June 28, 2004

MEMORANDUM

To: Joe Wood, MICG/ESD/OAQPS/EPA

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SUBJECT: Use of "low-mercury" feed and fuel to reduce mercury emissions from portland cement manufacturing

**Introduction**

Mercury air emissions from portland cement manufacturing originate from the feed materials (e.g., limestone, clay, shale, sand, among others) and fuels (e.g., coal, coke, tires, oil). The relationship between the amount of mercury that goes into a portland cement manufacturing kiln from raw feed and fuel materials and the amount that is emitted has not been adequately studied to quantify the relationship. Although perhaps not a one-to-one correlation, reductions in the amount of mercury entering a portland cement manufacturing plant, specifically the kiln, will result in a reduction in mercury emissions from the plant. This memorandum examines the feasibility of reducing mercury emissions by replacing feed and fuel with materials containing less mercury ("low-mercury" feed and fuel) and estimates the relative contribution of mercury to kilns from the feed materials and from fuel.

**Replacing Existing Raw Materials with "Low-Mercury" Materials**

Information on the mercury content of limestone and other feed materials was examined in order to evaluate the feasibility of using "low-mercury" limestone and other feed materials. Several issues associated with the replacement of feed materials with typical levels of mercury with "low-mercury" feed materials were identified and are discussed below.

<u>Limestone</u>

According to the Portland Cement Association (PCA), the main ingredient in the feed materials is limestone (or other calcium carbonate sources such as shells or chalk), with smaller amounts of clay or shale and other materials such as sand and iron ore.[1] As shown in Table 1, the makeup of raw feed materials can vary widely. This variation is a result of variations in composition of mineral deposits as well as differences in formulations necessary for specific products.

Table 1. Reported Makeup of Raw Feed Materials [a]

| Source | Limestone (and other calcareous materials) | Aluminous (Clay, shale, and other) | Siliceous (sand, sandstone, other) | Ferrous (Iron ore, pyrites, millscale, other) | Other |
|---|---|---|---|---|---|
| USGS, 1998[2] | 88.0 | 8.3 | 2.3 | 1.4 | 0 |
| Trip report, 1992[3] | 80 | 20 | 0 | 0 | 0 |
| Trip report, 1992[4] | 80 | 0 | 10 | 1 | 9 |
| Bye, 1983[5] | 75-80 (77.5) | Most of the remainder of material added (22.5) [b] | 0 | 0 | 0 |
| Meade, no date[6] | 75 | 18-20 (19) | 0 | 0 | 0 |
| Average | 80 | 14 | 3 | 1 | 2 |

[a] Where a percentage was not reported for a raw material, its value was assumed to be zero. Values in parentheses are the average of a reported range.
[b] For purpose of this table, assumed aluminous content of 20 - 25 percent and an average of 22.5 percent.

Using information from the USGS and information supplied by lime manufacturing plants, the mercury content of limestone was estimated to range from about 0.01 to 0.1 ppm with an estimated average mercury content of 0.02 ppm.[7] These values are used to estimate the contribution of mercury to the kiln from feed materials (see Mercury Input to Kilns from Feed Materials). Information from the Bureau of Mines states that the mercury content of limestone ranges from 0.02 to 2.3 µg/g (1 µg/g = 1 ppm).[8] No information was found regarding how mercury levels in limestone throughout the U.S. are distributed, i.e., nothing suggests that there is a widespread distribution of "low-mercury" limestone deposits in this country.

Another barrier to the use of "low-mercury" limestone by the portland cement industry (assuming there were any such deposits available) is the cost of shipping feed materials. Limestone extracted from a quarry is typically processed at a portland cement plant that is located at or near the limestone quarry. The economics of the portland cement industry require minimal investment in transportation to be successful.[1]

Because limestone's composition varies with location, because limestone must be processed locally to be profitable, and because portland cement plants must formulate the mixture of limestone with other materials to attain the desired composition and performance characteristics of their product, access to limestone is exclusive to each portland cement plant, i.e., no plant typically can gain access to another plant's limestone. This exclusivity would preclude plants from mining from a common, "low-mercury" limestone quarry. In addition, we would expect that even an individual cement kiln's proprietary feed materials would experience significant Hg variability (i.e., within-quarry natural variability), so that even the same kiln could have trouble duplicating emissions results. See discussion below regarding the variability of mercury in a single area of oil shale.

