as well as price and availability when choosing a fuel (Sauers, Beige, and Smith, 1993a).

2.3.3 Final Product Substitution Possibilities

The chemical properties and composition of the lime produced relate directly to the characteristics of the limestone used as kiln feed (Gutschick, 1994). Most plants use kiln feed from an adjacent quarry, so the type of lime the plants manufacture is limited. However, commercial plants have substitution possibilities regarding the form of their final product. Lime can be sold as quicklime in various particle sizes, or it can be further processed into one of the forms of hydrated lime (see Table 2-2) (Boynton, 1980).

2.4 COSTS OF PRODUCTION

The costs incurred by lime manufacturers are labor, materials, and capital. This section provides data on these costs and discusses economies of scale.

2.4.1 Cost Data

Table 2-3 provides expenditures for wages, materials, and new capital from 1977 to 1997 in both current and 1997 dollars. Costs of materials include all raw materials, containers, scrap, and supplies used in production, repair, or maintenance during the year, as well as the cost of all electricity and fuel consumed. Costs are included for materials whether they are purchased from outside the company or transferred from within the company. (Cost of materials includes the cost of quarrying limestone.) New capital expenditures include permanent additions and alterations to facilities and machinery and equipment used for expanding plant capacity or replacing existing machinery.

This table shows that the cost of materials (which includes quarrying of limestone) is by far the greatest cost to lime producers. Lime producers spend as much as three to four times more on materials than they do on labor. A large part of the materials cost is fuel costs.

TABLE 2-3. LABOR, MATERIAL, AND NEW CAPITAL EXPENDITURE COSTS FOR SIC 3274 (NAICS 32741) LIME MANUFACTURING: 1977-1997

	Wages		Cost of Materials		New Capital Expenditures	
Year	Current $\$(10^6)$	1997 $\$(10^6)$	Current $\$(10^6)$	1997 $\$(10^6)$	Current $\$(10^6)$	1997 $\$(10^6)$
1977	59.4	115.0	264.8	512.6	29.7	57.5
1978	74.4	133.7	317.7	571.0	62.7	112.7
1979	75.9	121.1	322.4	514.6	38.3	61.1
1980	76.2	106.7	316.9	443.4	69.7	97.5
1981	85.5	109.7	359.0	460.2	56.7	72.6
1982	79.4	99.8	298.2	374.6	36.0	45.2
1983	81.1	100.5	305.6	379.0	20.9	25.9
1984	91.0	110.2	347.6	421.2	72.9	88.3
1985	100.4	122.2	359.2	437.2	70.1	85.3
1986	101.7	127.6	351.8	441.1	38.8	48.7
1987	103.6	126.6	364.5	445.5	33.0	40.3
1988	113.9	133.9	413.9	486.5	28.0	32.9
1989	115.9	129.8	385.0	431.1	41.7	46.7
1990	111.7	120.7	300.6	324.7	43.7	47.2
1991	103.4	111.5	299.8	323.3	66.4	71.6
1992	121.3	130.0	446.2	478.3	47.9	51.3
1993	125.2	132.3	480.0	507.1	35.5	37.5
1994	125.5	131.0	529.9	552.9	21.6	22.5
1995	120.1	121.0	365.3	368.0	21.2	21.3
1996	168.5	171.3	378.4	384.6	60.4	61.4
1997	203.5	203.5	558.0	558.0	61.9	61.9

Prices were deflated using the producer price index (PPI) from the Bureau of Labor Statistics. <http://146.142.4.24/cgi-bin/srgate>. 2000.

Sources: U.S. Department of Commerce, Bureau of the Census. 1997 Census of Manufactures, Industry Series—Concrete, Plaster, and Cut Stone Products. Washington, DC: Government Printing Office. 1999c.
U.S. Department of Commerce, Bureau of Census. 1994 Annual Survey of Manufactures. M94(AS)-1. Washington, DC: Government Printing Office. 1996.
U.S. Department of Commerce, Bureau of Census. 1995 Annual Survey of Manufactures. M95(AS)-1. Washington, DC: Government Printing Office. 1997.
U.S. Department of Commerce, Bureau of the Census. 1996 Annual Survey of Manufactures. Washington, DC: Government Printing Office. 1999a.
U.S. Department of Commerce, Bureau of the Census. 1997 Census of Manufacturing, Manufacturing Industry Series—Lime Manufacturing. EC97M-3274A. Washington, DC: Government Printing Office. 1999b.

For 1996, the Annual Survey of Manufactures reported that the lime industry spent $138.2 million on energy, which is 31.4 percent of total materials costs for that year (U.S. Department of Commerce, 1997). Table 2-4 contains a more detailed breakdown of the costs of materials used in the production and manufacture of lime.

2.4.2 Economies of Scale

As a rule, unit costs decline as output increases so that larger lime plants have lower unit costs than smaller plants. However, operating costs within this industry vary significantly, and there may be exceptions to this rule (Boynton, 1980).

Capacity varies with kiln type. Rotary kilns can operate at a rate of 100 to 1,500 tons per day, while shaft kilns (vertical and parallel flow) can produce 50 to 600 tons per day (Sauers, Beige, and Smith, 1993b). To keep unit costs to a minimum, producers must operate at nearly full capacity. Running kilns at less than full capacity is very inefficient, because it requires the same amount of fuel as operating at full capacity (Miller, 1997d). Operating at 90 to 95 percent capacity is optimal, but pushing a plant to 100 percent of its capacity can damage equipment (Boynton, 1980).

TABLE 2-4. MATERIALS, INGREDIENTS, AND SUPPLIES BY KIND FOR SIC 3274 (NAICS 32741) LIME MANUFACTURING: 1987, 1992, and 1997

Material	1997		1992		1987	
	Delivered Cost ($\$10^6$)	Percent	Delivered Cost ($\$10^6$)	Percent	Delivered Cost ($\$10^6$)	Percent
Materials, ingredients, containers, and supplies	254.1	100	208.7	100	181.4	100
Paper and allied products		NA	NA	NA	NA	NA
Paperboard liners	NA	NA	NA	NA	NA	NA
Paper shipping sacks and multiwall bags	22	8.7	9	4.3	8.4	4.6
Other paper and allied products	NA	NA	0.9	0.4	NA	NA
Stone, clay, glass, and concrete products						
Refractories, clay or nonclay	17.2	6.8	22.1	10.6	4.9	2.7
Minerals and earths, ground or otherwise treated	3.6	1.4	2.1	1	10.7	5.9
Other stone, clay, glass, and concrete products	1.3	0.5	NA	NA	NA	NA
Crushed and broken stone (including cement rock, limestone)	145.8	57.4	67.2	32.2	48.9	27
All other materials and components, parts, containers, and supplies	61.4	24.1	95.8	45.9	86.4	47.7
Materials, ingredients containers and supplies, not specified by kind	2.8	1.1	8.7	4.2	22.1	12.2

NA = Not available.
Prices were deflated using the producer price index (PPI) from the Bureau of Labor Statistics. <http://146.142.4.24/cgi-bin/srgate>. 2000.
Note that 1987 figures are adjusted for 1997.

Sources: U.S. Department of Commerce, Bureau of the Census. 1997 Census of Manufactures, Industry Series—Concrete, Plaster, and Cut Stone Products. Washington, DC: Government Printing Office. 1999c.
U.S. Department of Commerce, Bureau of the Census. 1997 Census of Manufacturing, Manufacturing Industry Series, Lime Manufacturing. EC97M-3274A. Washington, DC: Government Printing Office. 1999b.

SECTION 3
THE DEMAND SIDE

In addition to the supply side, estimating the economic impacts of the regulation on the lime manufacturing industry requires characterizing various aspects of the demand for lime. This section describes the product characteristics desired by end users; the numerous uses for lime, including agricultural, chemical and industrial, construction, and environmental uses; and possible substitutes for lime.

3.1 PRODUCT CHARACTERISTICS

Because the quality and characteristics of lime vary considerably, consumers often use chemical and physical tests to ensure that the lime being purchased meets their requirements. The American Society for Testing and Materials (ASTM) provides specifications and tests for various uses of lime. Many of these tests are too time consuming and costly for use in routine quality control, so they are performed only occasionally. Less involved tests of physical and chemical qualities can be done depending on the consumer's needs. Depending on the intended end use, consumers may test lime for impurities, consistency, plasticity, particle size, compressive strength, settling rate, slaking rate, and chemical composition (Boynton, 1980).

For most purposes, dolomitic and high-calcium lime can be used interchangeably. For certain purposes, however, one or the other may be preferable. For example, dolomitic lime is used for agricultural liming in areas where the soil is deficient in magnesium (Boynton, 1980).

Quicklime and hydrated lime are also interchangeable for most purposes. The choice between quicklime and hydrated lime depends on the quantity needed and the storage facilities available. Quicklime is more concentrated than hydrated lime, and costs 50 to 60 percent less per ton. However, quicklime must be stored carefully and must be slaked, or hydrated, prior to use. The consumer must weigh the cost of owning and operating slaking equipment against the savings from buying less expensive quicklime. High-volume consumers generally purchase quicklime, while smaller consumers usually buy hydrated lime (Boynton, 1980).

Almost all quicklime is shipped in bulk in covered hopper rail cars. The small quantities of quicklime that are packaged are placed in extra-heavy paper sacks. Hydrated lime is available both in bulk and packaged in multiwall, 50-pound bags. Bulk hydrate is loaded pneumatically onto tank trucks for shipment (Boynton, 1980).

3.2 USES AND CONSUMERS

Table 3-1 presents data on quantities, percentages, and dollar values of lime used by various industries in 1999. Uses fall into one of the following general categories: agriculture, chemical and industrial (which includes steel), construction, environmental, and refractory. Agriculture consumed less than 1 percent of lime produced in the U.S. Chemical and industrial uses accounted for 64 percent of the lime consumed, and the steel industry alone consumed 30.5 percent. Within the chemical and industrial category, other significant uses included pulp and paper production (5 percent), precipitation of calcium carbonate (6.1 percent), and sugar refining (4 percent). Construction accounted for 10.6 percent of the lime consumed, and most lime in this category is used for soil stabilization. Environmental uses for lime accounted for 23.9 percent of the market. Within this category, the largest use for lime was flue gas desulfurization (15.9 percent), followed by water purification (7.1 percent).

TABLE 3-1. QUANTITIES, PERCENTAGES, AND VALUES FOR LIME BY USE: 1999[a]

	1,000mt[b]	Percent	Value 10^3
Agriculture	23	0.1	1,900
Chemical and industrial			
Glass	98	0.5	5,650
Pulp and paper	971	5.0	57,700
Precipitated calcium carbonate	1,200	6.1	71,100
Sugar refining	783	4.0	45,800
Other chemical and industrial	1,920	9.8	121,000
Metallurgical	5,000	25.5	303,000
Basic oxygen furnaces	3,930	20.1	220,000
Electric arc furnaces	1,810	10.7	107,000
Other	239	1.2	14,700
Total metallurgical	5,970	30.5	342,000
Nonferrous metals			
Aluminum and bauxite	303	1.5	17,800
Other nonferrous metallurgy	1,270	6.5	73,200
Total nonferous metallurgy	1,570	8.0	91,000
Total metallurgical	7,550	38.5	433,000
Total chemical and industrial	12,550	64.0	736,000
Construction			
Asphalt paving	362	1.8	26,500
Soil stabilization	1,280	6.5	82,700
Other	427	2.2	42,500
Total construction	2,070	10.6	152,000
Environmental			
Flue gas sulfur removal	2,750	15.9	142,000
Sewage treatment	245	1.3	15,500
Water purification	1,400	7.1	88,600
Other	297	1.5	18,600
Total environmental	4,690	23.9	265,000
Refractory lime (dead-burned dolomite)	300	1.5	24,400
Grand Total	19,600		1,180,000

[a] Numbers include commercial sales and captive supply use. Regenerated lime is not included.
[b] To convert to short tons, multiply metric tons by 1.10231.

