Beneficial Use of
Spent Calcium Hydroxide from
Fruit Cold Storage Warehouses

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FINAL REPORT

Prepared for:

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a division of the Washington State Department of Community, Trade & Economic Development

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EXECUTIVE SUMMARY

Each year, approximately 14,000 tons of bagged calcium hydroxide are used in controlled atmosphere (CA) warehouse facilities throughout Washington to keep stored fruit from ripening prior to shipment to domestic and overseas markets. Through adsorption of carbon dioxide, the calcium hydroxide converts to calcium carbonate (lime) while still in the bag. At present, only a small portion of the calcium carbonate by-product is reused, with the balance either disposed at the county landfill, stockpiled long-term, or illicitly dumped on vacant land. Disposal of the lime is considered a significant problem by the Washington State Department of Ecology and numerous local regulators and municipalities.

The most desirable solution to this significantly excess by-product is to reprocess the spent CA lime into high-value lime products for use as a filler material in numerous industrial and agricultural applications. Processing would be conducted to mill the calcium carbonate to an average particle size range of 2 to 3 microns, to meet various industrial specifications. These processes could be accomplished economically, in an enclosed light industrial setting with dust controls throughout the processing area.

This project describes an outstanding opportunity to implement full recycling and beneficial re-use of an existing industrial by-product in Central Washington. It is particularly appealing because the by-products are contained in kraft bags and stored on pallets, and as such are free of contaminants. Nearly all of the material, including the bag, can be reprocessed into products of equal or greater value than the original raw material.

INDUSTRIAL DEMAND AND MARKET VALUE

To assess potential markets for the reprocessed calcium carbonate, five industries that use high-quality calcium carbonate were considered as part of this study, including manufacturers of PVC pipe, rubber, paint, joint and caulk compounds, and agricultural feed. Representatives from each of these industries were asked to estimate the quantity of calcium carbonate their company used on an annual basis, and a typical cost range for materials that meet their specifications.

The PVC pipe industry used the largest quantity overall, ranging upwards of 1,400 tons of calcium carbonate per month at the one facility contacted, at a cost of $200 to $240 per ton. The quantities used by the other filler industries contacted ranged between 20 and 60 tons per month, at a cost of $60 to $200 per ton. Calcium carbonate as a feed supplement is used at a rate of approximately 100 tons per month by the one supplier contacted, at a cost of $20 to $30 per ton.

LIME CHARACTERIZATION

To determine the degree of processing required for use of the lime in the targeted industries, the physical and chemical compositions of the residual lime were evaluated. To accomplish this, a sampling plan was prepared and implemented for the purpose of obtaining representative composite samples of the lime by-products. All of the material samples were from the two primary producers of calcium hydroxide: Continental Lime, Inc., of Tacoma, Washington, and Chemical Lime Company, Inc., of Langley, British Columbia, Canada.

Representative samples of the lime by-product were obtained, and then analyzed in the laboratory. The analytical test results indicate that there is considerable variability in the degree of conversion of calcium hydroxide to calcium carbonate, based on age of the spent lime, the placement of individual bags on the pallets and within the storage rooms, and the method of handling and storing the spent products. Given the difference in the molecular weight of each of these materials (calcium hydroxide with a molecular weight of 74 and calcium carbonate, 100), it is possible to separate these materials using air classification.
It may also be possible to complete the conversion process by exposing the unconverted calcium hydroxide to carbon dioxide during the refining process.

The whiteness and brightness of the Chemical Lime and Continental Lime products is quite variable, with the Chemical lime being considerably whiter and brighter than the Continental lime. To produce high-quality calcium carbonate for use in producing higher value products (i.e., white PVC pipe, paint and caulk compounds) it will be necessary to segregate the two products to avoid blending and discoloration of the whiter/brighter Chemical Lime product. The Continental Lime will be well suited to those industries where color is of less concern (gray or black PVC pipe, rubber and agricultural feed supplements). The separate handling of the bagged spent lime materials will need to be incorporated into the general operations plan of a processing facility.