Furthermore, for the reasons described above - the lack of information supporting the availability of "low-mercury" limestone; the high shipping costs that would be associated with transporting such limestone, assuming such limestone exists, to portland cement facilities; and the exclusivity of rights to limestone deposits - the use of a "low-mercury" limestone to reduce mercury emissions from portland cement kilns is not feasible.

Other Feed Materials

In identifying sources of mercury from feed materials in lime and cement manufacturing, the Bureau of Mines[8] identified only limestone; none of the other feed materials (e.g., clay and shale) used in the manufacture of portland cement was identified as a source of mercury. The U.S. Geological Survey reports mercury in two U.S. shale formations; however, these appear to be oil shale formations. Some fairly extensive analyses of trace element content of oil shales have been conducted. This type of shale is not optimal for cement manufacturing, and the mercury contents may not be directly useful. However, the variability of mercury contents within a single area of oil shale suggests that it may not be feasible to associate a mercury content with a particular source of shale quarried over an extended period of time. Giauque et. al.[9] analyzed shale from two individual core holes in Naval Oil Shale Reserve Number 1, located in the Green River Basin of Colorado. Mercury contents varied from 0.01 to 0.50 µg/g in core hole 15/16 and from 0.03 to 0.21 µg/g in core hole 25. In addition, significant variations were found within each of the four (hole 25) or five (hole 15/16) zones identified along the vertical dimension of the cores. Based on 280 analyses, Giauque concluded that stratigraphic mercury deposits were not uniform, as the 99 percent error limits on mean content (within these two holes) exceeded two times the mean mercury content. Studies of other shales (possibly of greater use in cement manufacturing) that would permit this level of variability determination were not identified.

Dragun and Chiasson[10] reported the following concentrations of mercury in shales and clays:

- shales and clays 0.05 - 0.51 ppmw
- black shales 0.03 - 2.8 ppmw

Consistent, reliable estimates of the mercury content of clay by location and type (e. g., kaolin, ball clay, fire clay, Fuller's earth, etc.) are not available. Data relating to the variability of mercury content in different types of clay within a deposit and between various deposits are also unavailable.

On a nationwide basis, EPA has estimated an emission factor of 7.5E-6 lb mercury emitted per ton of bricks manufactured in gas fired kilns.[11] Assuming that bricks are 100 percent clay, that all of the mercury present in the clay is emitted, that brick making clay is comparable to that used in cement manufacture, that no mercury is emitted from the fuel used to fire the brick kiln, and that EPA's emission factor for brick making is valid, this is equivalent to a mercury content of 3.75E-3 µg mercury/gram clay. This is low, both in comparison to the mercury content of coal and oil, and to the analytical detection limits achievable for mineral analysis.

Although not currently available, the U.S. Geological Service reports that "Regional databases are being developed that contain geologic and geochemical information necessary to establish environmental characteristics that affect the use of clays and clay minerals. Environmental characteristics include the nature and distribution of inorganic contaminants, such as metals and metalloids including arsenic, iron, and lead, in clay-bearing rocks. These environmental factors have the potential to affect the use of clays in natural and industrial applications." [12]

For purposes of estimating the mercury input to kilns from feed materials and given the absence of consistent, reliable estimates of the mercury content of clay or shale, the mercury content of clay and/or shale is assumed to be 3.75E-3 μg/g. As shown later (see <u>Mercury Input to Kilns from Feed Materials</u>), mercury from clay or shale does not significantly contribute to the overall mercury input to kilns and, if "low-mercury" clay and/or shale did exist, its use would not decrease mercury emissions by an appreciable amount.

The limited information on mercury concentrations in iron ore, a minor constituent of portland cement feed materials, shows that mercury may be present in trace amounts, 0.00000029 ppm to 0.0000022 ppm.[13] At these low concentrations and given the relatively small quantities of iron ore in the feed to kilns, the contribution of iron ore to mercury input to kilns is negligible. No information was found that would indicate that mercury is present in any of the other feed materials.