Source: Miller, M.M. 1999b. Minerals Yearbook: Lime. Reston, VA, U.S. Department of the Interior, Geological Survey. <http://minerals.usgs.gov/minerals/pubs/commodity/lime/index.html#myb>.

Table 3-2 contains information on lime use for 1998 and 1999; quantities and percentages for quicklime and hydrated lime are presented separately. For both years, the quantity of quicklime consumed was about six times greater than the quantity of hydrate consumed. The construction industry used more hydrate than quicklime, but for environmental, steel, and other purposes listed, quicklime use greatly exceeded hydrate use. All lime sold for refractory purposes was quicklime. The following section discusses some of the many uses of lime in more detail.

3.2.1 Agriculture

Lime is applied to fields to neutralize acid soils, offset acidity created by nitrogen fertilizers, add nutrients to the soil (calcium and magnesium), and improve soil structure. Agricultural use of lime in the U.S. takes place almost exclusively in the east, since western states tend to have alkaline soils (Gutschick, 1994).

3.2.2 Chemical and Industrial

Lime serves many diverse and important functions in a broad range of industries. As previously mentioned, more than 60 percent of the lime consumed per year is used in chemical and industrial applications, including steel manufacturing, pulp and paper manufacturing, and sugar refining. Industries can meet their demand for lime by either purchasing lime from commercial producers or by manufacturing their own lime onsite (captive production). For example, all beet sugar producers and alkali plants operate their own lime plants to supply the large quantities of lime and carbon dioxide they require. Some steel producers, as well as manufacturers of copper, alumina, and magnesium also operate captive lime kilns (Boynton, 1980). The following section describes in more detail how a number of industries use lime.

TABLE 3-2. LIME SOLD BY PRODUCERS IN THE U.S., BY USE (THOUSANDS METRIC TONS)[a]

Use	12 Months 1998	Percentages 1998	12 Months 1999	Percentages 1996
Quicklime				
Construction				
Soil Sabilization	795	4.0	842	4.3
General Construction	16	0.08	32	0.2
Total Construction	816	4.1	874	4.5
Refractory dolomite	300	1.5	300	1.5
Environmental	4,544	22.7	4,174	21.3
Steel, iron related	7,794	38.9	7,528	38.4
Other chemical and industrial	4,264	21.3	4,524	23.1
Total quicklime	17,718	88.4	17,400	88.7
Hydrate				
Construction				
Soil stabilization	485	2.4	438	2.2
General construction	679	3.4	758	3.9
Total construction	1,164	5.8	1,196	6.1
Environmental	576	2.9	516	2.6
Steel, iron related	46	0.02	22	1.1
Other chemical and industrial	549	2.7	476	2.4
Total hydrate	2,335	11.6	2,210	11.3
All Lime				
Total construction sales	1,980	9.9	2,070	10.6
Total refractory sales	300	1.5	300	1.5
Total environmental sales	5,120	25.5	4,690	23.9
Total steel, iron-related sales	7,840	39.1	7,550	38.5
Total chemical and industrial sales	1,950	9.7	1,920	9.8
Total sales of lime	20,053	100.0	19,610	100.0

[a] To convert metric tons to short tons, multiply metric tons by 1.10231.

Source: Miller, M.M. Minerals Information: Lime. Reston VA, U.S. Department of the Interior, U.S. Geological Survey. 1999a. <http://minerals.usgs.gov/minerals/pubs/commodity/lime/390499.pdf>.

Iron and Steel Metallurgy. Lime is used as flux in the manufacture of steel. It reacts with impurities such as phosphorus, silica, and sulfur to form slag, which is removed from the metal. The types of steel furnaces that consume lime are the basic open-hearth furnace, the basic Bessemer furnace, and the basic oxygen furnace (Boynton, 1980). The basic oxygen furnace produces about two-thirds of the steel in the U.S. Electric furnaces that purify steel scrap also use lime as flux. Dead-burned dolomite is used to protect the refractory linings of open-hearth and electric furnaces and manufacture refractory brick (Gutschick, 1994).

Nonferrous Metallurgy. The production of magnesium metal or magnesia requires lime as a raw material. Lime is also used to purify nonferrous ores, including copper, gold, silver, uranium, zinc, nickel, and lead. Large quantities of lime are used in the production of alumina from bauxite (Boynton, 1980).

Sugar Refining. The beet sugar industry uses large quantities of both lime and carbon dioxide in its refining process. (Small quantities are used in the refining of cane sugar.) To meet their needs, all beet sugar manufacturers maintain their own captive lime kilns and purchase limestone to use as kiln feed, but they generally do not operate their own limestone quarries (Gutschick, 1994). Captive lime kilns only operate in the fall after the beet harvest. Manufacturers use both the lime and the carbon dioxide that captive lime kilns produce (Boynton, 1980).

Precipitated Calcium Carbonate (PCC). PCC is a pure white powder with uniform particle size, which is an important input in many production processes. It is used as a pigment in paint; a coating and filler for paper; a filler in rubber products; and an ingredient in putties, dentifrices, and pharmaceuticals. It is manufactured directly from lime and is also a by-product of the production of soda ash at alkali plants (Boynton, 1980).

Pulp and Paper. Quicklime is used in sulfate-process pulp plants in combination with "black liquor" (waste sodium carbonate solution), allowing sodium hydroxide (caustic soda) to be recovered. As part of this process, 92 to 98 percent of lime is also recovered. Sludge is dewatered and pelletized then fed through captive rotary kilns where it is calcined back into lime for reuse. Pulp plants also use lime to make calcium hypochlorite for bleaching paper and for treating wastewater (Boynton, 1980). The pulp and paper industry has been moving away from the sulfate process to an alkaline process, which produces higher quality paper at lower cost. This process still requires lime, however, in the form of PCC. As previously mentioned, PCC is used as a filler and coating material for high quality paper. Some pulp and paper manufacturers have installed PCC plants on site (Gutschick, 1994).

Other Chemical and Industrial Uses. Lime is used in the production of a number of chemicals, such as soda ash and sodium bicarbonate (alkalies), and calcium carbide. Various forms of lime are also used to produce plastics and glass. Lime is also used as a carrier for pesticides and in the production of bleaching agents. Calcium and magnesium salts such as dicalcium phosphate, magnesium chloride, and lithium salts also come from lime. Lime is used in refining food-grade salts and in producing numerous food additives (Gutschick, 1994).

3.2.3 Construction

The largest use of lime for construction is for soil stabilization. It is used in constructing roads, parking lots, runways, building foundations, embankments, earthen dams, railroad beds, and irrigation canal linings. When lime is added to clay soils, which contain silica, and the soil is then compacted, the lime reacts with the silica, greatly increasing the soil's stability and strength. For soils low in silica, builders use lime together with fly ash, which contains silica. Lime is also used to dry up saturated soils (Gutschick, 1994).

Lime is an important component of asphalt used for paving. It improves the asphalt's ability to adhere to the surface to which it is applied and adds to its durability (Gutschick, 1994). Lime is also used to produce building materials such as mortar, plaster, and stucco (Boynton, 1980).

3.2.4 Environmental

Environmental protection is a large and growing market for lime, and lime is used in various environmental applications.

Air Pollution Control. The Clean Air Act of 1970 created a new market for lime in the area of flue gas desulfurization, which has now become the second largest domestic market for lime (Miller, 1996c). Flue gas desulfurization uses lime to remove sulfur dioxide from stack gases at utility and industrial plants that burn coal. They employ both wet and dry scrubbers. Wet scrubbers, which use slurries of lime and produce a liquid waste product, can remove up to 99 percent of sulfur dioxide from stack gases. Dry scrubbers, which produce a dry waste, can remove sulfur with 70 to 90 percent efficiency. Lime can also be used to neutralize wastes from sulfuric acid plants, as well as other wastes such as hydrochloric acid, hydrofluoric acid, and nitrogen oxide. It can also be used to scrub stack gases from incinerators and small industrial coal-fired boilers (Gutschick, 1994).

Water Treatment. Lime is used to treat potable water for softening (removing minerals), purifying (killing bacteria), and clarifying. Lime is also effective at preventing lead and copper from entering distribution systems. It does this by raising the pH of the water so that these metals remain insoluble (Gutschick, 1994).

Sewage Treatment. Lime is used to treat wastewater at sewage treatment plants. The addition of lime to wastewater causes phosphates and most heavy metals to precipitate. It also causes solid and dissolved organic compounds to coagulate and ammonia to volatilize. Lime also raises the pH to a point where bacteria, viruses, and odor are destroyed. Lime is used heavily in the treatment of sewage sludge as well. It controls odors, kills germs, and precipitates heavy metals, allowing sludge to be disposed of safely in landfills or to be used as a soil amendment (Gutschick, 1994).

Industrial Wastewater Treatment. Many industries, including the electroplating, chemical manufacturing, and textile industries, use lime to treat their wastewater. In addition, lime is used to treat effluents that are high in sulfuric acid and iron oxides from both abandoned and active coal mines (Gutschick, 1994).

3.3 SUBSTITUTION POSSIBILITIES IN CONSUMPTION

As mentioned in Section 3.1, the various forms of lime can often be used interchangeably. For some purposes, limestone can be used as a substitute for lime. For example, in the flue gas desulfurization market, high purity limestone can be used instead of lime for scrubbing, and it is considerably less costly than lime. However, lime is more reactive than limestone, and the capital investment required for limestone scrubbers is higher than that for lime scrubbers. In the steel industry, basic open-hearth furnaces can use limestone instead of lime as flux. However, the basic oxygen furnace, which uses only lime as flux, has almost entirely replaced the open-hearth furnace (Gutschick, 1994). Limestone cannot replace lime for soil stabilization, but for agricultural purposes, ground limestone can be used instead of lime (Boynton, 1980).

For industrial wastewater treatment, limestone can be used to a limited extent for acid neutralization, raising pH to 6 to 6.5. However, to precipitate iron and other ferrous metals, a pH of 9 to 10 is necessary, and for this range, only lime is effective (Gutschick, 1994). Caustic soda also competes with lime in the acid neutralization market. Caustic soda is highly effective, but its price tends to be volatile (Miller, 1997d).

Whiting, a type of limestone, can be used as a diluent and carrier of pesticides in lieu of hydrated lime (Gutschick, 1994). Calcined gypsum is an alternative material used in industrial plasters and mortars. Cement, lime kiln dust, and fly ash are also potential substitutes for lime in some construction uses (Miller, 1996a).

SECTION 4
INDUSTRY ORGANIZATION

This section examines the organization of the U.S. lime industry, including plant location and production characteristics, commercial and captive producers, firm characteristics, market structure, and degree of integration. The industry's organization helps determine how it will be affected by complying with the Lime Production NESHAP.

