Why industrial customers don't implement cost-effective energy efficiency opportunities: A closer look at California's cement industry

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Abstract
Industry uses large amounts of energy and, on paper, there appear to be numerous cost-effective energy efficiency improvements that customers are not implementing. Program planners need to better understand opportunities and barriers in the industrial sector to better design energy efficiency programs geared toward this sector. Case study findings from California's cement industry are reviewed in light of currently available energy efficiency programs to assess how these programs are succeeding and to offer suggestions for improvement at addressing the most important barriers to increased energy efficiency.

We first examine studies to date addressing this issue, and identify major barriers to industrial implementation of energy efficiency measures. We then narrow our focus to California industrial energy efficiency potential, and find that energy savings of only 5 % in California, an attainable savings based on scoping study results, would save the state 2,600 GWh and 315 million therms per year. If policy makers plan to capture these savings, a thorough understanding of actual industrial energy efficiency practices is needed.

We present the results of a case study analysis of one of California's largest energy-consuming industrial segments, the cement industry. Energy efficiency practices and decision-making are compared across facilities within this industry and in summary analysis, across California industries. Customers' energy efficiency decision-making attributes are analysed relative to facility energy efficiency to identify barriers to increased uptake of energy efficiency measures.

Introduction
Recent industrial energy efficiency programs have had spotty success. Those opposed to funding these types of programs argue that companies have already realized all cost-effective opportunities. This is untrue; while opportunities do still exist, their character has changed since the 1970s. We must re-examine firms' decision-making processes with respect to energy-related issues. As California strives to increase the adoption of electricity and natural gas efficiency measures and practices, it is clear that utility programs that have traditionally targeted residential and commercial market segments will need to expand to better encompass the industrial sector. It is imperative that program planners understand the current barriers facing the success of industrial energy efficiency in order to design cost-effective programs with tangible results.

A Changing Landscape for Industrial Decision-Makers
The energy efficiency landscape has changed considerably in the past thirty years, and United States' industrial energy efficiency practices have adapted accordingly. During the 1970s, energy price spikes resulted in a dramatic decrease in energy intensity by the early 1980s. The '80s were a time of rapid technological innovation in the industrial sector. Energy efficiency was secondary to gross production as an industry goal, but received strong attention nonetheless. While energy prices were high, energy efficiency was an integral component of general industrial efficiency (Shipley et al 2006).

Low energy prices in the 1990s meant that energy efficiency took a back seat in equipment decisions; energy considerations

became separated from productivity, and energy efficiency program planners touted "non-energy benefits" of energy efficiency measures, such as staff productivity (Elliott & Pye 1997).

Now, we have rising energy prices once again, but global competition for energy-intensive industries may mean that rather than another period of rapid energy efficiency growth, we will experience a loss of energy-intensive industries in this country. It is forecasted that non-energy intensive industries will grow faster than energy intensive industries in this country in the coming years; in general, industry is expected to grow more slowly than the overall economy (2.1 % versus 3.0 %).

Is this an inevitable change? Perhaps not. Shipley and Elliott (2006) argue that energy efficiency opportunities can be divided into two categories: low cost, involving changes in operating/maintenance practices; and higher-cost measures involving capital investments. We are at the end of a period of production capacity consolidation within the industrial sector; in response to the '70s energy crisis, plant managers began eliminating inefficient excess capital, and most industries are now functioning at close to 100 % capacity (Shipley & Elliott 2006). Thus, opportunities for gross waste elimination may be less than they were thirty years ago, so the focus should be on purchase and optimization of more efficient technologies. Properly advised industrial firms can purchase new, energy efficient capital in order to both increase production capacity and remain in business despite rising energy prices. If energy-efficient capital investments are prohibitively expensive, a firm can still dramatically improve its bottom line through energy-efficient operations and maintenance. Once again, energy efficiency is potentially intertwined with production efficiency, and it is up to efficiency program designers and implementers to foster this connection.

A THREE-PRONGED BARRIER TO INDUSTRIAL ENERGY EFFICIENCY: COSTS, CAPITAL, AND TIMING

If changing energy prices have affected all economic sectors, why is market penetration of energy efficiency measures more difficult in the industrial sector than in other sectors? Numerous studies have addressed this question, and certain themes have emerged. First, energy costs are generally a small fraction of total industrial costs, which means that the typical firm pays only limited attention to their energy bills. Additionally, for most firms, capital is scarce. Because high priority goals such as improvements in plant productivity, product quality, environmental emission requirements, and labor and materials efficiency are no longer obviously connected to energy efficiency, energy-efficiency projects are considered non-strategic and take low priority when industrial firms allocate capital (Jordon & Nadel 1992, Mengal et al 2002). A one- to three-year payback is often required for cost- saving investments such as energy-efficiency projects. Capital rationing, a common budgeting approach, further hinders energy-efficiency investments, since fewer investments are undertaken that would be justified by more conventional budgeting analysis.

Many industrial firms also have concerns about the long-term persistence of savings of energy-efficiency measures, the amount of downtime that will result from measure installation and maintenance, and the effect of process changes on productivity and ongoing operations. For some firms, there are doubts as to whether the technologies even save energy. The lack of easily accessible information on the availability and/or economic and technical viability of energy-efficiency measures under full-scale, actual usage conditions amplifies the skepticism (Jordon & Nadel 1992). Smaller-sized firms in particular often do not even know about the specific technologies that are available. In particular, many small- to medium-sized industrial firms do not have the expertise on their staff nor the time to address energy efficiency in isolation from more strategic concerns (Mengal et al 2002).