<u>Mercury Input to Kilns from Feed Materials</u>

Based on the makeup of raw material feed to the kiln and the mercury content of feed materials, mercury input to portland cement kilns from raw feed materials was estimated for different model kiln types (preheater, precalciner, wet, dry) and for typical clinker production rates. Total feed material input is based on an average of 1.65 tons of feed material needed to produce 1 ton of clinker.[14] The amounts of limestone, clay or shale, and other materials added as feed material are the average values taken from Table 1. Feed material amounts for each model kiln and the mercury content of feed materials are summarized in Table 2. As described earlier, the mercury content of limestone ranges from 0.01 to 0.1 μg/g and averages 0.02 μg/g. These values are used to estimate a minimum, maximum, and average mercury input from limestone. For the other feed materials, only an average or representative value is used because information on a range of concentrations was not available. As described in earlier paragraphs, the mercury content of clay fed to kilns was estimated to be 3.75E-3 μg/g. This value is used to estimate the mercury input to kilns from alumina as clay (or shale) feed materials. Because mercury is present in iron ore in trace amounts, the mercury content of iron ore was assumed to be zero. No information was found that suggests the presence of mercury in sand or other ingredients, therefore, their mercury content was also assumed to be zero. Using the amount of kiln input for each feed material and the mercury content of feed material, the amount of mercury entering the kiln from feed materials was calculated and is shown in Table 3.

## Table 2. Feed Materials and Mercury Content of Feed Materials at Model Portland Cement Kilns

| Model kiln | Clinker Production, tpy | Feed Materials Input (tpy)[a] | | | | | | Mercury Content of Feed Materials (µg/g) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Total feed material input[b] | Limestone input (80%) | Alumina, as clay/shale, input (14%) | Silica, as sand, input (3%) | Iron/ magnesium, as iron ore, input (1%) | Other materials input (2%) | Limestone Hg content [c] | Alumina(as clay/shale) Hg content [d] | Silica (as sand) Hg content [e] | Iron/ magnesium (as iron ore) Hg content [f] | Other materials Hg content [e] |
| Preheater | 600,000 | 990,000 | 792,000 | 138,600 | 29,700 | 9,900 | 19,800 | | | | | |
| (min) | | | | | | | | 0.01 | 0.00375 | 0 | 0 | 0 |
| (avg) | | | | | | | | 0.02 | 0.00375 | 0 | 0 | 0 |
| (max) | | | | | | | | 0.1 | 0.00375 | 0 | 0 | 0 |
| Precalciner | 1,200,000 | 1,980,000 | 1,584,000 | 277,200 | 59,400 | 19,800 | 39,600 | | | | | |
| (min) | | | | | | | | 0.01 | 0.00375 | 0 | 0 | 0 |
| (avg) | | | | | | | | 0.02 | 0.00375 | 0 | 0 | 0 |
| (max) | | | | | | | | 0.1 | 0.00375 | 0 | 0 | 0 |
| Wet | 600,000 | 990,000 | 792,000 | 138,600 | 29,700 | 9,900 | 19,800 | | | | | |
| (min) | | | | | | | | 0.01 | 0.00375 | 0 | 0 | 0 |
| (avg) | | | | | | | | 0.02 | 0.00375 | 0 | 0 | 0 |
| (max) | | | | | | | | 0.1 | 0.00375 | 0 | 0 | 0 |
| Dry | 300,000 | 495,000 | 396,000 | 69,300 | 14,850 | 4,950 | 9,900 | | | | | |
| (min) | | | | | | | | 0.01 | 0.00375 | 0 | 0 | 0 |
| (avg) | | | | | | | | 0.02 | 0.00375 | 0 | 0 | 0 |
| (max) | | | | | | | | 0.1 | 0.00375 | 0 | 0 | 0 |

[a] Source of feed materials proportions: see Table 1.
[b] Total feed materials input to kiln is 1.65 times the amount of clinker produced.[14]
[c] Minimum, maximum, and average concentration of mercury in limestone from Reference 7. (See discussion under Limestone.)
[d] Estimated mercury content of alumina (as clay or shale) based on mercury content of clay used in brick manufacturing[11]; no range of values available. (See discussion under Other Feed Materials.)
[e] No information supporting Hg in these materials; zero used for calculations.
[f] Trace amounts Hg (0.00000029 ppm - 0.0000022 ppm) have been reported in iron ore.[13] Zero used for calculations.