4.1 LIME MANUFACTURING PLANTS

Lime manufacturing plants may be broadly divided into those that produce lime to be sold (commercial lime plants) and those that produce lime as part of a vertically integrated production process whose purpose is to produce another good, such as steel, paper, or beet sugar (captive lime plant). This section provides plant-level data on both commercial and captive lime plants.

Table 4-1A lists all of the commercial lime facilities in the 50 states and Puerto Rico and provides location, capacity, and kiln information. Information on the number and location of lime facilities was obtained from the United States Geological Survey (USGS) within the Department of the Interior (U.S. Department of the Interior, 1999). Table 4-1B presents the location and kiln-type information for the U.S. captive supply lime industry.

TABLE 4-1A. COMMERCIAL LIME MANUFACTURING PLANTS

Company	Facility	Location	Capacity (tpy[a])	Number of Kilns	Type of Kiln[b]
Ash Grove Cement Co.	Springfield	Springfield, MO	>66,000	2	V,O
Ash Grove Cement Co.	Portland	Portland, OR	128,400	3	O
Austin White Lime Co.	McNeil	McNeil, TX	CBI	CBI	R
Blue Circle Inc.	Roberta	Calera, AL	NS	4	R
Carmeuse North America (Eastern Region)/ Ohio Lime, Inc	Maple Grove	Maple Grove, OH	NS	NS	R
Carmeuse North America (Eastern Region)/ Millersville Lime, Inc	Millersville	Millersville, OH	NS	NS	R
Carmeuse North America (Eastern Region)/ Pennsylvania Lime, Inc.	Millard	Annville, PA	415,425	5	R
Carmeuse North America (Eastern Region)	Hannover	Hanover, PA	196,800	3	O
Carmeuse North America (Northern Region)/ Detroit Lime, Inc.	Detroit	Detroit, MI	NS	NS	R
Carmeuse North America (Northern Region)/ Marblehead Lime, Inc	River Rouge	River Rouge, MI	NS	NS	R
Carmeuse North America (Southern Region)/ Dravo Lime, Inc.	Longview	Saginaw, AL	NS	NS	R
Carmeuse North America (Southern Region)	Black River (UG)	Carntown, KY	NS	NS	R
Carmeuse North America (Southern Region)	Maysville (UG)	Maysville, KY	NS	NS	R
Carmeuse North America (Southern Region)	Pelican	Baton Rouge, LA	NS	NS	H
Carmeuse North America (Southern Region)/ San Antonio Lime, Inc.	Bexar	San Antonio, TX	NS	NS	R
Carmeuse North America (Western Region)/ Marblehead Lime, Inc.	South Chicago	South Chicago, IL	NS	NS	R
Carmeuse North America (Western Region)	Buffinton	Buffinton, IN	NS	NS	R
Chemical Lime Co.	Alabaster	Alabaster, AL	162,400	2	R
Chemical Lime Co.	O'Neal	Calera, AL	NS	NS	R
Chemical Lime Co.	Montevallo	Montevallo, AL	753,750	4	R
Chemical Lime Co.	Douglas	Douglas, AZ	NS	3	R,V
Chemical Lime Co.	Nelson	Nelson, AZ	>480,000	2	R

(continued)

TABLE 4-1A. COMMERCIAL LIME MANUFACTURING PLANTS (CONTINUED)

Company	Facility	Location	Capacity (tpy[a])	Number of Kilns	Type of Kiln[b]
Chemical Lime Co.	Ste. Genevieve	Ste. Genevieve, MO	NS	NS	R
Chemical Lime Co.	City of Industry	City of Industry, CA	NS	NS	H
Chemical Lime Co. (managed by)	Natividad	Natividad, CA	NS	NS	R
Chemical Lime Co.	Stockton	Stockton, CA	NS	NS	H
Chemical Lime Co.	Tensile	Bancroft, ID	210,000	1	V,R
Chemical Lime Co.	Belen	Belen, NM	NS	NS	H
Chemical Lime Co.	Apex	North Las Vegas, NV	391,000	3	R
Chemical Lime Co.	Henderson	Henderson, NV	NS	3	R
Chemical Lime Co.	Clifton	Clifton, TX	388,200	3	R,V
Chemical Lime Co.	Marble Falls	Marble Falls, TX	219,000	1	V,R
Chemical Lime Co.	New Braunfels	New Braunfels, TX	CBI	CBI	V,R
Chemical Lime Co.	Grantsville	Grantsville, UT	70,000	1	R
Chemical Lime Co.	Plant #1	Kimbalton, VA	CBI	CBI	R
Chemical Lime Co.	Plant #2	Kimbalton, VA	CBI	CBI	R
Cheney Lime & Cement Co.	Allgood	Allgood, AL	NS	NS	H
Cheney Lime & Cement Co.	Landmark	Siluria, AL	148,750	1	R
Cutler-Magner Corp.	Superior	Superior, WI	NS	NS	R
Con Lime Co.	Bellefonte (UG)	Bellefonte, PA	NS	NS	R
Falco Lime, Inc.	Vicksburg	Vicksburg, MS	NS	NS	H
Florida Crushed Stone Co.	Brooksville	Brooksville, FL	NS	NS	H
Global Stone Co. (Global Stone Georgia Hydrate, Inc.)	Macon	Macon, GA	NS	NS	H
Global Stone Co. (Global Stone St. Clair, Inc.)	Marble City	Marble City, OK	210,000	2	R
Global Stone Co. (Global Stone Tenn Luttrell, Inc.)	Luttrell (UG)	Luttrell, TN	268,000	1	R,V
Global Stone Co. (Global Stone Chemstone, Inc.)	Dominion	Strasburg, VA	CBI	CBI	V,R,O
Global Stone Co.	Winchester	Clear Brook, VA	NS	NS	R
Graymont Ltd. (Continental Lime Inc.)	Tacoma	Tacoma, WA	102,000	1	R
Graymont Ltd. (Continental Lime Inc.)	Pilot Peak	Wendover, NV	365,000	2	R
Graymont Ltd. (Continental Lime Inc.)	Cricket Mountain	Delta, UT	1,095,000	4	R
Graymont Ltd. (Continental Lime Inc.)	Indian Creek	Townsend, MT	365,000	2	R

(continued)

TABLE 4-1A. COMMERCIAL LIME MANUFACTURING PLANTS (CONTINUED)

Company	Facility	Location	Capacity (tpy[a])	Number of Kilns	Type of Kiln[b]
Graymont Ltd. (Genlime)	Genoa	Genoa, OH	131,400	3	R
Graymont Ltd. (Graybec Lime Ltd.)	Bellefonte	Bellefonte, PA	328,000	2	R
Graymont Ltd. (Graybec Lime Ltd.)	Pleasant Gap	Pleasant Gap, PA	255,750	3	R
Greer Lime Co.	Riverton	Riverton, WV	NS	NS	R
Huron Lime	Huron	Huron, OH	383,250	3	R
Pete Lien & Sons, Inc.	Rapid City	Rapid City, SD	119,340	1	R
Pete Lien & Sons, Inc. (Colorado Hydrate)	Laporte	Laporte, CO	NS	NS	H
Linwood Mining & Minerals Corp.	Linwood (UG)	Linwood, IA	146,000	3	R
Mercer Lime and Stone Co.	Branchton	Branchton, PA	NS	NS	R
National Lime & Stone Co.	Carey	Carey, OH	NS	NS	O
Palmetto Lime LLC	Palmetto	Charleston, SC	NS	NS	V
Puerto Rican Cement Co., Inc.	Ponce	Ponce, PR	37,200	1	R
Rockwell Lime Co.	Manitowoc	Manitowoc, WI	116,550	2	R
Shen-Valley Lime Corp.	Stephens City	Stephens City, VA	NS	NS	H
Southdown Corp	Lee	Lee, MA	NS	NS	R
U.S. Lime & Minerals, Inc. (Arkansas Lime Co.)	Batesville	Batesville, AR	NS	NS	V
U.S. Lime & Minerals, Inc. (Texas Lime Co.)	Plant #1	Cleburne, TX	NS	NS	R
USG Corp	New Orleans	New Orleans, LA	48,635	1	R
Vulcan Materials Co.	Manteno	Manteno, IL	NS	NS	R
Vulcan Materials Co.	McCook	McCook, IL	NS	NS	R
Western Lime Corp.	Green Bay	Green Bay, WI	144,010	1	R
Western Lime Corp.	Eden	Eden, WI	73,360	1	R
Wyoming Lime Producers	Frannie	Frannie, WY	NS	NS	R

CBI = Confidential Business Information
NS = Not surveyed/no response
[a] Tons per year
[b] V = vertical or shaft; O = other; R = rotary; H = hydrator only

Sources: U.S. Department of the Interior, U.S. Geological Survey. 2000. 1999 Directory of Lime Plants in the United States. Mineral Industry Surveys. Reston, VA. <http://minerals.usgs.gov/minerals/pubs/commodity/lime/index.html#myb>.
Memorandum from Wood, Joseph P., U.S. Environmental Protection Agency, to Chappell, Linda M., U.S. Environmental Protection Agency. November 1996. Engineering industry profile for the economic analysis.

TABLE 4-1B. CAPTIVE SUPPLY LIME MANUFACTURING PLANTS

Company	Facility	Location	Type of Kiln[a]
Amalgamated Sugar Co., The	Twin Falls	Twin Falls, ID	V
Amalgamated Sugar Co., The	Nampa	Nampa, ID	O
Amalgamated Sugar Co., The	Mimi-Cassia	Paul, ID	V
Amalgamated Sugar Co., The	Nyssa	Nyssa, OR	NA
American Crystal Sugar Co.	Moorhead	Moorhead, MN	NA
American Crystal Sugar Co.	Crookston	Crookston, MN	V
American Crystal Sugar Co.	East Grand Forks	East Grand Forks, MN	V
American Crystal Sugar Co.	Drayton	Drayton, ND	V
American Crystal Sugar Co.	Hillsboro	Hillsboro, ND	NA
Baker Refactories Co.	York	York, PA	R
Bowater Southern Paper Corp.	Calhoun	Calhoun, TN	R
Dow Chemical Co., The	Ludington	Ludington, MI	R
Elkem Metals Co.	Ashtabula	Ashtabula, OH	V
Graymont Ltd .(Continental Lime, Inc.)	Tacoma	Tacoma, WA	R
Great Lakes Sugar Co., The	Fremont	Genoa, OH	O
Holly Sugar Corp.	Brawley	Brawley, CA	V
Holly Sugar Corp.	Tracy	Tracy, CA	V
Holly Sugar Corp.	Woodland	Woodland, CA	V
Holly Sugar Corp.	Sidney	Sidney, MT	V
Holly Sugar Corp.	Hereford	Herford, TX	V
Holly Sugar Corp.	Torrington	Torrington, WY	V
Holly Sugar Corp.	Worland	Worland, WY	V
Ispat Inland, Inc.	Indiana Harbor	Indiana Harbor, IN	R
LTV Steel	Grand River	Grand River, OH	R
Martin Marietta Magnesia Specialties, Inc.	Woodville	Woodville, OH	V
Michigan Sugar Co.	Sebewaing	Sebewaing, MI	V
Michigan Sugar Co.	Carolton	Carolton, MI	V
Michigan Sugar Co.	Croswell	Croswell, MI	V
Michigan Sugar Co.	Caro	Caro, MI	V
Minn-Dak Farmers Coop.	Minn-Dak	Wahpeton, ND	V
Mississippi Lime Co.	Ste. Genevieve	Ste. Genevieve, MO	R,V
Monitor Sugar Co.	Bay City	Bay City, MI	V
NorthWest Alloys, Inc.	Addy	Addy, WA	R
Riverton Corp.	Riverton	Riverton, VA	V
Southern Minnesota Sugar Corp.	Renville	Renville, MN	V
Specialty Minerals, Inc.	Adams	Adams, MA	O
Western Sugar Co.	Fort Morgan	Fort Morgan, CO	V
Western Sugar Co.	Greeley	Greeley, CO	O
Western Sugar Co.	Bayard	Bayard, NE	O
Western Sugar Co.	Mitchell	Mitchell, NE	V
Western Sugar Co.	Scottsbluff	Scottsbluff, NE	V
Western Sugar Co.	Billings	Billings, MT	V

[a] R = rotary; V = vertical or shaft; O = other; NA = not available

Sources: U.S. Department of the Interior, U.S. Geological Survey. 2000. 1999 Directory of Lime Plants in the United States. Mineral Industry Surveys. Reston, VA. <http://minerals.usgs.gov/minerals/pubs/commodity/lime/index.html#myb>.
U.S. Department of the Interior, U.S. Geological Survey. Directory of Lime Plants in the United States. Reston, VA, U.S. Department of the Interior, U.S. Geological Survey. 1999.