MANUFACTURER'S TESTING

Samples of the lime by-product were tested by two manufacturers of processing equipment to evaluate appropriate processing technologies, procedures, and economics, which in turn would determine the suitability and feasibility of using the calcium carbonate materials as additives in the selected industrial applications. Tests conducted by Union Processing Company and Jet Pulverizer Company demonstrated that two distinct processing technologies could be used to meet the average 2- to 3-micron particle size specification. The equipment costs provided by these respective manufacturers were used in the facility economic evaluation.

COST EVALUATION

An economic analysis was conducted for a lime recycling facility with equipment suitable for processing an estimated 10 tons per hour of CA lime. The resultant capital costs and revenues are presented in the following table.

Economic Analysis Summary Tons Per Year (TPY)		
Description	**12,000 TPY**	**15,000 TPY**
Facility	70,000	70,000
Equipment	744,000	744,000
Annual Equipment Loan Payments	124,713	124,713
Payroll plus Benefits	135,072	151,392
Total Annual Operating Cost	553,585	579,905
Total Annual Revenue	1,517,400	1,896,750
Total Annual Revenue/Ton Lime Sold	126	158
Cost of Sales	581,264	608,900
Cost of Sales/Ton Lime Sold	48	41
Net Annual Revenue	936,136	1,287,850
Net Annual Revenue/Ton Lime Sold	78	117

CONCLUSIONS

This evaluation has demonstrated that the spent lime can be reprocessed to meet stringent industry product-quality specifications. Economically, filler markets also represent an outstanding opportunity, given that calcium carbonate is currently being purchased for upwards of $200 per ton for use in making various PVC pipe products. The primary marketing focus should therefore be to demonstrate that a high-grade recycled calcium carbonate product(s) can be produced for specific filler markets in quantities that are sufficient to match industry demand. Other markets also exist for both the residual calcium hydroxide and kraft paper bags, both of which would contribute to the revenue stream of the facility.

Several potential end use industries are located in close proximity to the controlled atmosphere warehouses that generate the spent calcium carbonate. A centralized lime recycling facility could easily be located in the same geographic area, thereby minimizing the cost of transport of the finished product More distant markets also exist and the processed lime could be transported by road or rail, although this is less favorable because of the cost of transportation.

This project further demonstrated through actual manufacturer's testing that processing equipment is readily available to reduce the particle size of the lime to meet the industry specification of 2 to 3 microns (average size range) and 8 microns (maximum). As part of the recycling process, residual calcium hydroxide would likely be separated as a separate product, and the remaining minor quantities of calcium hydroxide would be converted to calcium carbonate through exposure to carbon dioxide.

The economic analysis conducted for this project relied upon conservative assumptions, and the result of this evaluation was that calcium carbonate recycling is economically feasible given the projected costs and anticipated market value. In addition to the exciting economic opportunities, this project also represents an opportunity to convert a problem "waste material" into a range of products that are 100 percent recycled, and that reduce the demand placed on natural limestone resources at the quarry.

1. INTRODUCTION

1.1 PROJECT OVERVIEW

Each year, approximately 14,000 tons of calcium hydroxide are used in controlled atmosphere (CA) warehouse facilities throughout Washington to keep fruit from ripening prior to shipment to domestic and overseas markets. The calcium hydroxide is contained in 35 and 50 pound bags and stacked on pallets. When removed from the CA facilities, much of the calcium hydroxide has converted to calcium carbonate with a net gain of approximately 15 pounds per bag. The conversion and increase in unit weight result from the adsorption of carbon dioxide, causing an increased molecular weight for the calcium carbonate. As a result of this increase in weight, approximately 20,000 tons of “waste” calcium carbonate are produced each year. At present, only a small portion of the calcium carbonate by-product is reused, with the balance either disposed in landfills, stockpiled long-term, or illicitly dumped on vacant land. Disposal of the lime by-product is considered a significant problem by the Washington State Department of Ecology and numerous local regulators and municipalities.

At the present time, there are limited, low-value alternatives for reuse of the unprocessed calcium carbonate (mostly as an agricultural soil amendment) because of strict industrial product specifications and the cost of transportation. Existing technologies have not been implemented to reprocess these materials.