LOST POTENTIAL

Given market conditions and the aforementioned barriers to adoption, are there still cost-effective opportunities for energy efficiency improvements in the industrial sector? It seems so. Jordan and Nadel (1992) compiled a database of 31 U.S. energy efficiency programs, and found the 12 "successful" programs within this group had common components: they addressed the industrial customer's perspective; used effective marketing strategies; offered a flexible program package; offered financial incentives; and performed extensive marketing research and program evaluations.[1] Among their recommendations were that there should be improved information exchange, both between different utilities, and between utilities and industrial customers via industrial energy conferences and training sessions; and that there must be coordination between industrial trade associations and state industrial efficiency programs.

More recently, Shipley and Elliott have compiled energy efficiency potential studies and found savings potential between 8 % and 9 % for natural gas, and 10 % and 35 % for electricity. In these studies, industrial efficiency potential differs based on model assumptions:

- Technical potential: the complete penetration of all measures analyzed in applications where they were deemed technically feasible from an engineering perspective
- Economic potential: technical potential of those energy conservation measures that are cost effective when compared to supply-side alternatives, using the total resource benefit-cost (TRC) test[2]
- Achievable potential: the amount of savings that would occur in response to specific program funding and measure incentive levels (market intervention)
- Naturally occurring potential: the amount of savings estimated to occur as a result of normal market forces

Industrial Sector Decision Process

An important point to keep in mind when considering industrial energy efficiency potential is that, within firms, not all energy efficiency related decisions are made in the same way,

1.These programs meet one or more of the following four criteria and cost the utility no more than $ 0.045/kWh saved: (a) annual participation rate of at least 8 %; (b) annual savings as a percent of 1989 industrial sales of at least 0.5 %; (c) cumulative participation rate of at least 12 %; and/or (d) cumulative savings as a percent of industrial sales of at least 0.7 %.

2. The TRC ratio is the net present value of the supply-side costs avoided by the demand-side resource option (including energy and delivery costs) divided by the net present value of the total costs of the demand-side option, including both the participants' costs and the utility's/implementer/s costs (including equipment, installation, operation and maintenance, and program administrative costs).

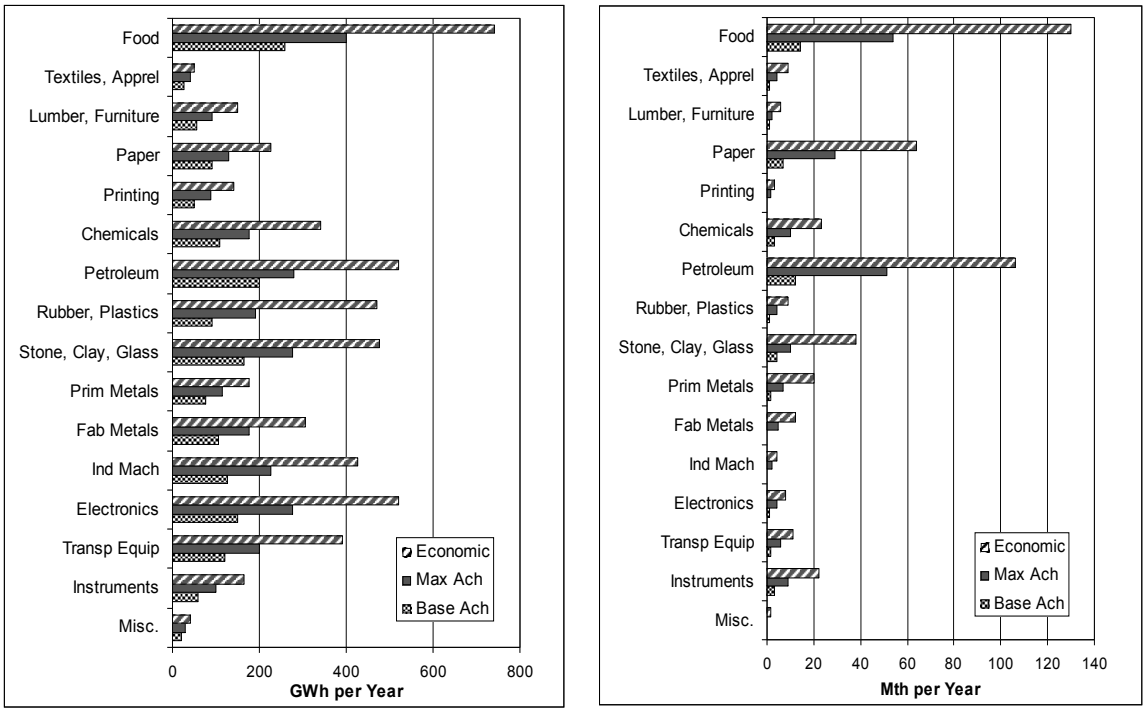

Figure 1. Potential California Energy Savings by Industry Group

by the same person or group. In fact, decision-making is not focused on return on investment or direct economic returns, but on factors that promote larger revenue enhancement, productivity, and other non-energy elements of their business.(Peters et al 1996). Megdal et al (2003) examined decision-making specifically in small and medium-sized industrial firms, and found that decision-making is characterized by different decision and authority structures and that each of these structures are equally common. They found trends in decision-making processes across firms for certain types of decisions: O&M so less influence by corporate and more influence by plant managers, facility managers, and O&M staff; motor and pump decisions saw more involvement from production managers and less committee decision-making; and production process design decisions often included plant managers, production personnel, and other staff. Clearly, this research suggests that energy efficiency program implementers should adapt programs targeted at small and medium-sized customers to the decision-making process of each customer (Mengal et al 2002).