4.1.1 Lime Plant Location

Table 4-2 presents a list of the number of commercial and captive lime facilities by state, based on the information provided in Tables 4-1A and 4-1B. Overall, Ohio has the largest number of facilities (ten), followed by Michigan (eight). Alabama and Pennsylvania each have seven plants, and Texas, California, and Virginia each have six plants.

4.1.2 Commercial Lime Facilities

Alabama has the largest number of commercial lime facilities (seven) in the country, followed by Pennsylvania and Ohio with six each. Texas and Virginia each have five commercial lime facilities.

Sales and employment ranges for the commercial lime facilities vary greatly. EPA obtained data on plant-specific sales and employment ranges for approximately 61 of the plants listed in Table 4-1A (ABI, 1997). Sales at these plants vary from a range of $1 to $2.5 million per year to as much as $500 million in annual sales. Similarly, facilities employing ten workers contrast with those employing hundreds of workers. Generally, however, these plants are characterized by relatively low employment and moderate plant-level sales. Of the 61 plants for which data were obtained, 21 have fewer than 10 employees, and another 12 have between 10 and 19. Sixteen have between 20 and 49 employees, while only 12 employ over 50. Plant-level sales are also relatively low. Sixteen of the 61 plants have sales less than $1 million per year, and another 22 plants have sales between $1 million and $5 million per year. Eight plants have sales between $5 million and $10 million per year. Only 15 plants report sales exceeding $10 million per year.

TABLE 4-2. NUMBER OF LIME MANUFACTURING FACILITIES BY STATE

State	Number of Commercial Facilities	Number of Captive Supply Facilities	Number of Facilities Supplying Both Commercial and Captive Users	Total
Alabama	7	0	0	7
Alaska	0	0	0	0
Arizona	2	0	0	2
Arkansas	1	0	0	1
California	3	3	0	6
Colorado	1	2	0	3
Connecticut	0	0	0	0
Delaware	0	0	0	0
District of Columbia	0	0	0	0
Florida	1	0	0	1
Georgia	1	0	0	1
Hawaii	0	0	0	0
Idaho	1	3	0	4
Illinois	2	1	0	3
Indiana	1	1	0	2
Iowa	1	0	0	1
Kansas	0	0	0	0
Kentucky	2	0	0	2
Louisiana	2	0	0	2
Maine	0	0	0	0
Maryland	0	0	0	0
Massachusetts	1	0	1	2
Michigan	2	6	0	8
Minnesota	0	4	0	4
Mississippi	0	1	0	1
Missouri	2	0	1	3
Montana	1	2	0	3
Nebraska	0	3	0	3
Nevada	1	2	0	3
New Hampshire	0	0	0	0
New Jersey	0	0	0	0
New Mexico	1	0	0	1
New York	0	0	0	0
North Carolina	0	0	0	0
North Dakota	0	3	0	3
Ohio	6	2	2	10
Oklahoma	1	0	0	1
Oregon	1	1	0	2
Pennsylvania	6	0	1	7

(continued)

TABLE 4-2. NUMBER OF LIME MANUFACTURING FACILITIES BY STATE (CONTINUED)

State	Number of Commercial Facilities	Number of Captive Supply Facilities	Number of Facilities Supplying Both Commercial and Captive Users	Total
Puerto Rico	1	0	0	1
Rhode Island	0	0	0	0
South Carolina	1	0	0	1
South Dakota	0	0	0	0
Tennessee	1	1	0	2
Texas	5	1	0	6
Utah	2	0	0	2
Vermont	0	0	0	0
Virginia	5	1	0	6
Washington	0	1	1	2
West Virginia	1	0	0	1
Wisconsin	4	0	0	4
Wyoming	1	3	0	4
Totals	68	41	6	115

Source: U.S. Department of the Interior, U.S. Geological Survey. 2000. 1999 Directory of Lime Plants in the United States. Mineral Industry Surveys. Reston, VA. <http://minerals.usgs.gov/minerals/pubs/commodity/lime/index.html#myb>.

4.1.3 Captive Supply Lime Facilities

Michigan has the largest number of captive supply lime facilities, with six. Minnesota has four captive lime producers. California, Idaho, Nebraska, North Dakota, and Wyoming have three captive facilities each.

Table 4-1B shows the name, location, and kiln type for these plants. Captive supply lime plants are part of vertically integrated production operations that use the lime they produce as an input in the production of other goods, such as paper, steel, or beet sugar. The lime plants are generally located at the same geographic site as the production facilities for the goods the lime is used to produce. Thus, plant-level sales and employment would reflect not only lime production levels, but also production of other goods made at those sites. For this reason, we do not present graphical descriptions of plant level sales and employment for captive producers.

4.2 FIRM CHARACTERISTICS

A "facility" is a site of land with a plant and equipment that combine inputs (limestone, fuel, and labor) to produce an output (lime). Companies that own these facilities are legal business entities that conduct transactions, and make decisions that affect the facility. The terms "facility," "establishment," and "plant" are synonymous in this study, and refer to the physical location where products are manufactured. Likewise, the terms "company" and "firm" are used interchangeably to refer to the legal business entity that owns one or more facilities. This section presents information on the companies that own both the captive and commercial manufacturing plants identified in the previous section.

4.2.1 Ownership

Using information obtained from the U.S. Geological Survey (USGS), the Information Access Company (Information Access Corporation, 1997), and American Business Information (ABI, 1997), 57 companies were identified that produce lime for either commercial or captive supply purposes. Thirty-six of these companies produce lime solely for the commercial market, while 21 engage in captive production, either entirely, or in combination with some commercial production. Data on companies owning lime plants is shown in Table 4-3. Table 4-3 lists information on organization type, number of facilities, sales, employment and parent companies for the commercial producers and for captive producers.

Firms Owning Commercial Lime Producers. Twenty of the 36 commercial lime companies are owned by parent companies. The 36 commercial lime companies together

TABLE 4-3. COMPANY-LEVEL DATA FOR THE COMMERCIAL AND CAPTIVE SUPPLY LIME INDUSTRY: 2000

Company	Organization Type	Number of Facilities	Years for Financial Data	Sales ($\$10^6$)	Employment	Parent	Parent Sales ($\$10^6$)	Parent Employment
Commercial Lime Industry								
Arkansas Lime Co.	Private subsidiary	1	1999	$5–10	100	United States Lime & Minerals	31.5	205
Ash Grove Cement Co.	Private	2	1998	365	1,800	None		
Austin White Lime Co.	Private	1	1997	12	150	None		
Blue Circle Inc.	Public subsidiary	1	1999	100–500	200	Blue Circle Industries PLC	3,295.4	18,637
Chemical Lime Co.	Private subsidiary	19	1998	250	1,000	Lhoist	NA	NA
Cheney Lime & Cement Co.	Private	2	1999	15	50	None		
Con Lime Co.	Private	1	1994	7	65	None		
Cutler-Magner Co.	Private	1	1999	10–25	75	None		
Detroit Lime, Inc.	Private subsidiary	1	1999	10–20	50	Carmeuse Lime Inc. (subsidiary of Carmeuse Chimie Minerale of Belgium)	240	1,200
Dravo Lime, Inc.	Private subsidiary	4	NA	NA	NA	Carmeuse Lime Inc. (subsidiary of Carmeuse Chimie Minerale of Belgium)	240	1,200
Falco Lime, Inc.	Private	1	1999	20–50	65	None		
Florida Crushed Stone Co.	Private	1	1998	97	600	None		
Genlime Inc.	Private subsidiary	1	1999	NA	NA	Graymont Ltd.[a]	203.7	1,000
Global Stone Co. (Global Stone James River)	Private subsidiary	5	1999	20	109	Carmeuse Lime Inc. (subsidiary of Carmeuse Chimie Minerale of Belgium)	240	1,200
Graybec Lime, Inc.	Private subsidiary	1	1999	25.2	230	Graymont Ltd.	203.7	1,000
Greer Lime Co.	Private subsidiary	1	1998	NA	NA	Greer Industries Inc.	150	650
Huron Lime Co.	Private	1	1999	35	35	None		
Linwood Mining & Minerals Corp.	Private subsidiary	1	1999	20–50	100	McCarthy Bush Corp.	50.3	300
Marblehead Lime, Inc.	Private subsidiary	3	1999	>500	NA	Carmeuse Lime Inc. (subsidiary of Carmeuse Chimie Minerale of Belgium)	240	1,200
Mercer Lime and Stone Co.	Private susidiary	1	1999	14	62	Star Group, Inc.	22.2	80
Millersville Lime, Inc.	Private subsidiary	1	1999	NA	100	Carmeuse Lime Inc. (subsidiary of Carmeuse Chimie Minerale of Belgium)	240	1,200

(continued)

TABLE 4-3. COMPANY-LEVEL DATA FOR THE COMMERCIAL AND CAPTIVE SUPPLY LIME INDUSTRY: 2000 (CONTINUED)