The spent CA lime consists of roughly 20 percent non-reacted calcium hydroxide and 80 percent calcium carbonate limestone, all of which is contained in kraft paper bags. Virtually 100 percent of these materials, including the bags, are recyclable.
Utilization of this by-product has numerous economic and environmental advantages over mining and processing quarried limestone to effectively yield the same products. For this reason, the lime by-product is considered a veritable “mine in a bag.”

The most desirable solution to this significant by-product problem is to reprocess the spent CA lime into high-value lime products for use as a filler material in numerous industrial and agricultural applications. The reprocessing would utilize existing technologies, and would begin with breaking open the bags of spent lime, separating the calcium carbonate (blocky consistency) and unconverted calcium hydroxide (fine powder consistency), and then reducing the calcium carbonate to a uniform coarse powder consistency. The calcium hydroxide fraction could be readily diverted for use in the paper (or other) industry, or converted to calcium carbonate by exposing it to carbon dioxide during the refinement process. Additional processing would then be conducted to mill the calcium carbonate to meet various industrial specifications. These processes could be accomplished economically, in an enclosed light-industrial setting, with dust controls throughout the processing area.

This project describes an outstanding opportunity to implement full recycling and beneficial use of an existing industrial by-product in Central Washington. This is particularly true because the by-products are contained in kraft bags and stored on pallets, and as such are free of contaminants. Nearly all of the material, including the bags, can be reprocessed into products of equal or greater value than the original raw material.

1.2 PURPOSE AND OBJECTIVES

The purpose of this project was to analyze and determine the physical and chemical characteristics of spent CA lime from fruit storage warehouses in Central and Eastern Washington, and to identify technologies to separate and reprocess this lime into specific high-value industrial lime products.

The principal objectives include the following:
Estimate the quantities of calcium carbonate generated annually in Washington;
Develop a set of specifications for specific industrial reuse options;
Characterize the calcium lime by-product;
Evaluate re-processing alternatives;
Conduct an economic evaluation; and
Prepare a Draft Operations Plan for full scale recycling.

2. ESTIMATE OF LIME BY-PRODUCT TONNAGE

The manufacturers of calcium hydroxide and the individuals who market this material to the CA industry estimate that 20,000 tons of spent lime are generated each year by the CA storage facilities in Central and Eastern Washington. This is based on estimated annual sales of 14,000 tons at 35 and 50 pounds per bag, and a known increase of weight to 50 and 65 pounds per bag due to conversion to calcium carbonate (a weighed conversion factor of 1.4).

To test the validity of the estimated amount of lime by-product produced, a brief questionnaire was prepared and distributed to the managers of 25 medium to large CA facilities. The total number of CA facilities in the Central Washington area is estimated at over 100, and the Yakima Valley Growers-Shippers Association indicates that at least forty new CA rooms are being constructed in preparation for the 1997 harvest. Most of these new facilities will rely on the use of calcium hydroxide for adsorption of carbon dioxide in the CA rooms, thereby leading to an increase in the production of calcium carbonate by-product.

The questionnaire requested information on the total amount of lime used by the CA facility, and current methods of disposal of the spent calcium carbonate. Of the 25 questionnaires that were distributed, nine were completed and returned. The total amount of lime by-product generated by these nine facilities was reported to be 3,808 tons. Of these nine CA facilities, the maximum amount of lime by-product generated by any one facility was reported to be 1,287 tons, and the minimum was reported to be 62 tons. The average amount (mean) was calculated to be 422 tons per facility. Assuming that this average value is indicative of the 25 CA facilities, an estimated 10,550 tons of lime by-product would be produced annually by these facilities alone. Based on these numbers, it is reasonable to project the total generation of calcium carbonate by-product to equal or exceed the 20,000 tons previously stated.