Industrial Energy Efficiency Potential in California

California has recently specified very aggressive electricity and natural gas energy efficiency targets for its investor-owned utilities. In order to meet these targets, programs that have been traditionally targeted at the residential and commercial must expand to better address industrial customers. A 2003 study by KEMA and Lawrence Berkeley National Lab (LBNL) used a compilation of industry-specific secondary-source research to conduct an energy efficiency potential analysis for California's industrial sector (Coito et al 2003). This study examined technical, economic, achievable, and naturally occurring potential.

KEMA developed a model called DSM ASSYST to produce estimates of the energy-efficiency potentials introduced above. The model integrates technology-specific engineering and customer behavior data with utility market saturation data. Researchers first obtained baseline energy usage information for California industries, then fed this baseline consumption information into the model to obtain energy efficiency potential results. Figure 1 displays, by industry group, cumulative achievable savings projects in 2016 in comparison to total economic potential. For electricity, savings potential is distributed fairly well across industrial groups, with Food, Petroleum, Stone/Clay/Glass, Industrial Machinery, and Electronics showing the most potential. For natural gas, savings potential is most concentrated in the Food, Paper, and Petroleum industrial segments. In terms of specific measures, improved process controls, system optimization, and O&M measures are key components of potential savings for both electricity and gas. These are types of measures that will require continued customer information and education efforts to facilitate increased measure adoption.

Table 1 summarizes the benefit-cost estimates for the achievable program scenarios. As shown, the program scenarios all have estimated TRC ratios that are greater than one, indicating program cost effectiveness. For electricity, net benefits are estimated to be $ 0.9 billion (€ 0.67 billion) for the base scenario and $ 1.3 billion (€ 0.97 billion) for the maximum achievable scenario (5 % and 8 % of base usage, respectively). For natural gas, net benefits are estimated to be $ 0.4 billion (€ 0.3 billion) for the base and $ 1.3 billion (€ 0.97 billion) for the maximum achievable scenario (1 % and 5 %, respectively). The benefit and cost estimates reflect the assumption that all estimated potential savings can be captured with the estimated program and measure cost outlays. There is uncertainty regarding the estimated relationships between costs, impacts, and associated benefits as

Table 1. Summary of Net Achievable Industrial Potential Results for California

Result	Electricity		Natural Gas	
	Base	Max	Base	Max
Program Costs (Mil.)	$317 (€ 238)	$779 (€ 584)	$48 (€ 36)	$275 (€ 206)
Participant Costs (Mil.)	$285 (€ 214)	$247 (€ 185)	$24 (€ 18)	$61 (€ 46)
Avoided Cost Benefits (Mil.)	$1,523 (€ 1,143)	$2,353 (€ 1,765)	$497 (€ 373)	$1,608 (€ 1,206)
Net Benefits (Mil.)	$921 (€ 691)	$1,336 (€ 1,002)	$426 (€ 320)	$1,271 (€ 953)
Net Savings	1,706 GWh/Yr 216 MW	2,748 GWh/Yr 378 MW	47 Mth/Yr	192 Mth/Yr
Program TRC Ratio	2.5	2.3	7.0	4.8

Present value of benefits and costs over 20-year normalized lives for 12 program years (2005-2016), nominal discount rate of 8 %, inflation rate of 3 %, energy savings are cumulative. Euro conversions are based on an exchange rate of 1 EUR = 1.33324 USD.

we extent out into the forecast period. This uncertainty is greatest for the maximum achievable scenario as it is a considerable extension beyond recorded program experience.

Case Study: The Cement Industry

A case study of the cement industry, one of the largest industrial segments in California, was developed to help program planners improve their understanding of industrial customers' opportunities to save energy and associated costs. The goals of this case study included: identifying key energy-efficiency opportunities and associated technical potential; identifying key barriers that preclude cement customers from adopting energy efficient practices and equipment; and examining how current utility- and Public Goods Charge (PGC)- funded programs can better address these customers' barriers to implementation of more energy-efficiency measures. The primary approach to this case study involved analysis of secondary source data, walk-through surveys of customer facilities, in depth interviews with customer decision makers, and subsequent analysis of collected data.

BACKGROUND

California is the largest cement producing state in the U.S., accounting for between 10 % and 15 % of U.S. cement production and cement industry employment. The cement industry in California consists of 31 sites that consume large amounts of energy, annually: 1,600 GWh of electricity, 22 million therms of natural gas, 2.1 million tones of coal, 0.23 million tones of coke, and smaller amounts of waste materials, including tires (USGS, various years). Eleven of these sites are involved in full-scale cement production, while the remainder of the facilities provides grinding and mixing operations only. The eleven full-operation sites account for over 90 % of the California cement industry's electric use and 80 % of the natural gas use.