Company	Organization Type	Number of Facilities	Years for Financial Data	Sales ($\$10^6$)	Employment	Parent	Parent Sales ($\$10^6$)	Parent Employment
Commercial Lime Industry (cont)								
National Lime & Stone Co.	Private	1	1999	50	400	None		
Ohio Lime, Inc.	Private subsidiary	1	1999	5–10	50	Carmeuse Lime Inc. (subsidiary of Carmeuse Chimie Minerale of Belgium)	240	1,200
Palmetto Lime LLC	Subsidiary	1	NA	NA	NA	SCANA Corporation	1,650	5,488
Pennsylvania Lime, Inc.	Private subsidiary	2	NA	NA	NA	Carmeuse Lime Inc. (subsidiary of Carmeuse Chimie Minerale of Belgium)	240	1,200
Pete Lien & Sons, Inc.	Private	2	1999	65.8	350	None		
Puerto Rican Cement Co., Inc.	Public	1	1999	173.3	1,053	None		
Rockwell Lime Co.	Private	1	1999	8.2	48	None		
San Antonio Lime, Inc.	Private subsidiary	1	NA	NA	NA	Carmeuse Lime Inc. (subsidiary of Carmeuse Chimie Minerale of Belgium)	240	1,200
Shen-Valley Lime Corp.	Private	1	1999	1–2.5	2	None		
Southdown Corp.	Private subsidiary	1	1999	20–50	40	Southdown, Inc	203.2	4,100
Texas Lime Co.	Private subsidiary	1	1999	20–50	80	United States Lime & Minerals	31.5	205
USG Corp.	Public	1	1999	36,000	143,000	None		
Vulcan Materials Co.	Public	2	1999	2,355.8	9,245	None		
Western Lime Corp.	Private	2	1999	35.5	92	None		
Wyoming Lime Producers	Private subsidiary	1	1999	2.5–5	13	Basin Electric Power Cooperative	757.3	1,661
Captive Supply Lime Industry								
The Amalgamated Sugar Co.	Cooperative	4	1999	250	3,000	None		
American Crystal Sugar Co.	Cooperative	5	1999	844.4	1,292	None		
Baker Refractories Co.	Private	1	1999	10–20	110	None		
Bowater Southern Paper Corp.	Private	1	1999	NA	1,225	None		
Continental Lime Inc.	Private subsidiary	4[b]	1999	12	202	Graymont Ltd.	203.7	1,000

(continued)

TABLE 4-3. COMPANY-LEVEL DATA FOR THE COMMERCIAL AND CAPTIVE SUPPLY LIME INDUSTRY: 2000 (CONTINUED)

Company	Organization Type	Number of Facilities	Years for Financial Data	Sales ($\$10^6$)	Employment	Parent	Parent Sales ($\$10^6$)	Parent Employment
Captive Supply Lime Industry (cont)								
The Dow Chemical Co.	Public	1	1999	18,929	39,239	None		
Elkem Metals Co.	Subsidiary	1	1999	400	1,300	Elkem Holdings Inc. (subsidiary of Elkem ASA, Noraway)	420	1,300
The Great Lakes Sugar Co.	Private subsidiary	1	1999	NA	19	Imperial Sugar Company	1,888.6	3,800
Holly Sugar Corp.	Private subsidiary	8	1999	460	1,200	Imperial Sugar Company	1,888.6	3,800
Ispat Inland, Inc.	Private subsidiary	1	1999	1,075.4	8,200	Ispat International NV, Netherlands	NA	NA
LTV Steel	Private subsidiary	1	1999	4,280	14,000	LTV Corporation	4,270	14,800
Martin Marietta Mag. Specialties, Inc.	Private subsidiary	1	1999	NA	NA	Martin Marietta Materials, Inc.	6,100	1,258.8
Michigan Sugar Co.	Private subsidiary	4	1999	200	1,200	Imperial Sugar Company	1,888.6	3,800
Minn-Dak Farmers Coop.	Private	1	1999	136.5	480	None		
Mississippi Lime Co.	Private	1	1998	80–99	900	None		
Monitor Sugar Co.	Private subsidiary	1	1999	75	660	Sucre Holding Inc.	76	660
Northwest Alloys, Inc.	Private subsidiary	1	1999	70	349	Alcoa Inc.	16,323	127,000
Riverton Corp.	Private	1	1999	14	150	None		
Southern Minnesota Sugar Corp.	Private	1	1999	135	500	None		
Specialty Minerals, Inc.	Public subsidiary	1	1999	1,150	429	Minerals Technologies Inc.	637.5	2,236
Western Sugar Co.	Private subsidiary	7	1999	400	2,500	Tate and Lyle Inc.	6,326	22,000

[a] Sales and employment data for Graymont Ltd. are from 1993.

[b] Continental Lime Inc. has one captive plant and three commercial plants. The sales and employment figures here are the totals for all four facilities.

Sources: National Register Publishing. 1999 Directory of Corporate Affiliations. Volume 4. U.S. Private Companies. "Who Owns Whom." New Providence, NJ: Reed Elsevier Inc. 1999.
Gale Group. Ward's Business Directory of U.S. Private and Public Companies. Volume 1. Detroit: Gale Group. 1999.
Dun & Bradstreet, Inc. D&B Business Rankings 2000. Bethlehem, PA: Dun & Bradstreet. 2000.
The McGraw-Hill Companies, Inc. Standard & Poor's Register of Corporations. Volume 1. Charlottesville, VA: The McGraw-Hill Companies, Inc. 2000.
Lycos Small Business. <http://www.companiesonline.com>.
Hoover's Online. <http://www.hoovers.com/>.
Reference USA. 2000. InfoUSA Resource. <http://reference.infousa.com>.

operate a total of 72 facilities. Most of these companies (26) operate single facilities. Eleven companies operate between two and five facilities. The Chemical Lime Company owns by far the largest number of facilities devoted to commercial lime production. This company owns 19 facilities, either directly or through their subsidiary, Chemical Lime Southwest Inc. Of the commercial companies for which data are available, only four are owned by publicly held corporations. Twenty-eight are either private companies or private subsidiaries.

Firms Owning Captive Lime Producers. According to the available data, 12 of the 21 companies owning captive producing lime facilities are owned by parent companies. The 21 captive lime producers operate a total of 47 facilities. Sixteen of these companies operate single facilities. Ownership in the captive supply lime industry is somewhat more complicated than for the commercial industry. The Holly Sugar Company, which is a subsidiary of Imperial Holly, operates seven facilities. Imperial Holly also controls the Spreckels Sugar Company, a one-facility company in Woodland, CA. Thus, Imperial Holly is responsible for the operations of eight facilities. Savannah Foods and Industries (SFI) exhibits a similar relationship between parent and subsidiaries. Great Lakes Sugar Company, which operates one plant, is a wholly-owned subsidiary of the Michigan Sugar Company. The Michigan Sugar Company, which operates four plants of its own, is a subsidiary of Savannah Foods and Industries (SFI). SFI, therefore, operates a total of five captive supply lime plants. The two other large captive supply lime companies are the Amalgamated Sugar Company with four plants, and American Crystal Sugar with five plants. Sixteen of the captive facilities for which data are available are operated by either private companies or private subsidiaries. One is publicly held, and two are cooperatives.

4.2.2 Size Distribution

This section examines the size of the companies owning lime producers, where size is defined in terms of company sales and employment. Data are incomplete for many of these companies, because they are subsidiaries and privately held. Thus, many of the traditional financial databases do not provide data on them. The size characterizations provided below are defined in terms of annual sales and employment, based on available data. According to both measures, companies owning lime plants tend to be relatively small.

Company Sales. The available information on sales for companies owning commercial lime producers is shown in Table 4-3. As indicated, these data represent annual sales for years ranging from 1994 to 1999. Of the 29 companies with sales data, eleven had annual sales less than $20 million. Another nine had sales between $20 million and $50 million. Thus, more than half of the companies had sales less than $50 million. The two commercial producers with the highest annual sales, USG Corporation and Vulcan Materials Company, each had sales in excess of $1 billion in 1999.

Company Employment. Employment data for companies owning commercial lime facilities are also shown in Table 4-3. Of the 29 companies with data, 17 employ 100 or fewer workers. Twenty-three companies are reported to have fewer than 500 employees.

4.2.3 Horizontal and Vertical Integration

Companies that are vertically or horizontally integrated may have market power, because they control supplies of critical inputs or because they provide a larger share of market supply.

The Concise McGraw-Hill Dictionary of Modern Economics provides the following definition of horizontal integration: "The situation existing in a firm whose products or services are competitive with each other. The term also applies to the expansion of a firm into the production of new products that are competitive with older ones. Horizontal integration may be the result of a merger of competing firms in the same market, or involve expansion of a firm from its original base to a wider area, as in the case in the growth of retail chains. The advantages of horizontal integration stem primarily from economies of large-scale management, large-scale buying from suppliers, and large-scale distribution. Horizontal integration may result in a monopoly in a particular market" (Greenwald, 1984).

According to this definition, there is some evidence of horizontal integration among both the commercial and captive lime producers. Among commercial producers, there are 11 companies that operate more than one facility. Five of the captive producers operate more than a single facility.

The definition of vertical integration is somewhat more straightforward. A vertically integrated company produces inputs to be used in its own production process. A company that has undergone complete vertical integration would be involved in all stages of production from the processing of the raw materials through the distribution of the final product (Greenwald, 1984). Operators of captive supply facilities are by definition vertically integrated. They produce their own lime to be used as an input in the manufacture of a product such as beet sugar or aluminum. Commercial lime producers are generally vertically integrated as well. They own and operate limestone mines to supply kiln feed for the manufacture of lime.

4.3 SMALL BUSINESSES THAT OWN LIME FACILITIES

To determine the possible impacts on small businesses, both captive and commercial supply companies are categorized as small or large using the Small Business Administration's (SBA) general size standard definitions (SBA, 1998). For commercial lime firms, a small company has 500 or fewer employees. For captive supply companies that are beet sugar or pulp and paper producers, small is defined as having 750 or fewer employees. For captive suppliers that are steel companies, small is defined as having 1,000 or fewer employees.

Table 4-4 lists the employment and sales data for the small companies that are owners of lime-producing facilities. Data on employment and sales for many of these companies is

TABLE 4-4. CHARACTERISTICS OF SMALL BUSINESSES IN THE LIME INDUSTRY

Company	Organization Type	Number of Facilities	Sales ($\$10^6$)	Employment
Commercial Suppliers				
Austin White Lime Co.	Private	1	12	150
Cheney Lime & Cement Co.	Private	2	15	50
Con Lime Co.	Private	1	7	65
Cutler Magner Co.	Private	1	$17.5	75
Falco Lime, Inc.	Private	1	35	65
Huron Lime Co.	Private	1	35	35
McCarthy Bush Corp.	Private	1	50.3	300
National Lime & Stone Co.	Private	1	50	400
Pete Lien & Sons, Inc.	Private	2	65.8	350
Rockwell Lime Co.	Private	1	8.2	48
Shen-Valley Lime Corp.	Private	1	1.8	2
Star Group Corp.	Private	1	22.2	80
United States Lime & Minerals	Private	2	31.5	205
Western Lime Corp.	Private	2	35.5	92
Captive Suppliers				
Baker Refractories Co.	Private	1	15	110
Minn-Dak Farmers Coop.	Private	1	136.5	480
Riverton Corp.	Private	1	14	150
Southern Minnesota Sugar Corp.	Private	1	135	500
Sucre Holding Inc.	Private	1	76	660

Sources: National Register Publishing. 1999 Directory of Corporate Affiliations. Volume 4. U.S. Private Companies. "Who Owns Whom." New Providence, New Jersey: Reed Elsevier Inc. 1999.
Gale Group. Ward's Business Directory of U.S. Private and Public Companies. Volume 1. Detroit: Gale Group. 1999.
Dun & Bradstreet, Inc. D&B Business Rankings 2000. Bethlehem, PA: Dun & Bradstreet. 2000.
The McGraw-Hill Companies, Inc. Standard & Poor's Register of Corporations. Volume 1. Charlottesville, VA: The McGraw-Hill Companies, Inc. 2000.
Lycos Small Business. <http://www.companiesonline.com>.
Hoover's Online. <http://www.hoovers.com/>.
Reference USA. 2000. InfoUSA Resource. <http://reference.infousa.com>.

difficult to acquire, because they are privately held. However, the National Lime Association and the Beet Sugar Development Foundation have provided EPA with lists of their members that qualify as small businesses under the above criteria. Fourteen companies owning commercial lime plants are small companies, while five companies owning captive lime plants are small. These are shown in Table 4-4.