The estimated volume of lime by-product was further checked by taking the total number of boxes of apples produced in a given year and multiplying this number by the amount of lime used per box in the CA facilities. The amount of lime used in the CA rooms is determined on the basis of how long the fruit will remain in storage. For short-term storage, CA managers typically use one-quarter to one-half pound of calcium hydroxide per box of apples, whereas for long term storage they use up to three-quarters pound per box. Table 1 shows the potential volume of lime by-product calculated for the 1995 harvest season for each of three conditions, including short, intermediate and long term storage. The actual quantity of lime by-product would then be expected to fall somewhere within this range.

Table 1-Potential Annual Quantity of Lime By-product Generated

Boxes Total	Term in CA Storage	Lb./Box Ca Hydroxide	Tons Ca Hydroxide	Tons By-product Ca Carbonate
114,648,000*	Short	0.25	14,330	20,500
114,648,000*	Intermediate	0.50	28,660	41,000
114,648,000*	Long	0.75	42,990	61,500

* As reported by the Yakima Valley Shippers-Growers Association, Short ~ 30 days, Intermediate ~ 90 days, Long ~ 180 days

Based on the recorded number of boxes produced in 1995, the estimate of 20,000 tons of calcium carbonate by-product is reasonable and may be safely used for planning purposes.

3. INDUSTRIAL RE-USE SPECIFICATIONS

3.1 INDUSTRIES IDENTIFIED

At the outset of this project, the National Lime Association was contacted to determine which industries are large users of calcium carbonate. The list of end-use markets is considerable, and includes such industries as the following:

- Extender and Filler Minerals
- Asphalt Roofing Products
- Glass Manufacturing
- Flue-Gas Desulfurization
- Floor Coverings
- Animal Feed
- Beet Sugar Refining
- Dry Wall Compounds
- Cultured Marble
- Agriculture Soil Amendments

From this list, the most viable uses for the recycled lime by-product were determined to be as extender and filler minerals, agricultural feed supplements, and agricultural soil amendments. The principal extender and filler industries include those that produce paint, paper, plastics, rubber and adhesives, and sealants.

Recycling of the lime will also produce potentially large quantities of residual calcium hydroxide. While the calcium hydroxide has economic value, recovering and marketing this material was not the main focus of this study. The recovered calcium hydroxide can be used for a wide variety of purposes, including the following:

Controlled Atmosphere (CA) food storage

Water and waste-water treatment
Neutralization pH adjustments in the paper industry
Pathogen control, sterilization and pasteurization of organic waste materials
Soil and waste stabilization or solidification

3.2 INDUSTRY SPECIFICATIONS

In developing an appropriate laboratory testing program, the five potential end-user industries were surveyed to determine appropriate specifications for calcium carbonate as a raw material for their respective processes. The physical and chemical parameters are discussed in the following sections and the actual specifications for several different industries are summarized in Table 2.

Table 2-Calcium Carbonate Specifications: Five Industrial Users					
Specification	**PVC Pipe**	**Rubber**	**Paint**	**Caulk**	**Animal Feed**
Physical Properties					
Specific Gravity	2.7	2.7	2.7	2.7	
Pounds/Gallon - Dry	22.5	22.5	22.6	22.6	
Mean Particle Size (Microns)	3.0	3.5	3.0-6.0	3.0-50.0[1]	Flowing Granules (Fine Powder)
Particle Size Distribution					
Finer than 15 Microns (%)		99.5			
Finer than 12 Microns (%)	99.9				
Finer than 10 Microns (%)		95.0			
Finer than 3 Microns (%)	50.0	50.0			
Finer than 1 Micron (%)	17.0				
Finer than #12 Sieve (%)					100.0
Finer than #14 Sieve (%)					98.0
Finer than #100 Sieve (%)					20.0
Finer than #325 Sieve (%)			Nil - 0.005		
500 Mesh Residue (%)	0.003	Nil			0.5
ISO Brightness	93.0 ± 1	94.0			
Dry Brightness			94.0-96.0	85.0-90.0	
Color				White[2]	Off White-Gray
Oil Absorption (cc/100 g)	17.0	21.0	12.0-18.0	12.0-18.0	
Hegman Grind	6.0 min.	6.0	2.0-6.0	4.0-6.0	
Moisture (%)	0.2	0.2		0.2	
Chemical Properties					
$CaCO_3$ (%)	98.0	98.0		96.0 +	95.0
$MgCO_3$ (%)	1.0	1.0		2.0-3.5	0.5
Acid Insolubles (%)	1.0	1.0		9.0 +	
pH Factor	9.5	9.5	9.0-9.4		
Magnesium (%)					0.3
Iron (%)					0.2