Table 3. Mercury Input to Kilns from Feed Materials

| Model kiln | Clinker Production, tpy | Mercury Input to Kilns from Feed Materials (lb/yr) | | | | | |
|---|---|---|---|---|---|---|---|
| | | Hg input from limestone | Hg input from clay/shale | Hg input from sand | Hg input from iron ore | Hg input from other materials | Total Hg input from feed materials |
| Preheater | 600,000 | | | | | | |
| (min) | | 15.84 | 1.04 | 0.00 | 0.00 | 0.00 | 16.88 |
| (avg) | | 31.68 | 1.04 | 0.00 | 0.00 | 0.00 | 32.72 |
| (max) | | 158.40 | 1.04 | 0.00 | 0.00 | 0.00 | 159.44 |
| Precalciner | 1,200,000 | | | | | | |
| (min) | | 31.68 | 2.08 | 0.00 | 0.00 | 0.00 | 33.76 |
| (avg) | | 63.36 | 2.08 | 0.00 | 0.00 | 0.00 | 65.44 |
| (max) | | 316.80 | 2.08 | 0.00 | 0.00 | 0.00 | 318.88 |
| Wet | 600,000 | | | | | | |
| (min) | | 15.84 | 1.04 | 0.00 | 0.00 | 0.00 | 16.88 |
| (avg) | | 31.68 | 1.04 | 0.00 | 0.00 | 0.00 | 32.72 |
| (max) | | 158.40 | 1.04 | 0.00 | 0.00 | 0.00 | 159.44 |
| Dry | 300,000 | | | | | | |
| (min) | | 7.92 | 0.52 | 0.00 | 0.00 | 0.00 | 8.44 |
| (avg) | | 15.84 | 0.52 | 0.00 | 0.00 | 0.00 | 16.36 |
| (max) | | 79.20 | 0.52 | 0.00 | 0.00 | 0.00 | 79.72 |

**Replacing Existing Fuels with "Low-Mercury" Fuels**

Coal

In the U.S., coal is the predominant source of fuel for the production of portland cement; in 1991, 87 percent of the total U.S. kiln capacity used coal, coke, or a combination of coal and coke as the primary fuel.[15] The mercury content of coal ranges from 0.0 to 1.3 µg/g with an average of approximately 0.09 µg/g.[7] The amount of mercury entering model kilns from coal was estimated using minimum, maximum, and average values for the mercury content of coal, coal requirements per ton of feed, heat input requirements, and the ratio of feed to clinker. Estimated mercury inputs to model kilns are shown in Table 4. Total mercury input to kilns from feed materials and coal, on a model plant basis, and the relative contribution of each to total mercury input is shown in Table 5. Based on average mercury concentrations of feed materials and coal, Table 5 demonstrates that the largest contributor of Hg to kilns is from feed materials, which account for between 55 percent and 75 percent of the Hg. Contributions of Hg from coal account for between 30 percent (model precalciner kiln) and 45 percent (model wet kiln) of the mercury input to kilns.

The existence and availability of "low-mercury" coal was examined. In a January 2000 memo,[7] the mercury concentrations in nine types of coal plus petroleum coke and tire-derived fuel were reported. In 1999, approximately 91 percent of the coal burned by the electric utility industry was bituminous and subbituminous coal types. Although bituminous and subbituminous coals are now believed to contain less mercury than lignite on a heating value basis,[7] the variability in mercury across coal seams and within coal seams is too high to establish one coal type or selected deposit(s) as a designated low-mercury coal to use. Furthermore, Hg is not the only trace metal or potential HAP present in coal. When levels of Hg in coal are relatively low, concentrations of other HAP metals and other potential pollutants (such as chlorine, fluorine, and sulfur compounds), may be elevated.[16] The availability of low mercury coal to the portland cement industry is even more questionable given the pre-existing supply and transportation relationship with electric utilities. For these reasons, use of "low-mercury" coal by the portland cement industry is not an achievable practice.

Natural Gas

Other fuels used in the portland cement industry include natural gas, fuel oil, petroleum coke, and scrap tires. Natural gas has no mercury when sent to market. EPA identified the mercury concentration in number 6 fuel oil as 0.0092 ppmw[17] while the Bureau of Mines[8] reports 0.4 ppmw. Mercury concentrations in petroleum coke and scrap tires were reported to average 0.054 ppmw (dry) for scrap tires used as fuel and 0.049 ppmw (dry) for petroleum coke used as fuel in the portland cement industry.[7] Since the absence of mercury in natural gas would potentially offer the best benefits, the feasibility of its use was examined, although there are major hurdles to the total substitution of natural gas for coal.