4.4 INDUSTRY CONCENTRATION AND MARKET STRUCTURE

Market structure, which characterizes the level and type of competition among lime producers, determines the behavior of producers and consumers in the industry, including their power to influence market price. If an industry is perfectly competitive, then individual producers have little market power; they are not able to influence the price of the outputs they sell or the inputs they purchase. Perfectly competitive industries have a large number of firms, the products sold are undifferentiated, and the entry and exit of firms is unrestricted.

Conversely, imperfectly competitive industries or markets are characterized by a smaller number of firms, differentiated products and restricted entry or exit. Product differentiation can occur both from differences in product attributes and quality and from brand name recognition of products. Entry and exit of firms are restricted in industries when government regulates entry through licenses or permits, etc.), when one firm holds a patent on a product or production technology, when one firm owns the entire stock of a critical input, or when a single firm is able to supply the entire market.

When compared across industries, firms in industries with fewer firms, more product differentiation, and restricted entry are more likely to have the power to influence the price they receive for a product by reducing output below perfectly competitive levels. Having this ability to influence price is referred to as exerting market power. At the extreme, a single monopolistic firm may supply the entire market and hence set the price of the output. On the input market side, firms may be able to influence the price they pay for an input if few firms, both from within and outside the industry, use that input. At the extreme, a single monopsonist firm may purchase the entire supply of the input and hence set the price of the input.

4.4.1 Measures of Industry Concentration

To assess the competitiveness of an industry, economists often estimate four-firm concentration ratios (CR4), eight-firm concentration ratios (CR8), and Herfindahl-Hirschmann indexes (HHI) for the subject market or industry. The CR4s and CR8s measure the percentage of sales accounted for by the top four and eight firms in the industry. The HHIs are the sums of the squared market shares of firms in the industry. Table 4-5 shows concentration ratios for the lime industry.

TABLE 4-5. MARKET CONCENTRATION MEASURES FOR SIC 3274 LIME MANUFACTURING: 1992

Measure	Value
Herfindahl-Hirschmann Index (HHI)	693
Four-firm concentration ratio (CR4)	46
Eight-firm concentration ratio (CR8)	61
Number of companies	57
Number of facilities	88
Value of shipments	$903.7 million

Sources: U.S. Department of Commerce, Bureau of the Census. Concentration Ratios in Manufacturing. Washington, DC, Government Printing Office. 1993a.
U.S. Department of Commerce, Bureau of the Census. 1992 Census of Manufactures. Washington, DC, Government Printing Office. 1993b.
U.S. Department of Justice and the Federal Trade Commission. Horizontal Merger Guidelines. April 8, 1992. <http://www.ftc.gov/bc/docs/horizmer.htm>.

Unfortunately, there is no objective criterion for determining market structure based on the values of these concentration ratios. However, there are criteria for determining market structure based on the HHIs for use in merger analyses, which are provided in the 1992 Department of Justice's Horizontal Merger Guidelines (U.S. Department of Justice and the Federal Trade Commission, 1992). According to these criteria, industries with HHIs below 1,000 are considered unconcentrated (i.e., more competitive), those with HHIs between 1,000 and 1,800 are considered moderately concentrated (i.e., moderately competitive), and those with HHIs above 1,800 are considered highly concentrated (i.e., less competitive). Firms in less-concentrated industries are more likely to be price takers, while firms in more-concentrated industries are more likely to be able to influence market prices. These measures of market concentration can be computed by four-digit SIC codes based on U.S. Bureau of the Census data (U.S. Department of Commerce, 1993a). Based on the HHI criteria, the lime industry is not concentrated. These indices are measures of concentration of the industry at the national level. There is reason to believe, however, that the markets for lime may be regional rather than national.

4.4.2 Market Structure

As noted above, lime producers can be broadly characterized as captive and commercial. This discussion deals only with the commercial market for lime. Captive lime producers produce lime that is used by other operations within the same company, frequently at the same plant location. Most captive lime producers are owned by companies that produce either iron and steel or beet sugar. The lime produced by captive lime plants is not marketed. The only markets associated with captive lime production are those for the products the lime is used to produce (such as steel, or beet sugar). While an important input, the cost of lime production is small enough relative to the total cost of production of the final goods (lime costs generally represent less than 5 percent of the value of shipments of beet sugar or iron and steel) that changes in the cost of lime production resulting from this regulation are not likely to have significant influence on the markets for those products. Thus, the analysis of market structure will focus on the structure of the commercial market for lime.

The structure of the commercial market for lime is affected by the physical characteristics of lime. Because lime is heavy and bulky, it is difficult and costly to transport. The heaviness and bulkiness of the limestone input has resulted in many lime plants being located at or near limestone quarries, and the heaviness and bulkiness of lime means that most customers for lime tend to buy from the lime manufacturer nearest to them. Most lime is priced f.o.b. the lime plant, and the customer must pay to have the lime shipped to his location. Because of lime is heavy and bulky, it is costly to transport. This restricts the geographical extent of each plant's market. Most customers of commercial lime plants are located within a few hundred miles of the plant (Miller, 1997c).

Thus, the market for lime is not national or international; instead, it is regional or local. In other words, a lime producer does not compete with all the other lime producers in the country, but only with the ones located near his plant. While there are exceptions in the case of particular lime customers or specialized types of lime products, most lime is sold in regional markets to customers that are nearby.

Within a regional market, each lime producer has only a limited number of competitors. This means that the individual regional markets for lime may be characterized by imperfect competition (either monopoly or oligopoly), although this is not necessarily so. For an undifferentiated product, there may be enough competition on price from just a few producers that the markets are competitive. In addition, producers may keep prices below monopoly levels to forestall new entry into the market.

In imperfectly competitive markets, producers have market power that enables them to affect the price of their commodity. Monopolists set their production and price to maximize their profits. Oligopolistic producers are aware of their competitors and determine their price and quantity based on their expectations of how their competitors will behave. In both market structures, the market price is higher and the quantity traded lower than would be the case in a perfectly competitive market.

4.5 CURRENT TRENDS IN THE LIME INDUSTRY

In 1999, the U.S. lime industry overall operated at 76 percent of capacity, down from a rate of 79 percent the previous year (Miller, 1999c). Rates of capacity utilization ranged between about 65 percent and 88 percent depending on region. Plants in the Western Midwest (including Illinois, Indiana, Iowa, Missouri and Wisconsin) operated at the lowest percent of capacity (about 65 percent), while plants in the Eastern Midwest (including Michigan, northern Kentucky, Ohio and western Pennsylvania) operated at the highest capacity (approximately 88 percent) (Miller, 1997a). Capacity utilization would be slightly lower if the capacity of several idle or moth-balled plants were factored into the calculations.

Between 1995 and 1999 the lime industry increased capacity more than it increased production, leading to the decline in the rate of capacity utilization during that period. In 1995, Chemical Lime Company constructed a new plant at St. Genevieve, MO, and both Dravo Lime and Greer Lime increased their capacities. Together, these expansions created an additional 1,510,000 tons (1,665,000 short tons) of capacity for the industry. Expansion of existing facilities continued in 1996, adding another 1,000,000 tons (1,100,000 short tons) of capacity. During this period, the expansion was only partially offset by the closing of two Marblehead Lime Company plants in Illinois and Michigan. These plants had a combined capacity of 557,000 tons (614,000 short tons) (U.S. Department of the Interior, 1997). There has been rapid consolidation in the industry over the past few years with accompanying renovations, closings, and expansion of several plants.

4.6 SUMMARY

Lime producers may be subdivided into two broad categories: commercial producers and captive producers. Commercial lime producers specialize in lime manufacturing. They may be vertically integrated with limestone quarrying operations, and their outputs are quick lime and hydrated lime, which they market to customers generally located within a few hundred miles of their plant. Captive lime producers are parts of vertically integrated manufacturing operations that use lime to produce paper, iron and steel, or beet sugar. The lime they produce is not sold, but is used internally by the same firm.

Companies owning lime production plants are generally private and relatively small. Thirteen companies owning commercial lime manufacturing plants are considered "small entities," based on the Small Business Administration company size definition for SIC 3274 (NAICS 327410), Lime Manufacturing. Three companies owning captive lime plants are considered small, according to the criterion for beet sugar producers.

While national measures of industry concentration do not suggest that lime manufacturing is concentrated, EPA believes that commercial lime manufacturers may have the ability to affect the price for their commodity (have market power), because the markets for lime are regional, and the number of competitors facing each lime producer is therefore limited.

SECTION 5
MARKETS

This section provides information on the markets for lime. Quicklime, hydrated lime, and dead-burned dolomitic lime have different characteristics and uses and separate markets. In addition, the markets for lime are believed to be regional as opposed to national or international, because lime is heavy relative to its value and costly to transport. According to M. Michael Miller (1997d), U.S. Geological Survey's lime expert, most lime is consumed within a few hundred miles of where it is produced.

5.1 HISTORICAL MARKET DATA

This section provides data on historical quantities of each type of lime produced and consumed in the U.S., the quantities imported and exported, and prices.

5.1.1 Domestic Production

Figure 5-1 illustrates the quantities of domestically produced quicklime, hydrated lime, and dead-burned dolomitic lime from 1971 through 1999. The data used to create this graph are also presented in the first four columns of Table 5-1. Prior to 1996, quicklime, which makes up approximately 80 percent of domestically produced lime, reached a peak in production of over 16 million metric tons in 1974. Between 1975 and 1981, production of quicklime fluctuated between 14.4 and 15.9 million metric tons. In 1982, production dropped considerably to about 10.6 million metric tons and did not begin to increase steadily

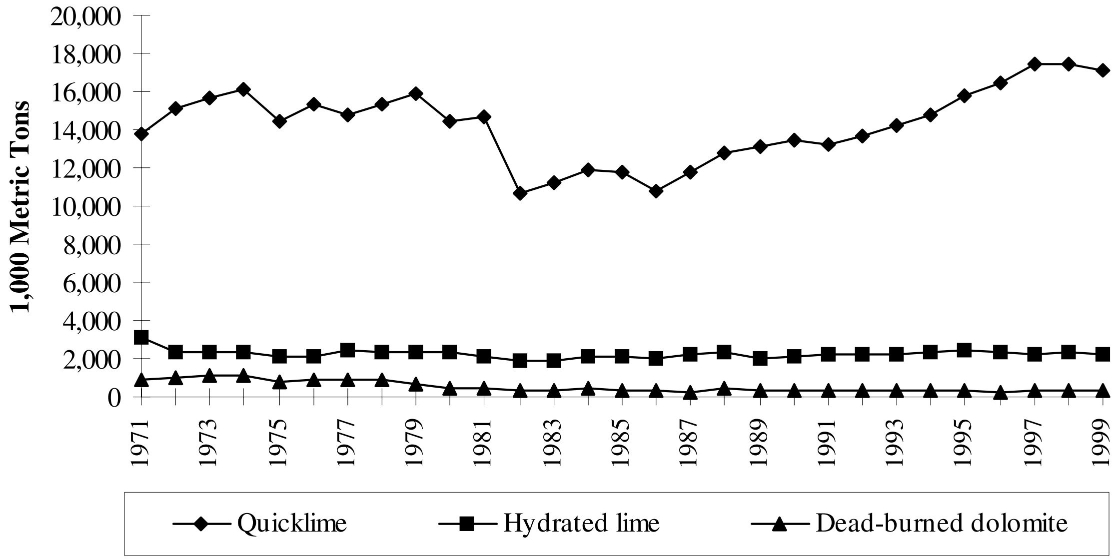

Figure 5-1. Production of lime: 1971-1999.