The case study summarized in this paper focused on providing background information, an assessment of energy-efficiency opportunities and barriers, and program recommendations that can be used by program planners to better target products to the cement industry. The primary approach to this case study involved walk-through surveys of customer facilities and in depth interviews with customer decision makers and subsequent analysis of collected data. In addition, a basic review of the cement production process was developed, and summary cement industry energy and economic data were collected, and analyzed. The analysis of secondary data provides background information on the cement industry and identification of potential energy-efficiency opportunities. The interviews provide some understanding of the customer perspective about implementation of energy-efficiency projects.

STUDY APPROACH

This case study utilized secondary source data, combined with interviews of cement customers, to provide insight into the size and workings of the cement industry as well as identification of opportunities and barriers to increased energy efficiency. Key cement industry statistics were obtained from the 1997 Economic Census, the 1998 Manufacturing Energy Consumption Survey (MECS), utility billing data, and data from the California Energy Commission (CEC). In addition, a variety of secondary sources were utilized by Lawrence Berkeley National Laboratory (for this and other studies) to develop an understanding of the cement production process and associated energy-efficiency opportunities. In depth interviews were conducted with senior representatives from four cement companies representing operations at five California cement plants. A senior KEMA engineer, who was knowledgeable about cement plant operations, conducted the interviews. The interview process included a technical discussion of each facility's operations, but mainly focused on various aspects of the customers' decision-making process, especially as it applies to purchases of energy-efficiency products and services. The secondary data and related analyses provide background information on the cement industry, along with potential energy-efficiency opportunities. The interviews provide some understanding of the customer perspective about implementation of energy-efficiency projects, including major barriers to increased energy efficiency.

CEMENT INDUSTRY STATISTICS

In California, the cement industry employs about 2,000 workers and has an annual value of shipments of about $ 850 million (€ 637 million). Table 2 presents economic statistics for the California cement industry, as compared to U.S. cement industry totals. Fuel costs are the single largest variable production cost at cement plants. Variable costs are typically about 50 % of overall operating costs, so energy is frequently the single largest production cost, besides raw materials. Labor is relatively small at a cement plant.

Table 2. Cement Industry Economic Statistics

	California	U.S.	CA Share of U.S.
Total Establishments	31	279	11%
Establishments with 20 employees or more	15	136	11%
Number of employees	1,927	16,973	11%
Payroll ($1,000's)	93,795 (€ 70,315)	735,506 (€ 551,377)	13%
Number of production workers	1,461	12,524	12%
Total hours worked (1,000's)	3,118	27,294	11%
Total Wages ($1,000's)	66,434 (€ 49,809)	498,875 (€ 374,032)	13%
Value added ($1,000's)	486,760 (€ 364,944)	4,027,714 (€ 3,020,094)	12%
Cost of materials ($1,000's)	354,774 (€ 266,019)	2,479,050 (€ 1,858,905)	14%
Value of shipments ($1,000's)	846,898 (€ 635,043)	6,540,243 (€ 4,904,196)	13%
Total capital expenditures ($1,000's)	66,207 (€ 49,645)	506,015 (€ 379,435)	13%

Source: 1997 Economic Census, http://www.census.gov/eped/www.econ97.html. Euro conversion based on an exchange rate of 1 EUR = 1.33360 USD.

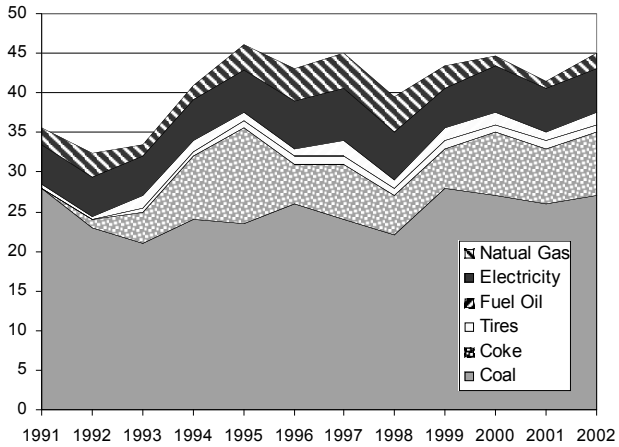

Figure 2. California Cement Industry Energy Consumption

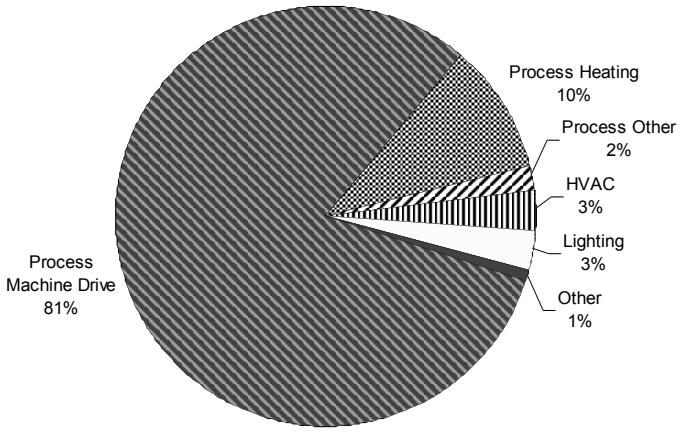

Figure 3: Cement Industry End Use Electricity Consumption

Table 3: Cement Industry Electricity and Natural Gas Consumption

Energy Use Type	California	U.S.	CA Share of U.S.
GWh per year, electricity	1,620	11,900	14%
MW, electricity	224	*na*	*na*
Million therms per year, natural gas	22	260	8%