Table 4. Mercury Input to Kiln from Coal

| Model kiln | Clinker Production, tpy | BTU needed to produce ton of clinker[17] | BTU needed/yr | BTU/ton coal[17] | Coal input to kiln, tpy | Coal Hg content, µg/g[7] | Hg input from coal, lbs/yr |
|---|---|---|---|---|---|---|---|
| Preheater | 600,000 | 3,800,000 | 2.28E+12 | 24,500,000 | 93,061 | | |
| (min) | | | | | | 0 | 0.00 |
| (avg) | | | | | | 0.09 | 16.75 |
| (max) | | | | | | 1.3 | 241.96 |
| Precalciner | 1,200,000 | 3,300,000 | 3.96E+12 | 24,500,000 | 161,633 | | |
| (min) | | | | | | 0 | 0.00 |
| (avg) | | | | | | 0.09 | 29.09 |
| (max) | | | | | | 1.3 | 420.24 |
| Wet | 600,000 | 6,000,000 | 3.6E+12 | 24,500,000 | 146,939 | | |
| (min) | | | | | | 0 | 0.00 |
| (avg) | | | | | | 0.09 | 26.45 |
| (max) | | | | | | 1.3 | 382.04 |
| Dry | 300,000 | 4,500,000 | 1.35E+12 | 24,500,000 | 55,102 | | |
| (min) | | | | | | 0 | 0.00 |
| (avg) | | | | | | 0.09 | 9.92 |
| (max) | | | | | | 1.3 | 143.27 |

## Table 5. Total Mercury Input to Kiln

| Model kiln | Clinker Production, tpy | Total Mercury Input (lb/yr) | | | Percent Mercury from | |
|---|---|---|---|---|---|---|
| | | From feed | From coal | Feed & coal combined | Feed | Coal |
| Preheater | 600,000 | | | | | |
| (min) | | 16.88 | 0.00 | 16.88 | 100.00 | 0.00 |
| (avg) | | 32.72 | 16.75 | 49.47 | 66.14 | 33.86 |
| (max) | | 159.44 | 241.96 | 401.4 | 39.72 | 60.28 |
| Precalciner | 1,200,000 | | | | | |
| (min) | | 33.76 | 0.00 | 33.76 | 100.00 | 0.00 |
| (avg) | | 65.44 | 29.09 | 94.53 | 69.22 | 30.78 |
| (max) | | 318.88 | 420.24 | 739.12 | 43.14 | 56.86 |
| Wet | 600,000 | | | | | |
| (min) | | 16.88 | 0.00 | 16.88 | 100.00 | 0.00 |
| (avg) | | 32.72 | 26.45 | 59.17 | 55.30 | 44.70 |
| (max) | | 159.44 | 382.04 | 541.48 | 29.45 | 70.55 |
| Dry | 300,000 | | | | | |
| (min) | | 8.44 | 0.00 | 8.44 | 100.00 | 0.00 |
| (avg) | | 16.36 | 9.92 | 26.28 | 62.26 | 37.74 |
| (max) | | 79.72 | 143.27 | 222.99 | 35.75 | 64.25 |

Assuming complete conversion to natural gas, the quantity of natural gas that would be required to fuel the portland cement manufacturing industry was estimated. Annual clinker production for each of the four kiln types and average Btu requirements to produce a ton of clinker for each of the kiln types were used to project annual BTU's needed if the portland cement industry switched completely to natural gas. [NOTE: Preheaters and precalciners are the most energy efficient kilns and comprise 16 and 13 percent, respectively, of the national kiln inventory. In general, older-style wet kilns comprised 35 percent of the industry while 65 percent used the dry kiln process (including traditional dry kilns as well as preheaters and precalciners.][19] Assuming that the heating value of natural gas averages 1,000 Btu/cu. ft.,[20] the natural gas requirement by kiln type and the total nationwide natural gas requirement were estimated (see Table 6). On a nationwide basis, the portland cement industry would consume an estimated 370 billion cu. ft. of natural gas annually or 1.6 percent of the total U.S. natural gas consumption (22.8 trillion cubic feet in the year 2000) and 3.9 percent of total industrial natural gas consumption (9.6 trillion cu. ft.).[21]

