Cement Industry Standard Practice to Add a Percentage of Limestone During Grinding

California Public Utilities Commission
Energy Division
505 Van Ness Avenue
San Francisco, CA 94102

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Summary

California Public Utilities Commission staff (Commission Staff) received a request from Southern California Edison (SCE) for an ex ante review of a proposed project to provide incentives to a cement plant (Project ID 500210832) to enable addition of limestone to the grinding process. SCE and its third party implementer state that limestone and other additives — together referred to as finish mill system additives — produce a fluxing effect and reduce specific energy consumption (kWh per ton). SCE estimates that the project would realize an annual energy savings of 9,379,927 kWh and a peak demand reduction of 1,162 KW.

Since 2004, the American Society for Testing Materials (ASTM) has allowed up to 5% addition of limestone into the specification for cement (ASTM C150). In practice, the cement industry in California relies largely on the California Department of Transportation (Caltrans) specifications for its output. In 2007, Caltrans allowed cement to be produced with up to 2.5% addition of limestone. This was later increased to up to 5%, after Caltrans performed a study to better understand the effects of the additional limestone on strength, permeability and drying shrinkage in concrete.[1] SCE and the third party implementer also propose to add finish mill system additives of up to 5% during the grinding process.[2] The finished mill additives are limestone, limestone dust, and clinker/kiln dust of which the limestone and clinker/kiln dust are already available as byproduct from the applicant's clinker manufacturing facility operating at another location. Therefore, only one of the three finish mill additives — limestone, which is not available at the cement manufacturing location — is to be procured, stored and added to the cement manufacturing operation. The proposed project summary and background are reproduced in Appendix A from SCE's feasibility study.[3]

The finish mill system additives would produce a product with entirely different characteristics as compared to the currently manufactured product, but the plant's decision to add finish mill system additives appears to have been dependent on the guidelines provided by the ASTM and Caltrans, not influenced by SCE. Therefore, the Commission Staff believes that the industry standard practice (ISP) must be established to determine the appropriate baseline per the CPUC Decision 11-07-030. The ISP determination would establish the typical practice followed

[1] http://www.dot.ca.gov/hq/esc/Translab/ClimateActionTeam/limestone-in-cement.html

[2] From SCE's report: "According to Caltrans regulations (for cement which is to be used in highway construction), cement manufacturers are allowed to add and blend-in up to 5% of non-cementacious additives to their Type II/V cement. The mixture can include additives other than limestone as well, as long as the total percentage of additives is less than or equal to 5%, and their final product meets the strict QC tests applied regularly to assure the cement is satisfactory for end-use."

[3] The applicant's plant is a split cement plant. A primary ingredient of cement – clinker – is manufactured at a different location, which is about 12 miles away from the cement manufacturing plant. Two of the finish mill additives – limestone dust and clinker/kiln dust are byproducts of clinker manufacturing and may be transported to the cement manufacturing facility along with clinker. The cement manufacturing plant mixes clinker and gypsum to produce cement. The proposal is to add up to five percent finish mill additives during the cement manufacturing process. These additives are softer than the clinker they replace. Therefore, less energy is used in the grinding and mixing of clinker, gypsum and mill additives. Limestone is not available at the cement manufacturing location. The proposed project plans to build storage and conveyance equipment to facilitate the addition of limestone during cement manufacturing.

by the California cement industry to produce the proposed product using standard (and presumably less efficient) equipment and/or processes. Commission staff performed a survey of CA cement manufacturers to determine the ISP. In addition, a few cement plants in neighboring states were included in the survey to determine if there might be significant differences.

The ISP study found that all of the operating cement plants in California, except the applicant, are adding limestone to their cement for the past one to two years. The majority of cement plants contacted in neighboring states are also adding limestone. Hence, adding limestone to cement is an industry standard practice in California and very likely an industry standard in neighboring states. Thus, the proposed project is the same as the industry standard. In addition, Commission Staff analysis indicates that the simple payback period is less than six months, making this a very attractive investment without incentives. As a result, the energy savings from this project are not eligible in SCE's savings claim.

Methodology

A map of cement plants in California and in neighboring states was prepared and an internet search of cement mill certifications was undertaken. A list of plants to contact was drawn up and representatives of the plants were contacted by phone. A formal questionnaire was not prepared because (1) the survey was performed by an industry expert, (2) the sample size was small, and (3) only a few questions were asked. The survey questions focused on Type II/Type V cement, which accounts for the vast majority of cement produced in California. All respondents were asked whether their organization added limestone to the cement they produced. If they indicated that limestone is added, respondents were asked for the percentage of limestone added and for how long has the practice been in place.