Sources: Miller, M.M. Minerals Information: Lime Statistical Compendium. Reston, VA, U.S. Department of the Interior, U.S. Geological Survey. April 15, 1996.
Miller, M.M. Minerals Information: Lime. Reston, VA, U.S. Department of the Interior, U.S. Geological Survey. 1994a.
Miller, M.M. Minerals Information: Lime. Reston, VA, U.S. Department of the Interior, U.S. Geological Survey. 1995a.
Miller, M.M. Minerals Information: Lime. Reston, VA, U.S. Department of the Interior, U.S. Geological Survey. 1996b.
Miller, M.M. Minerals Information: Lime. Reston, VA, U.S. Department of the Interior, U.S. Geological Survey. 1999a. <http//minerals.usgs.gov/minerals/pubs/commodity/lime/390499.pdf>.

until after 1986. In 1996, quicklime production exceeded its 1974 level and continued to grow to over 17 million metric tons in 1999.

In 1971, the quantity of hydrated lime produced was just over 3 million metric tons. The following year, production fell to about 2.4 million metric tons and, through 1996, has remained steady at almost 2 million metric tons per year. The U.S. produces extremely small quantities of dead-burned dolomite, and the quantity has been declining. Like quicklime, 1974 was a year of peak production for dead-burned dolomite. In that year, production

TABLE 5-1. PRODUCTION, CAPTIVE SUPPLY USE, AND APPARENT CONSUMPTION OF LIME: 1971-1999 (10^3 METRIC TONS)[a]

	Sold or Used by Producers by Type			Combined Types			
Year	Quicklime	Hydrated Lime	Dead-Burned Dolomite	Lime Sold	Lime Used	Total Lime Sold and Used[b]	Apparent Consumption[c]
1971	13,733	3,126	914	11,192	6,581	17,773	17,932
1972	15,069	2,362	975	12,114	6,293	18,407	18,597
1973	15,631	2,368	1,134	13,058	6,075	19,133	19,402
1974	16,143	2,298	1,159	13,281	6,319	19,601	19,949
1975	14,402	2,126	829	11,648	5,708	17,357	17,543
1976	15,353	2,085	914	12,722	5,629	18,351	18,632
1977	14,770	2,448	878	12,884	5,211	18,096	18,449
1978	15,282	2,342	922	13,664	4,882	18,546	19,058
1979	15,924	2,358	719	13,992	5,009	19,001	19,541
1980	14,490	2,308	448	12,527	4,718	17,246	17,643
1981	14,644	2,067	395	12,946	4,159	17,106	17,538
1982	10,615	1,848	306	9,848	2,920	12,769	13,063
1983	11,234	1,874	379	10,962	2,526	13,487	13,718
1984	11,915	2,088	442	11,851	2,593	14,444	14,646
1985	11,791	2,099	343	12,164	2,069	14,234	14,393
1986	10,750	1,995	385	10,974	2,156	13,131	13,298
1987	11,774	2,239	259	11,889	2,384	14,273	14,422

(continued)

TABLE 5-1. PRODUCTION, CAPTIVE SUPPLY USE, AND APPARENT CONSUMPTION OF LIME: 1971-1999 (10^3 METRIC TONS)[a] (CONTINUED)

	Sold or Used by Producers by Type			Combined Types			
Year	Quicklime	Hydrated Lime	Dead-Burned Dolomite	Lime Sold	Lime Used	Total Lime Sold and Used[b]	Apparent Consumption[c]
1988	12,760	2,296	413	13,368	2,102	15,469	15,647
1989	13,154	2,040	365	13,622	1,937	15,560	15,728
1990	13,392	2,098	342	14,014	1,818	15,832	15,949
1991	13,200	2,170	308	13,800	1,820	15,700	15,800
1992	13,700	2,230	302	14,300	1,890	16,200	16,300
1993	14,200	2,250	315	14,900	1,870	16,700	16,900
1994	14,800	2,290	300	15,500	1,910	17,400	17,500
1995	15,800	2,390	308	16,400	2,180	18,500	18,700
1996	16,500	2,280	271	16,900	2,170	19,100	19,300
1997	17,300	2,170	300	17,300	2,400	19,700	19,894
1998	17,500	2,340	300	17,800	2,310	20,110	20,285
1999	17,100	2,210	300	17,300	2,310	19,610	19,703

[a] Data do not include regenerated lime.
[b] Data may not add to totals due to rounding.
[c] Apparent consumption is calculated as sold or used plus imports minus exports.

Sources: Miller, M.M. Minerals Information: Lime Statistical Compendium. Reston, VA, U.S. Department of the Interior, U.S. Geological Survey. April 15, 1996.
Miller, M.M. Minerals Information: Lime. Reston, VA, U.S. Department of the Interior, U.S. Geological Survey. 1994a.
Miller, M.M. Minerals Information: Lime. Reston, VA, U.S. Department of the Interior, U.S. Geological Survey. 1995a.
Miller, M.M. Minerals Information: Lime. Reston, VA, U.S. Department of the Interior, U.S. Geological Survey. 1996.
Miller, M.M. Minerals Information: Lime. Reston, VA, U.S. Department of the Interior, U.S. Geological Survey. 1999a. <http//minerals.usgs.gov/minerals/pubs/commodity/lime/390499.pdf>.

reached 1.2 million metric tons. In 1999, production of dead-burned dolomite was only 300,000 metric tons.

5.1.2 Domestic Consumption

The last column of Table 5-1 contains data on domestic consumption of all kinds of lime. Quantities in this column include the amount of lime sold, plus the amount of lime used (captive supply use), plus imports, minus exports. Levels of domestic consumption have followed levels of quicklime production. Before 1998, at nearly 20 million metric tons, consumption was at its highest level in 1998. Consumption fell sharply in 1982 and did not approach its 1974 level again until 1996. In 1998, consumption peaked above 20 million metric tons. There are no government stockpiles of lime (Miller, 1996a).

5.1.3 Domestic Prices

Average lime prices between 1971 and 1999 are presented in both current and 1999 dollars in Table 5-2. Figure 5-2 presents this information graphically. Adjusted prices (1999$) for lime range from a low of $54.88 per metric ton in 1973 to a high of $74.56 per metric ton in 1978. Between 1975 and 1987, the adjusted price never fell below $66 per metric ton. From 1988 to 1996, the price never went above $65 per metric ton.

Table 5-3 shows separate prices for quicklime, hydrated lime, and all lime for the years 1991 through 1999 in both current and 1999 dollars. During this period the price of hydrated lime averaged 26 percent higher than the price of quicklime. There was a downward trend in real lime prices during this period.

Prices for lime used by various industries in 1999 are presented in Table 5-4. Hydrated lime used in construction had the highest price—$83.33 per metric ton,

TABLE 5-2. AVERAGE LIME PRICES: 1971-1999

	Total Value[a] ($\$10^3$)	Average Value per Metric Ton (Current $)	Average Value per Metric Ton (1999$)
1971	308,100	17.39	58.70
1972	339,304	18.50	59.79
1973	365,849	19.20	54.88
1974	473,685	24.27	58.35
1975	523,805	30.27	66.67
1976	609,010	33.28	70.06
1977	666,472	36.93	73.19
1978	749,667	40.52	74.56
1979	862,459	45.48	74.33
1980	842,922	49.05	70.26
1981	884,197	51.82	68.01
1982	696,207	54.53	70.10
1983	757,611	56.33	71.52
1984	811,183	56.35	69.90
1985	809,000	56.98	71.02
1986	757,867	57.87	74.29
1987	786,125	55.24	69.12
1988	817,893	53.04	63.82
1989	852,113	54.93	62.97
1990	901,549	57.09	63.14
1991	890,000	56.69	62.59
1992	950,000	58.60	64.31
1993	965,000	57.60	62.31
1994	1,020,000	58.80	62.82
1995	1,100,000	59.20	61.06
1996	1,140,000	61.50	61.06
1997	1,200,000	61.00	62.45
1998	1,210,000	60.40	60.60
1999	1,180,000	60.10	60.10

[a] Values are selling values, f.o.b. plant, excluding costs of containers.

Sources: Miller, M.M. Minerals Information: Lime Statistical Compendium. Reston, VA, U.S. Department of the Interior, U.S. Geological Survey. April 15, 1996.
Miller, M.M. Minerals Information: Lime. Reston, VA. U.S. Department of Interior. U.S. Geological Survey. 1999a. <minerals.usgs.gov/minerals/pubs/commodity/lime/390499.pdf>.

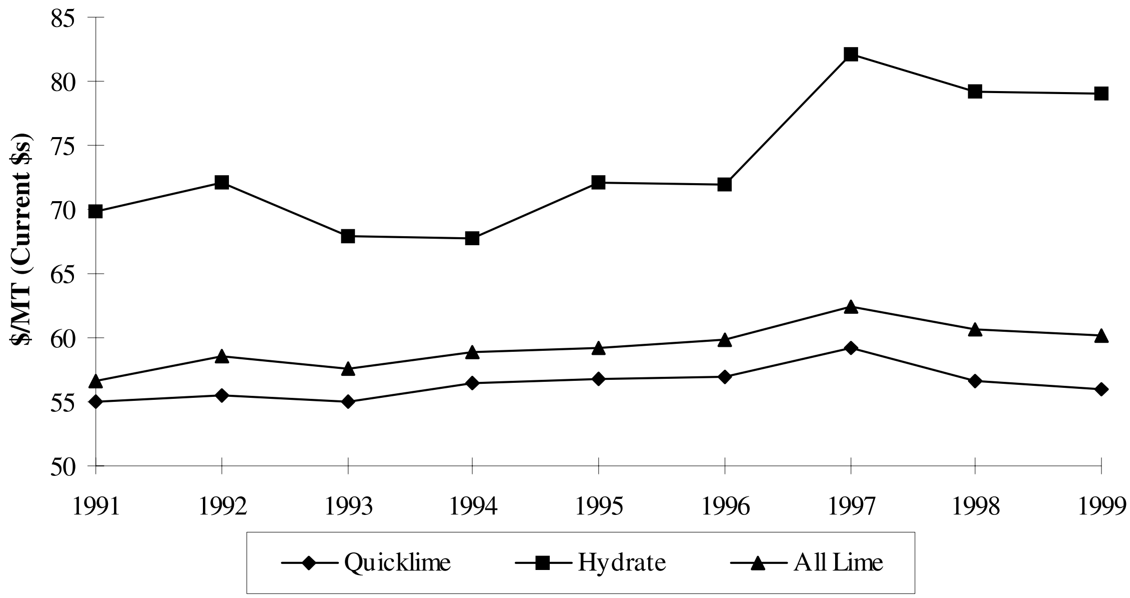

Figure 5-2. Average lime prices by type: 1991-1999.