Although U.S. natural gas reserves would likely be adequate to handle a conversion by the portland cement manufacturing industry to 100 percent natural gas, supply is constrained by the number and production rate of U.S. wells. In 1999, domestic production hit 18.6 trillion cu. ft. Domestic production increased about 0.7 trillion cu. ft. in 2000.[22] The Energy Information Agency reports "In recent years, production from new natural gas wells has been declining more rapidly than in the past. Although there is some year-to-year variation in the trend, lower 48 gas well half-lives have declined from 40 months in 1990 to 24 months in 1999. The more rapid decline in natural gas well production rates increases the requirement for investment in new wells in the next year and the year beyond. If natural gas well drilling were to stop completely, productive capacity in the lower 48 states would decline by between 14 and 22 percent after one year and between 26 and 39 percent after two years."[23]

Table 6. Comparison of the Costs of Burning Natural Gas (NG) vs Coal on a Nationwide Basis

| Kiln type | Clinker production (millions tons/yr) [19] | Heat input required to produce clinker (million Btu/ton clinker) [18] | Total heat input required (billion Btu/year) [a] | Coal consumed (million tons/yr) [b] | Purchase cost of coal ($million /yr) [c] | NG consumed (million cu ft/yr) [d] | Purchase cost of NG ($million /yr) [e] |
|---|---|---|---|---|---|---|---|
| Preheater | 16 | 3.8 | 60,800 | 2.5 | 77.8 | 60,800 | 365 |
| Precalciner | 21 | 3.3 | 69,300 | 2.8 | 88.7 | 69,300 | 416 |
| Wet | 25 | 6.0 | 150,000 | 6.1 | 192.0 | 150,000 | 900 |
| Dry | 20 | 4.5 | 90,000 | 3.7 | 115.2 | 90,000 | 540 |
| TOTAL | 82 | | 370,100 | 15.1 | 473.7 | 370,100 | 2221 |

a. Total heat input required = Clinker production x Heat input required to produce clinker
b. Coal consumed = Total heat input required/Btu value of coal. Btu value of bituminous coal = 12,250 Btu/lb coal = 24.5 million Btu/ton coal.
c. Purchase cost of coal = $31.36/ton coal. Year 2000 average purchase price of coal for the industrial sector (excluding electric utilities).[24]
d. NG consumed = Total Btu required/Btu value of NG. Btu value of NG = 1000 Btu/cu ft NG.[20]
e. Purchase cost of NG = $6.00/million Btu. June 2004 NYMEX spot price.

In 2000 and 2001, the price of natural gas was very volatile. Temporary increases in demand led to rapid price increases over short-term periods. This is most dramatically shown in the California energy crisis where natural gas prices rose 290 percent from third quarter 2000 to first quarter 2001.[22] The volatility in the market makes the use of natural gas as a fuel (with no alternate fuel capability) extremely risky for portland cement kilns.

The cost of fueling all kilns using coal versus the cost of fueling all kilns using natural gas is also compared in Table 6. For each kiln type, total U. S. clinker production and the heat requirement (Btus) to produce a ton of clinker is used to estimate the total heat input required for each kiln type. Based on the average heating value for bituminous coal and natural gas, the quantity of coal (tons/yr) and natural gas (cu. ft./yr) that would be required were estimated. Average costs for coal of $31.36/ton [24] and for natural gas of $6.00/million Btu were used to estimate the nationwide costs of the fuels for each kiln type. The cost of burning natural gas in all portland cement kilns is higher than the cost of burning coal in all kilns by a factor of 4.7. The cost of substituting natural gas for coal to reduce mercury emissions as shown in Table 7, is approximately $642,000/pound. This cost estimate does not include retrofit cost to convert to natural gas nor does it include any costs that may be associated with piping natural gas to the plant. Costs of pipeline extensions[25] are expected to range between $132,000/mile and $660,000/mile for those plants not currently served by gas pipelines. Based on an industry data compilation[26] listing primary and alternate fuel sources, approximately 45% of portland cement kilns did not have access to natural gas.