Source: Utility billing data, CEC forecast database, and 1998 MECS data

Figure 2 shows historical consumption of energy by California cement plants. While coal is the primary fuel used, significant amounts of electricity and natural gas are also consumed. These latter two fuels are of most interest to the California utilities.

In California, the cement industry consumes approximately 220 MW and 1,600 GWh per year of electricity, and 22 million therms per year of natural gas. This represents about 5 % of California manufacturing electricity consumption and 1 % of California manufacturing natural gas consumption. Table 3 compares cement industry electricity and natural gas use for California and the U.S.

Figure 3 shows typical end use electricity consumption shares, based on 1998 Manufacturing Energy Consumption Survey (MECS) data. Most of the usage is in the machine drive end use, associated with grinding, crushing, and materials transport. Cement industry natural gas consumption is concentrated in the process heating end use (about 90 % of total gas consumption), which involves clinker production in large kilns. In most cases natural gas is used as a supplemental fuel to coal. Only one California plant utilizes gas as a primary kiln fuel. This is a relatively small plant that produces white cement. The remainder of the natural gas usage is associated with boiler and machine drive end uses.

CEMENT PRODUCTION PROCESS

The most common raw materials used for cement production are limestone, chalk and clay. The major component of the raw materials, the limestone or chalk, is usually extracted from a quarry very close to the plant. In California, the limestone is extracted from open-face quarries. The raw materials are crushed, ground, and proportioned so that the resulting mixture has the desired fineness and chemical composition for delivery to the pyroprocessing systems. More than 1.5 tones of raw materials are required to produce 1 tone of portland cement (Greer et al. 1992; Alsop and Post 1995). In dry processing the materials are ground into a flowable powder in horizontal ball mills or

in vertical roller mills. Drying of raw materials before pyroprocessing is done utilizing waste heat from the kiln exhaust, clinker cooler hood, or auxiliary heat from a stand-alone air heater.

Clinker is produced by pyroprocessing in large kilns. These kiln systems evaporate the inherent water in the raw meal, calcine the carbonate constituents (calcination), and form cement minerals (clinkerization). The main pyroprocessing kiln type used in the U.S. is the rotary kiln. In these rotary kilns a tube with a diameter up to 7.6 meters is installed at a 3-4 degree angle that rotates 1-3 times per minute. The ground raw material, fed into the top of the kiln, moves down the tube counter current to the flow of gases and toward the flame-end of the rotary kiln, where the raw meal is dried, calcined, and enters into the sintering zone. In the sintering (or clinkering) zone, the combustion gas reaches a temperature of 1,816 – 1,982 °C. While many different fuels can be used in the kiln, coal has been the primary fuel in the U.S. since the 1970s. Once the clinker is formed in the rotary kiln, it is cooled rapidly to minimize the formation of a glass phase and ensure the maximum yield of alite (tricalcium silicate) formation, an important component for the hardening properties of cement. The main cooling technologies are either the grate cooler or the tube or planetary cooler. In the grate cooler, the clinker is transported over a reciprocating grate through which air flows perpendicular to the flow of clinker. In the planetary cooler (a series of tubes surrounding the discharge end of the rotary kiln), the clinker is cooled in a counter-current air stream. The cooling air is used as secondary combustion air for the kiln. After cooling, the clinker can be stored in the clinker dome, silos, bins, or outside. The material handling equipment used to transport clinker from the clinker coolers to storage and then to the finish mill is similar to that used to transport raw materials (e.g. belt conveyors, deep bucket conveyors, and bucket elevators). To produce powdered cement, the nodules of cement clinker are ground to the consistency of face powder. Grinding of cement clinker, together with additions (3-5 % gypsum to control the setting properties of the cement) can be done in ball mills, ball mills in combination with roller presses, roller mills, or roller presses. While vertical roller mills are feasible, they have not found wide acceptance in the U.S. Coarse material is separated in a classifier that is re-circulated and returned to the mill for additional grinding to ensure a uniform surface area of the final product.