Findings

The Commission Staff conducted a number of ISP surveys and undertook a financial analysis of the project. The results of the surveys and the financial analysis are discussed next.

ISP Surveys

Six different companies own a total of ten cement plants located in California, and two are currently closed. A survey of seven out of eight operating plants was conducted. The applicant of SCE project ID 500210832 was excluded from the survey. Appendix B provides a map of the different cement plant locations.

All of the seven operating plants in California are currently adding limestone to cement in the grinding process. The amount of limestone added ranged from 2% to 4.2%. When asked why limestone was not being added up to the maximum percentage (5%) allowed by Caltrans, the respondents cited chemistry as a limiting factor and clarified that a high percentage addition of limestone would mean that other parameters of cement would exceed the values specified in the ASTM C150. Four of the seven respondents knew when limestone addition started and reported that they have been adding limestone for one to two years. The other three California respondents did not know for how long they had been adding limestone.

A cement plant was contacted in Arizona, Nevada, Oregon and Utah to inquire about limestone addition practices. Three of the four out-of-state plants contacted were found to add limestone. The Oregon plant was adding only kiln dust. The amount of limestone added by out-of-state plants ranged from 2% to 4%, similar to the percentage limestone addition reported by the California respondents.

A list of the contacted cement companies, addresses, contact name, phone number and reported limestone addition is available, but was not included in this report due to confidentiality reasons. Cement mill certifications obtained through Internet search show the percentage of limestone added by five of the seven California respondents.

Project Economics

The Commission Staff research found that the motivation for a cement company to inter-grind 5% limestone (or in this case described as a blend of limestone, limestone dust and cement kiln dust — finished mill additives) is threefold:

1) Replacing clinker with additives saves money since the additives are cheaper than the clinker.[4]
2) Greenhouse gas (GHG) emissions are reduced by the amount of clinker no longer required. The GHG emissions occur from the calcination process in the kiln.
3) Energy savings from reducing the production of the clinker and replacing it with limestone.

The cost savings from replacing clinker with additives (see Item 1 above) are likely to be the largest. While production costs are plant-specific, a plant producing one million tons of cement per year will produce less clinker equivalent to the amount of finish mill additives added, i.e. 5% clinker saving in this case or 50,000 tons per year. Assuming a clinker cost at $25/ton, the plant would likely save $1.25 million per year. From this cost savings estimate, the cost of the additives will have to be subtracted. Additive costs vary depending on the source and transportation cost of the additives; the limestone dust and cement kiln dust are often waste byproducts with a zero or negative cost (a disposal cost). An industry expert estimates the cost of the additive blend at $10/ton. The additive costs is then 50,000 tons x $10 = $500,000. This yields a net annual cost savings of $750,000 ($1,250,000 - $500,000).

The cost savings from reduced greenhouse gasses (see 2 above) will only become apparent when the California Air Resources Board Cap and Trade program takes effect starting in January 2013. The 50,000 tons of clinker savings will have approximately 50,000 tons of GHG emission savings (approximately 1 tonne of GHG reduction for each

[4] Clinker is one of the two main ingredients of cement; Gypsum is the other ingredient. Clinker manufactured from limestone after heat treatment is in the form of hard rocks, typically 2" in size. Grinding clinker uses more energy as compared to softer materials such as the additive limestone, which is not heat treated.

tonne of clinker replaced).[5] Using a mean cost of $13.75/tonne for carbon allowances reported in ARB Auction 1 for Summary Results Report for 2013, annual cost savings would be $687,500 (50,000 tonnes of GHG emissions x $13.75 per tonne credit).[6]

It is likely that a cement manufacturer will want to add limestone to achieve these savings as well as energy savings. Finally non-energy co-benefits may include increased profit from higher production if existing permits (air quality and any other) allow for increased production and the market can absorb higher cement production. The marginal value of that increased production will be likely far more than the savings estimated above for GHG reduction and displaced material cost. Marginal sales revenue less marginal cost may range from $40 to $50 per ton, yielding an additional annual profit of more than $2 million.

These very preliminary cost savings calculations suggest that limestone addition would likely save the applicant close to $3.44 million per year ($2 million from marginal sales + $0.69 million from GHG reduction + $0.75 million from reduced material cost). Using SCE's preliminary project cost estimate of $5 million, the proposed project has a simple payback of 1.45 years without considering the energy cost savings.