Table 7. Comparison of the Costs of Burning Natural Gas (NG) vs Coal on a Nationwide Basis

| Kiln type | Clinker production (millions tons/yr) | Mercury emissions resulting from coal (lb/yr) [a] | Purchase cost of coal ($million/yr) | Purchase cost of NG ($million/yr) | Incremental Fuel Cost ($million/yr) | Cost of Mercury Reduction ($/lb) |
|---|---|---|---|---|---|---|
| Preheater | 16 | 447 | 77.8 | 364.8 | 287.0 | 642,000 |
| Precalciner | 21 | 510 | 88.7 | 415.8 | 327.1 | 642,000 |
| Wet | 25 | 1102 | 192.0 | 900.0 | 708.0 | 642,000 |
| Dry | 20 | 661 | 115.2 | 540.0 | 424.8 | 642,000 |
| TOTAL | 82 | 2720 | 473.7 | 1666.5 | 1746.9 | 642,000 |

a. Based on average mercury content of U. S. coal (0.09µg/g)

Another obstacle to completely replacing coal with natural gas is the inadequacy of the existing natural gas infrastructure, including storage facilities, pipeline distribution system, and compression facilities. Natural gas pipelines are relatively scarce in many U.S. areas compared to other utilities and may not be available in all areas in which portland cement manufacturing plants are located. Figure 1 depicts the nationwide natural gas pipeline corridors.[21] Figure 2 shows the location of portland cement facilities in 1994. Overall, U.S. pipeline capacity has been adequate to meet recent U.S. demand and appears to be adequate for the foreseeable future taking into account planned new pipeline capacity. However, regional pipeline constraints may exist that could affect the availability of natural gas. For example, rapidly growing gas demand and economic growth in California outstripped the State's rate of local infrastructure expansions. Although natural gas is often readily available in major metropolitan areas, rural and moderate-to-small cities often lack pipelines. In rural America, the lack of natural gas pipelines is considered by some developers to be a major deterrent to economic growth and the recruitment of industry. As with most mining activities, limestone quarries (and their associated portland cement manufacturing plants) are typically located in rural areas

Because natural gas is not a mandated utility, i.e., there is no government requirement to provide natural gas, there are areas of the country where, at the present time, natural gas is not available. Where natural gas is available, a business can request that the local distribution company (LDC) extend natural gas to their facility. Based on the cost of the pipeline and other factors, such as, how much natural gas the customer will use and the applicable rate schedule, the LDC prepares a feasibility assessment. If determined to be feasible, the LDC may extend a pipeline to the facility at no charge to the customer. If determined not to be feasible on the basis of pipeline costs, the amount of natural gas the facility will use, and the applicable rate schedule, the LDC can give the facility the option of paying a portion of the cost. Each LDC has its own policy regarding the feasibility of extending natural gas lines and because each situation would be different, no generalizations can be made as to when a portland cement facility would or would not be able to secure natural gas.

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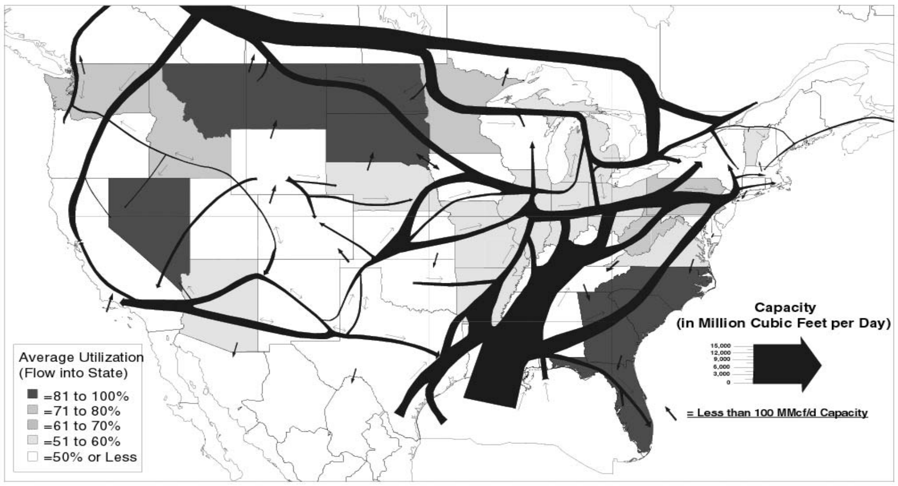
Figure 1. U.S. Natural Gas Pipeline Transportation Corridors and Average Interstate Pipeline Utilization Rates by State, 1999[20]




Note: The average utilization rate does not reflect seasonal load variations, which could be significant for some pipelines and States, especially in the northern tier of the country.

Source: Energy Information Administration, EIAGIS-NG Geographic Information System, Natural Gas Pipeline State Border Capacity (as of December 2000).

Figure 2.

## United States and Canadian Portland Cement Plant Locations

December 31, 1994