ENERGY USE IN CEMENT PRODUCTION

The cement sector energy consumption is comprised of energy used for raw material preparation, clinker production, and finish grinding. Raw material preparation is an electricity- intensive production step requiring generally about 25.3-35.2 kWh/tone (COWIconsult et al. 1993; Jaccard and Willis 1996), although it could require as little as 11 kWh/tone. Clinker production is the most energy-intensive stage in cement production, accounting for over 90 % of total industry energy use, and virtually all of the fuel use. Typical fuel consumption of a dry kiln with 4 or 5-stage preheating can vary between 2.97 and 3.3 MBtu/tone clinker. A six stage preheater kiln can theoretically use as low as 2.75 to 2.86 MBtu/tone clinker. The most efficient pre-heater, pre-calciner kilns use approximately 2.75 MBtu/tone clinker. Alkali or kiln dust (KD) bypass systems may be required in kilns to remove alkalis, sulphates, and/or chlorides. Such systems lead to additional energy losses since sensible heat is removed with the bypass gas and dust. Power consumption for grinding depends on the surface area required for the final product and the additives used. Electricity use for raw meal and finish grinding depends strongly on the hardness of the material (limestone, clinker, pozzolana extenders) and the desired fineness of the cement as well as the amount of additives. Blast furnace slags are harder to grind and hence use more grinding power, between 49.5 and 70.4 kWh/tone for a 3,500 Blaine 1 (expressed in cm2/g). Modern ball mills may use between 31.9 and 37.4 kWh/tone (Worrell and Galitsky 2004) for cements with a Blaine of 3,500.

TECHNICAL POTENTIAL FOR ENERGY EFFICIENCY

For this analysis, we compared current energy use (both for electricity and for fuels) for cement production in California (van Oss, 2003) to best practice values for these two types of fuels. The best practice value of 119.9 kWh/tone of cement for electricity production is based on expert judgment, taking into account the hard limestone found in California, as reported by representatives at Hansen Permanente Cement Company. The best practice value of 2.88 MBtu/tone of clinker is based on a plant built in Taiwan in the mid-1990s that has an intensity of 2.90 MBtu/tone (Die Zementindustrie Taiwans 1994) and a plant built in India that has an intensity of 2.84 MBtu/tone (Somani and Kothari 1997). Given these best practice values, we estimate potential electricity savings of about 35.2 kWh/tone of cement and potential fuel savings of about 0.77 MBtu/tone of clinker. Given 2002 production of 10,049,400 tones of cement and 10,068,300 tones of clinker in California, the technical potential electricity savings are about 360 GWh and fuel savings are about 7.8 TBtu (8,200 joules), with a technical potential savings for both fuels of about 20 % over 2002 levels.

ENERGY-EFFICIENCY OPPORTUNITIES

Energy efficiency opportunities can be categorized into three general categories:

Operations and maintenance (O&M): O&M practices include elements such as motor and bearing lubrication, motor belt replacement, fan blade cleaning, fan wheel balancing, and compressed air system maintenance. While most customers indicated that they tried to keep equipment in good working order, the primary focus is on keeping equipment operating to maximize production. Energy-efficiency considerations are not the primary concern.

High efficiency equipment/processes: Significant energy savings projects typically involve major process and/or equipment modifications that are industry-specific and highly specialized. Cement industry customers see their equipment vendors as "business partners" because the vendors tend to have the specialized expertise in their particular area (e.g. crushers/classifiers, kilns, conveyors). Some measures include: efficient materials transport systems; conversion of ball mills to roller mills for grinding; high efficiency classifiers; conversion to more efficient kilns such as vertical precalciner kilns; variable speed drives (VSDs) for fans and other variable load drives; and compressed air system improvements.

Table 4: Rating of Key Business Factors (0 = Unimportant, 5 = Extremely important)

Business Factors	Average Ranking
Meeting regulatory requirements (such as environmental requirements)	5.0
Meeting your production schedule	4.5
Maintaining product quality and consistency	4.3
Keeping up with new or shifting market demands	3.3
Having a reliable, high quality supply or electricity	3.3
Maintaining your market niche	2.5
Keeping up technologically with competitors	2.3
Maintaining a happy and productive staff	2.3
Identifying and implementing cost saving measures	1.3

Controls: Key opportunities for improved process controls involve clinker production and finish grinding, as well as operation of compressed air systems.

CUSTOMER INTERVIEWS

Customer interviews with key plant managers focused on various factors that affect their decision to undertake energy-efficiency investments. Results of the interviews are summarized, by topic.

Importance of Energy Costs

Energy costs are the single largest variable production cost at cement plants, as indicated by all interviewees. Variable costs are typically around 50 % of overall operating costs in the cement industry, so energy is often the single largest production cost. Electricity accounts for over 10 % of overall production costs and natural gas accounts for 1 to 5 % of production costs, as facilities utilize other fuels (coal, tires, etc.) in their kilns.

Energy in Relation to Other Business Factors

When asked about the factors considered key to their business, customers all agreed that these factors were: environmental regulations, market conditions, and energy costs. However, when rating key factors to their company's success, identifying and implementing cost saving measures was low on the list, see Table 4.

Energy Management Policy

Interviewed customers had a varying emphasis on energy management at their facilities: ranging from moderate for the less efficient plants to extensive for the most efficient facility. One interviewee provided a pretty good summary of the basic approach towards energy management as practiced by all surveyed firms and the competing objectives they must deal with:

"We have a strong emphasis on energy management. However, maintaining consistent production and product quality is the overriding concern. Although everyone at the plant is aware of energy and it is a key factor on which some operations are based, we have limited operating staff. Fine-tuning for optimizing efficiency, and developing, championing, and managing energy improvements takes staff time that is just not available given each person's day to day responsibility. We do have "special projects "engineering staff, but even they are too busy to take on energy projects that aren't related to maintaining production. Also, the plant must remain in production as much as possible. The interruptions and coordination required for retrofits can also restrict consideration of energy retrofits."