Sources: Miller, M.M. Minerals Information: Lime. Reston, VA, U.S. Department of the Interior, U.S. Geological Survey. 1995a.
Miller, M.M. Minerals Information: Lime. Reston, VA, U.S. Department of the Interior, U.S. Geological Survey. 1996b.
Miller, M.M. Mineral Commodity Summaries: Lime. Reston, VA, U.S. Department of the Interior, U.S. Geological Survey. January 1996a.
Miller, M.M. Mineral Commodity Summaries: Lime. Reston, VA, U.S. Department of the Interior, U.S. Geological Survey. February 1997c.
Miller, M.M. Minerals Information: Lime. Reston, VA, U.S. Department of the Interior, U.S. Geological Survey. 1999a. <http//minerals.usgs.gov/minerals/pubs/commodity/lime/390499.pdf>.

and quicklime used in chemical and industry had the lowest price—$53.42 per metric ton. The average price for all lime used in all industries was $60.20 per metric ton in 1999.

5.1.4 Import Volumes

Because limestone is plentiful in the U.S., and transportation for such a heavy, bulky commodity is expensive, imports make up only a small portion of the total consumption of lime. Table 5-5 displays quantities of exports and imports, both in metric tons and as

TABLE 5-3. AVERAGE LIME PRICES FOR QUICKLIME, HYDRATE, AND TOTAL: 1991-1999
(AVERAGE VALUE PER METRIC TON)

	Quicklime		Hydrate		All Lime	
	(Current $)	(1999$)	(Current $)	(1999$)	(Current $)	(1999$)
1991	55.04	60.77	69.78	77.04	56.69	62.59
1992	55.48	60.89	72.15	79.18	58.60	64.31
1993	55.02	59.51	66.87	73.39	57.60	63.21
1994	56.43	60.28	65.91	72.33	58.80	64.53
1995	56.77	58.56	67.75	74.35	59.20	61.06
1996	56.68	58.98	79.64	82.87	59.80	62.23
1997	57.80	59.18	80.20	82.11	61.00	62.45
1998	56.40	56.59	78.90	79.16	60.40	60.60
1999	56.00	56.00	79.00	79.00	60.10	60.10

Sources: Miller, M.M. Mineral Commodity Summaries. Lime. Reston, VA, U.S. Department of Interior, U.S. Geological Survey. 2000. <http://minerals.usgs.gov/ minerals/pubs/mcs/>.
Miller, MM. Minerals Information: Lime. Reston, VA, U.S. Department of Interior, U.S. Geological Survey. 1999a. <minerals.usgs.gov/minerals/ pubs/commodity/lime/390499.pdf>

TABLE 5-4. AVERAGE VALUE OF LIME USED OR SOLD BY PRODUCERS BY TYPE AND USE: 1999[a]

	Quicklime ($/Mg)	Hydrate ($/Mg)	All Lime ($/Mg)
Chemical and Industrial Lime	53.42	78.36	60.60
Environmental Lime	56.5	74.30	56.50
Construction Lime	59.77	83.33	73.43
Agricultural Lime	82.61	—	82.61
Metallurgical	57.32	69.55	51.64
Refractory Dolomite	81.33	—	81.33
Overall Average	65.16	76.39	60.20

[a] Values are f.o.b. plant basis.

Source: Miller, M.M. Minerals Information: Lime. Reston, VA, U.S. Department of the Interior, U.S. Geological Survey. 1999a. <http://minerals.usgs.gov/minerals/pubs/commodity/lime/>.

percentages of production and consumption from 1971 through 1999. During that period, imports averaged only 1.63 percent of total consumption. In 1979, imports were at their highest, both in absolute terms and as a percentage of consumption. That year, imports were almost 3 percent of consumption.

Table 5-6 contains data on the dollar values of lime exports and imports from 1991 through 1999. During that period, imports had an average value of about 20 million dollars per year (1999$). As Table 5-7 indicates, by far, the largest proportion of trade in lime occurs with Canada. Seventy-six percent of all imported quicklime and more than 10 percent of hydrated lime come from Canada. The balance comes almost entirely from Mexico.

5.1.5 Export Volumes

Lime is produced throughout the world. China is the world's largest producer of lime, followed by the U.S. (Miller, 1996a). Because transportation costs are high and lime is plentiful elsewhere, export volumes are an even smaller proportion of production than

TABLE 5-5. EXPORTS AND IMPORTS OF LIME: 1971-1999

	Exports (10^3 metric tons)	Exports as a Percentage of Production	Imports for Consumption (10^3 metric tons)	Imports as a Percentage of Consumption
1971	60	0.34	220	1.23
1972	34	0.18	225	1.21
1973	34	0.18	303	1.56
1974	29	0.15	377	1.89
1975	49	0.28	235	1.34
1976	51	0.28	331	1.78
1977	30	0.17	384	2.08
1978	41	0.22	553	2.90
1979	41	0.22	581	2.97
1980	38	0.22	435	2.47
1981	25	0.15	457	2.61
1982	21	0.16	316	2.42
1983	25	0.19	257	1.87
1984	23	0.16	224	1.53
1985	17	0.12	176	1.22
1986	15	0.11	182	1.37
1987	12	0.08	161	1.12
1988	14	0.09	191	1.22
1989	29	0.19	198	1.26
1990	40	0.25	157	0.98
1991	47	0.3	158	1.00
1992	59	0.36	193	1.18
1993	69	0.41	201	1.19
1994	74	0.43	204	1.17
1995	72	0.39	289	1.55
1996	50	0.26	262	1.36
1997	80	0.41	274	1.39
1998	56	0.28	231	1.15
1999	60	0.29	142	0.69

Sources: Miller, M.M. Minerals Information: Lime Statistical Compendium. Reston, VA, U.S. Department of the Interior, U.S. Geological Survey. April 15, 1996.
Miller, M.M. Minerals Information: Lime. Reston, VA, U.S. Department of the Interior, U.S. Geological Survey. 1995a.
Miller, M.M. Minerals Information: Lime. Reston, VA, U.S. Department of the Interior, U.S. Geological Survey. 1996b. <http://minerals.usgs.gov/minerals/pubs/commodity/lime/390300.pdf>.

TABLE 5-6. TOTAL VALUE OF LIME EXPORTS AND IMPORTS: 1991-1999 ($$10^3$)

	Value of Exports		Value of Imports	
	(current $)	(1999$)	(current $)	(1999$)
1991	6,060	6,690	11,100	12,255
1992	7,540	8,275	15,000	16,462
1993	7,830	8,470	13,300	14,388
1994	7,800	8,333	13,100	13,995
1995	8,490	8,757	20,200	20,835
1996	5,600	5,641	19,400	19,540
1997	9,550	9,777	26,500	27,130
1998	9,110	9,140	22,700	22,776
1999	8,020	8,020	15,400	15,400

Sources: Miller, M.M. Minerals Yearbook: Lime. Reston, VA, U.S. Department of the Interior, U.S. Geological Survey. 1999b. <http://minerals.usgs.gov/minerals/pubs/commodity/lime/>.
Miller, M.M. Minerals Yearbook: Lime. Reston, VA, U.S. Department of the Interior, U.S. Geological Survey. 1998. <http://minerals.usgs.gov/minerals/pubs/commodity/lime/>.
Miller, M.M. 1996 Minerals Yearbook: Lime. Reston, VA, U.S. Department of the Interior, U.S. Geological Survey. 1997a. <http://minerals.usgs.gov/minerals/pubs/commodity/lime/>.
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Miller, M.M. Minerals Information: Lime Statistical Compendium. Reston VA, U.S. Department of Interior, U.S. Geological Survey. 1996c.

imports are of consumption, averaging only 0.23 percent from 1971 through 1999 (see Table 5-5). Lime is generally used within a 300- to 400-mile radius of where it is produced (Miller, 1997d).

The average dollar value of lime exports between 1991 and 1999 was slightly less than $8 million dollars per year (1999$). Most exported lime goes to Canada, and small amounts are exported to Jamaica and Mexico (see Table 5-7).

TABLE 5-7. VALUE OF LIME IMPORTS AND EXPORTS BY COUNTRY: 1999

	Imports[a]		Exports[b]	
	Value ($\$10^3$)	Share (%)	Value ($\$10^3$)	Share (%)
Quicklime				
Canada	11,770,000	76.5	3,140,000	55.7
Mexico			1,240,000	22
All others	143,760	0.9	180,380	3.2
Total	11,913,760	77.4	4,560,380	80.9
Hydrated lime				
Canada	1,590,000	10.3	840,000	14.9
Mexico	1,490,000	9.7	7,400	0.13
All others	198,000	12.9	227,800	4
Total	3,278,000	21.3	1,075,200	19.1
Hydraulic lime				
Canada	2,750	0.02		
Mexico	189,000	1.2		
All others				
Total	191,750	1.2		
Total all lime	15,383,510		5,635,580	

[a] Customs Value Base.
[b] F.A.S. Value Base.

Source: Miller, M.M. Minerals Yearbook: Lime. Reston, VA, U.S. Department of the Interior, U.S. Geological Survey. 1999b. <http://minerals.usgs.gov/minerals/pubs/commodity/lime/index.html#myb>.

5.2 TRENDS AND PROJECTIONS

This section summarizes trends in lime consumption for various uses and provides information about projected production and consumption.

5.2.1 Environmental Uses

Demand for lime for the flue gas desulfurization (FDG) market is expected to show strong growth in the future. On January 1, 2000, Phase II of the Clean Air Act went into effect to regulate small utility generating units. This will further increase demand for lime, since lime scrubbers are well suited for controlling emissions from these facilities. Demand for lime to be used in scrubbers for small municipal incinerators and waste to energy incinerators is also expected to increase. Some analysts predict FDG demand for lime may reach 5 million tons by 2002 (Miller, 1997a).

5.2.2 Steel

In 1999, steel production decreased 4 to 5 percent. However, demand for lime from the U.S. steel industry is expected to increase to 1998 levels. In the long run, however, technological changes in steel production may lead to decreased demand for lime from this industry (Miller, 1997a).

5.2.3 Soil Stabilization

In 1999, the amount of lime used for soil stabilization maintained its 1998 levels. The demand for lime in this market is determined by levels of highway and related construction, as well as competition from alternative products such as cement. The use of lime in asphalt paving has been decreasing, although this had previously been considered a growth market (Miller, 1997a).

5.2.4 Pulp and Paper

In 2000, demand for lime from the pulp and paper industry is projected to grow 3 percent. Growth is the result of continued effort by pulp and paper manufacturers to reduce pollution control costs.

The market for precipitated calcium carbonate (PCC) is growing. PCC is used in the production of premium-quality coated and uncoated paper. This market for lime is projected to grow 7 percent by 2003. Manufacturers of PCC are trying to expand into the groundwood paper and paper coatings market (Miller, 1997a).

5.2.5 Overall Trends

As a result of strong competition and small increases in production costs, the annual rate of per ton quicklime at an f.o.b. plant has not kept up with the rate of inflation. The larger lime companies have added more efficient kilns, financed new construction, and acquired smaller companies. Phase II of the Clean Air Act is expected to increase demand for lime for environmental purposes.

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