Commission staff recognizes that the participant may see energy savings after implementing this project and such savings should be included in any cost-benefit analysis of this project. The proposed project will likely have total annual cost savings of $4.19 million after adding the annual electricity cost savings of $0.75 million (SCE's estimate) to the non-energy benefits of $3.44 million, yielding a simple payback period of 1.19 years without incentives. The simple payback is likely to be significantly less than one year because the non-energy benefits estimated above are based on annual production of 1 million tons.[7] The project cost from SCE's data is specific for the plant's capacity and will not change, resulting in a shorter payback period. For example, if the annual cement production for this plant is assumed at 2.5 million tons, the simple payback period without incentives would be about six months with the electricity cost savings and about seven months without the electricity cost savings.

Conclusion

The addition of limestone could not have been implemented until Caltrans accepted cement manufactured with limestone added. Therefore, the proposed project does not demonstrate the IOU program influence of the IOU program and ISP baseline applies. All of the operating cement plants in California are adding limestone to their cement for the past one to two years. The majority of cement plants contacted in neighboring states are also adding limestone to cement. Adding limestone to cement is an ISP in California and very likely an ISP in

[5] Caltrans estimates the GHG reduction from adding five percent limestone at five percent — a one-to-one equivalence. http://www.dot.ca.gov/hq/esc/Translab/ClimateActionTeam/limestone-in-cement.html

[6] http://www.arb.ca.gov/cc/capandtrade/capandtrade.htm

[7] The applicant's cement production is not reported in this document for confidentiality reasons.

neighboring states. The proposed project is the same as the established ISP. Therefore, the annual energy savings from this project are not eligible in SCE's savings claim.

Considering preliminary project economics, Commission staff believes that *even if the baseline ISP were determined as different from the proposed limestone addition,* the customer is likely a high probability freerider based on expected attractiveness of investment without incentives, as measured by the simple payback period, and lack of IOU influence. Any incentives paid for this project would not be a prudent use of ratepayer funds.

Appendix A — Project Description from the Feasibility Study

Project Summary

"The Southern California Edison Energy Management Solutions program is designed to assist SCE's customers with productivity-improving and energy savings investments. This Program Feasibility Study was prepared to assess the energy efficiency opportunity at XXXX Cement in ABCTown, CA of adding up to 5% of additives to their clinker/gypsum mixture, into the final processing steps to create finished Type II/V cement. (The plant manufactures 'plastic' cement as well, however Type II/V accounts for approximately 95% of the plant's production. This is of course taken into account in both the PFS Energy Savings Estimation calculations and in the corresponding M&V Plan.) The final processing steps are often referred to as the 'Finish Milling System' or FMS for short. This 5% of additives will be comprised of a mixture of up to three materials. These materials are limestone, limestone dust, and 'clinker/kiln dust' (hereafter CKD). The first material, 'limestone', is by necessity a high-grade (e.g. very pure) form of limestone. Since the cement plant's quarry does not yield limestone of this high purity, this material will be purchased by the plant from an outside source. The second and third materials, limestone dust and CKD, are both byproduct powders that will come from the clinkering portion of the plant operation (this part of their operation is often referred to as the 'quarry plant') and are currently discarded. After the project is installed and optimized, the ratio of the mass fractions of these three materials that collectively make up the total 5% additives and are added to the 'Finish Milling System' will become fairly constant with time. For the purposes of this PFS then, this mixture of additives added to the Finish Milling System will be termed 'Finish Milling System Additives', or 'FMS Additives' for short. The capital costs of this project are very large and therefore NMMP program incentives provide critical financial impetus for this project. Energy savings are achieved by reducing the power required to produce each ton of cement.

At XXXX, the present annual electrical energy requirement for manufacturing cement is estimated at about 269,181,018 kWh/yr. (NOTE: Since the XXXX cement manufacturing operation is split between two sites, there are two separate SCE site-accounts associated with this project. The "Annual MWh" in the table below reflects the sum of these two site accounts.) The proposed retrofit will reduce energy consumption to an estimated 259,801,092 kWh/yr for an estimated annual energy savings of 9,379,927 kWh/yr, representing an average peak-demand savings of approximately 1,168 kW. The cost to implement the measure is estimated at $5,000,000 . It is anticipated that, pending timely receipt of a funding letter from SCE for the NMMP incentive, this measure will be approved by the customer in 2012, and the first purchase orders for the equipment will be cut in Q1 2013. The primary equipment lead time is estimated at 6 months. It is estimated that the project will be complete in late 2013."