General Investment Decision-Making Practices

For the most part, each company's operations personnel are charged with identifying opportunities and specifying equipment to invest in. Senior management is responsible for approving all investments outside of normal O&M expenditures. Also, vendors were sometimes included in the equipment specification process. A detailed technical and financial review is required before investing in all projects. Returns on capital investments need to be pretty high to justify expenditures. The interviewees from the less efficient facilities indicated that their typical targeted payback for investments was 1.0-1.5 years. The more efficient plants indicated somewhat higher payback thresholds: two to three years. Other critical drivers for investment in new equipment included: capital availability, production effects, market conditions, and innovation. Additional considerations included: lost production time, reliability, and environmental issues.

Energy-Efficiency Decision-Making

All interviewees indicated that, energy-efficiency investments were treated similarly to other investment opportunities. One customer noted that specific-energy is considered in all investment decisions – consistent with energy being such a large part of operating costs. Another customer noted that the availability of incentives might cause them to look more favorably at energy-efficiency investments. Two of the four companies have policies in place to specify higher efficiency equipment when making investments. A third company had no formal procedures in place, but expected new equipment to lower or at least be neutral with respect to specific energy. The fourth customer, owner of a less efficient plant, had no energy-efficiency purchase policy. Only one of the four companies (at one of the more efficient facilities) indicated they had an employee dedicated to maintaining/improving energy efficiency at the plant. An additional two companies indicated that there were informal energy-efficiency "champions" at their plants.

O&M Practices

All customers indicated that the primary maintenance approach at their facilities was to do whatever was necessary to keep equipment running in order to maximize production. They all indicated that they tried to maintain equipment so as to minimize energy use, since energy was such a large part of their operations.

Attitudes Towards Energy Efficiency

Three of the four customers indicated that energy-efficiency equipment and practices were very important to their operations. One of the three acknowledged that they don't have enough staff and time to pursue most of their opportunities. The fourth customer indicated that they could do much better with regard to energy efficiency, but felt they were severely limited by capital and other resource constraints. Key limitations to increased energy efficiency for these customers are time and money. They have limited staff and limited capital, and most believe they are doing the best job they can with resources at hand. They all seem willing to do more to improve their plant's energy efficiency if they had more resources. The smaller energy-efficiency items at these facilities can amount to fairly large savings but don't get addressed because they are considered a hassle.

Energy Efficiency and Program Awareness/Participation

All customers claimed they utilized various sources to maintain awareness of energy efficiency measures, including: trade journals, vendors, utility staff, business associates, trade associations, and trade shows. Trusted sources of energy-efficiency information cited by all respondents included the IEEE Tech Committee and the Portland Cement Association (PCA). In addition, one customer cited his corporate staff and one customer cited his local utility. All respondents were aware of the Standard Performance Contract (SPC) and Express Efficiency Rebate Programs provided in California, and one respondent indicated he was aware of the availability of energy audits.

BARRIERS TO ENERGY EFFICIENCY

Barriers to increased energy efficiency were identified in discussions with cement customers and utility representatives who are in close contact with their cement customers:

- **Limited capital**: many of the energy-efficiency improvements in the cement industry involve large capital investments, and most customers cited limited capital availability as a key factor limiting increases in energy efficiency.
- **Production concerns**: keeping equipment operating and avoiding production disruptions was of the highest priority. Additionally, cement plants do not like to shut down except for once a year, largely because shut down stresses the ceramic insulation in the kiln.
- **Limited staff time**: while all customers want to stay as efficient as possible, staff's number one priority is "keeping things running."
- **Information**: while all customers feel they have access to the information they need to make energy-efficiency improvements, several customers indicated that they did not have time to focus on this information.
- **Reliability concerns**: since maintaining production is such a high priority, cement customers are very concerned about the reliability of all new equipment.
- **Hassle**: since staff time is limited, smaller energy-efficiency projects are not pursued because they "are not worth the trouble."
- **Facility uncertainty**: one customer indicated that they were currently investigating the feasibility of a complete plant overhaul. Uncertainty over the overhaul project has halted any possible efficiency projects.

BARRIERS TO PROGRAM PARTICIPATION

While all interviewed customers were aware of the basic California energy-efficiency programs, and two of the customers had participated in the SPC program, there were barriers to increased program participation cited:

- **Short program period**: it often takes three to five years for these customers to develop and implement a project, from the planning through construction stages. Programs that have a one or two year time period don't fit well with their operations.
- **Limited incentives**: many of the cement plant projects cost tens of millions of dollars. Incentives of a few hundred thousand dollars don't provide much incentive here.
- **M&V (measurement and verification) requirements**: past program M&V requirements have generally favored one-for-one equipment change outs where pre and post equipment efficiencies are more measurable. Measures that are more "holistic" and affect energy use of a system are harder to justify savings for and thus have had limited acceptance in the Program.
- **Program paperwork**: SPC Program participation was initially limited because the application process was time consuming and a burden on customer staff. Utility assistance to some customers with the applications, when necessary, has helped mitigate this barrier.