Project Background

"XXXX Cement of ABCTown, CA is a 'split' cement plant. The Quarry Plant quarries limestone for raw material and produces 'clinker' via the following steps:

1. "Quarrying": Limestone (and some shale) are mined
2. "Crushing": These large rocks are crushed into ~2" rocks
3. "Raw-Milling": These 2" rocks (and some additives) are ground to a fine powder
4. "Clinkering": This powder is sent through (A) the 'Pre-heat Tower' (PHT) to exchange heat between the kiln gases and raw meal powder, (B) the kiln, where a series of high-temperature chemical reactions occurs to create the intermediate product called clinker, and then (C) through the 'clinker-cooler', which exchanges heat between the clinker and the 'secondary air' that is used mainly to provide oxygen for combustion-heat for maintaining reaction temperature

Clinker is very hard marble-sized nodules with the approximate chemical composition of cement powder. Steps 2 and 3, the Crushing and Raw Milling processes, are very energy intensive. They can easily consume ~50-75 kWh of electricity per ton of clinker manufactured. Step 4 is energy intensive as well: there are usually 3 to 4 MW of electrical energy consumed to (A) move the process mass (the 'raw meal', reactant/product mix in the kiln, and clinker) through the PHT, kiln, and clinker-cooler, and (B) to grind the large amounts of solid fuel continuously fed to the kiln's burner-lance (required to maintain kiln temperature).

The clinker is then loaded aboard rail cars and transported 12 miles along Cemex's private rail line to their River Plant. The River plant uses clinker for raw material and produces cement via the following steps:

5. Pre-Mix: The clinker nodules are mixed with gypsum (and after this project, also the FMS Additives) to achieve the correct chemical composition for finished cement
6. "Finish Milling": That mixture is milled to a fine powder (cement).
7. The cement powder is packaged or loaded-to-transport for shipment / sale.

As with the crushing , raw-milling, and clinkering steps at the quarry plant, step 6, the finish-milling step, is also energy-intensive: grinding the ~5/8" clinker nodules, which are harder than limestone, back into powder usually consumes ~35-65 kWh/ton.

Note that in this scenario, all the material which comprises the cement product must go through the energy-intensive steps # 3 and #4 as well as # 6 - in essence, it must be milled twice: once in step 3 and again in step 6.

According to Caltrans regulations (for cement which is to be used in highway construction), cement manufacturers are allowed to add and blend-in up to 5% of non-cementacious additives to their Type II/V cement. The mixture can include additives other than limestone as well, as long as the total percentage of additives is less than or equal to 5%, and their final product meets the strict QC tests applied regularly to assure the cement is satisfactory for end-use. This means that for every 95 tons of [clinker+gypsum] mixture being discharged from step 5, the plant can add 5 tons of FMS Additives into step 6, the finish milling operation. Thus, this 5% of the finished cement product mass

- Need not go through steps 3 and 4, and hence requires none of the electrical energy spent in those processing steps
- Will, when added to the clinker/gypsum mixture, render the overall mixture less energy-intensive to mill back into a fine powder for several reasons:
    - First, the added limestone is much softer than the clinker which it is replacing.
    - Second: Because limestone and related materials have a high 'lubricity' value compared to clinker, these materials exhibit a 'fluxing' effect in the finish mills, further reducing the *specific milling energy* required for the resulting discharge of the finish mills (the 'finished-cement') to meet QC specifications. In previous projects of this type OEC has observed a decrease in specific finish milling energy of approximately 3 kWh/ton cement discharged by the FMS. However, since the lubricity of the CKD is likely to be lower than that of limestone or limestone dust, this value has been attenuated in the energy savings calcs to take this effect into account. NOTE: though it may or may not be possible to determine (e.g. solve for) the actual magnitude of the fluxing effect, the important consideration is that whatever the effect is, it will be included / inherent in the savings empirically determined during the Measurement and Verification step, per the attached M&V plan.
    - Third, the average particle size of the FMS additives is much closer to that of the finished cement than is the average particle size of the [clinker+gypsum] mixture, inherently reducing the work required by the Finish Milling System in order to mill the material down to a particle size that allows the product to meet QC specifications.

Note that this *specific milling energy* has units of *kWh per ton of mixture milled*.

Note also that the mixture of the [clinker+gypsum] and the FMS additives has the exact chemical composition as that of the 'finished' (milled-to-fine-powder) cement. The only difference between this mixture and finished cement is that this mixture has not yet been ground or milled back into a fine and homogeneous powder in the Finish Mill System.

Thus, the specific energy to produce a unit-mass of cement is reduced commensurately. Therefore the customer is considering moving ahead with this project."

Appendix B — California Cement Plant Location Map