ENERGY-EFFICIENCY ORGANIZATIONS/INITIATIVES

Various organizations and initiative are available to assist companies to improve their efficiency and reduce energy costs. Key initiatives currently affecting the cement industry include:

- **Portland Cement Association (PCA):** The organization has a double function, as it serves as the representation in Washington, DC, and as a research organization and clearinghouse focused on cement and concrete applications. Over 80 % of the cement plants in the United States and all California cement companies are associated with the PCA. The PCA has no special programs related to energy-efficiency improvement in the cement industry but serves as the conduit for national programs like ENERGY STAR® and ClimateVISION.
- **Cement Kiln Recycling Coalition:** The Cement Kiln Recycling Coalition (CKRC) is a trade association with member companies located throughout the United States (CKRC 2004). CKRC and its member companies support regulations related to the use of waste derived fuels including scrap tires. It disseminates information on the use of wastes as fuel in clinker kilns.
- **Climate VISION:** The federal government and industry organizations in 12 energy intensive economic sectors joined in a voluntary partnership called Climate VISION that

works with industry to identify and pursue cost-effective solutions to reduce emissions using existing technologies; develop tools to calculate and report emission intensity reductions; speed the commercial adoption of advanced technologies; and develop strategies to reduce emissions intensity in other economic sectors (ClimateVISION, 2004).

- **ENERGY STAR:** ENERGY STAR for industry (U.S. EPA, 2004a) aims at the development and institutionalization of strategic corporate energy management in participating companies. Within the "Focus" effort, the ENERGY STAR program collaborates with specific industries, such as cement 3. The Focus efforts include three elements: (1) support for a corporate energy management program; (2) a tool to analyze the performance of a plant compared to the peers in the U.S.; and (3) an Energy Guide (prepared by LBNL), providing descriptions of energy-efficiency measures in the Focus industry. The Guide for the cement industry was published in January 2004 (Worrell and Galitsky 2004).
- **Climate Leaders:** Climate Leaders is a voluntary industry-government partnership of the U.S. EPA that encourages companies to develop long-term comprehensive climate change strategies and set greenhouse gas (GHG) emissions reduction goals (U.S. EPA 2004b). Members of Climate Leaders set a long-term target for GHG emission reduction for the company.

PROGRAM RECOMMENDATIONS

Program recommendations, developed from analysis of secondary data and customer interviews that identified opportunities and barriers to energy efficiency include:

- **Increase program time limits for project implementation**: if program limits were increased to three years or more, the program participation process would fit better into customers planning, budgeting, and operations schedules.
- **Integrate industrial program activities with US Department of Energy and other initiatives**: as presented above, there are a number of organizations and initiatives that cement industry customers are involved in or have access to. Program funding could be utilized to support energy efficiency aspects of these initiatives directed towards California cement producers.
- **Provide energy manager funding**: while most customers indicate that they manage their energy use, and that staff are committed to improving energy efficiency, only one interviewed customer has employed a full time energy management position. It may be possible to use PGC funding to hire industry experts to serve as energy managers at interested facilities. These experts could take the lead on identification, planning, and implementation of energy-efficiency projects. This would help alleviate a key barrier to energy-efficiency improvements – limited staff time.
- **Increase rebate limits**: for cement customers, where energy-efficiency projects can cost many millions of dollars, caps on rebate levels limit their effectiveness in influencing customer decisions. The limited incentives primarily influence the smaller projects a customer will undertake, such as the installation of VSDs (variable speed drives). While larger projects may also qualify for incentives, it is likely that a small incentive will not influence a large project.
- **Make incentives conditional on customer installation of very cost-effective measures:** customers indicate that the hassle factor may cause them not to pursue some of the smaller energy-efficiency projects. If incentives for larger projects were conditional on customers implementing many of the smaller cost-effective projects, like those with paybacks of six months or less, it may be possible to get these smaller projects on the radar screen.
- **Provide audits for cross-cutting technologies**: while a high level of expertise is required for understanding and recommending energy-efficiency projects particular to the cement industry, audits may be useful in identifying good opportunities for some of the more standard end uses such as lighting, HVAC, compressed air, and pumping. Combined with an energy manager program, these audits could help customers more easily implement some of these smaller projects (a small project at an energy intensive cement plant may equate to a fairly large project at other businesses).
- **Provide funding for industry-specific education and training**: ongoing training of cement plant staff, with a special focus on energy efficiency, may be useful to maintain customer interest in improving plant efficiency. Such training could focus on the investments and practices that generally provide the best returns for a customer's efforts, as identified in reports and software tools developed for the cement industry. Such training could be coordinated with activities provided in other cement industry initiatives.

Conclusions

The energy efficiency decision-making landscape is changing, and energy efficiency programs will be critical to the survival of high energy-use customers such as California's cement industry. A review of studies to date addressing this issue reveals that cost-effective energy efficiency improvements do exist, but program designers and implementers need to identify opportunities, barriers, and decision-making processes by industry, and sometimes even by site. This case study provides a focused presentation of opportunities and barriers to increased energy efficiency in the cement industry, and suggests possible ways for utility-funded programs to affect these large industrial customers. We find that there are certainly differences across firms within the region based on each firm's money available for energy efficiency. We have targeted our recommendations to the firms with the least funding for capital investment; although this study targets the cement industry, it is likely that program recommendations that were developed will apply to similar types of large "heavy industry" facilities.

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