[1]The Biddle Company usually purchases two to three particles size to modify viscosity in different product.
[2] TiO_2 is used to offset dark Ca CO_3; however, this is costly.

3.2.1 Specific Gravity

The specific gravity of a substance is a unit-less number derived by dividing the weight of a unit-volume of the material by the weight of the same unit-volume of water. Pure calcium carbonate has a specific gravity of 2.7.

3.2.2 Mean Particle Size

The grain size distribution of a granular material is the measure of the range of particle sizes represented in the sample. A uniform material has a very narrow particle size distribution, while a non-uniform material has a wide range of particle sizes represented. The mean particle size is the average of all size fractions.

For material sizes in the micron range, the mean particle size can be a difficult value to ascertain. There are several methods that can be used, each with a bias that makes it difficult to cross compare size range values between methods of measuring grain size. For this project, a calcium carbonate product used in the manufacture of PVC pipe was obtained from Columbia River Carbonates, and used as a standard against which the particle size distribution of the processed recycled calcium carbonate was compared.

Based on conversations with industry representatives, the mean particle size is the most critical specification parameter for the PVC pipe, rubber, paint, and caulk materials. The fineness controls dispersion and blending of the calcium carbonate in the manufacturing process affects the plasticity, pliability or viscosity of the various finished products. In some cases, a coating material such as calcium stearate or stearic acid can be used with coarser materials to enhance their blending properties. However, these coatings add to the overall cost of the process.

For the feed supplement industry, specifically the poultry industry, the specified grain size distribution was for a comparatively coarse material that would not break down or pass through the animal too quickly.

While each of the industries can work with coarser materials, provided they have been coated, it is important for them to have a feedstock that is uniform and does not vary in particle size between shipments. The marketability of the recycled calcium carbonate will depend on producing product that consistently meets specification, particularly in terms of particle size distribution.

3.2.3 Color and Brightness

The color and brightness of calcium carbonate is measured using a variety of systems, each of which relies on comparison of a prepared sample against a standard white color tile. The standard white tile is coated with a titanium dioxide pigment with a glass finish. The testing equipment uses a standard lamp (e.g., pulsed xenon or tungsten halogen light source) and measures the reflectivity of this light within the range of wave lengths that are visible to the human eye (400 to 700 nanometers). The color of a sample is the measure of these wavelengths relative to the standard white tile, and brightness values are the measure of the reflective luminosity.

All of the equipment that is now being used throughout industry is computerized. Typically, the operator prepares a sample following a specified protocol and then places the sample into the fully-automated testing apparatus. The test data is collected and analyzed by the on-board computer program, and the numerical results are provided in terms of the "Whiteness Index."

Metric systems that are currently being used to measure and specify color and brightness include the International Organization for Standardization (ISO) brightness, which is used in the paper industry, the CIEY brightness as used with the Hunter comparative brightness test, and ASTM Method E-313 whiteness, as measured on the Hunter Colorimeter. ASTM Method C110.16 is also used to specify the methodology of measuring the dry brightness of limestone. All of these standards are based on a Perfect Reflecting Diffuser (PRD), which is the theoretical 100 percent reflectance.

The reflectance qualities of a material are affected by impurities contained in the test specimen, moisture content, fineness of the material, and sample preparation. The theoretical reflectance drops very quickly below the 100 percent value along with changes in these variables. For example, a standard white tile will have a Whiteness Index on the order of 84 to 85.

The standard white color tiles vary between industries and individual companies within each industry. The color and brightness of raw materials relative to finished products are routinely measured for the purpose of quality control.

Brightness of calcium carbonate is an important quality when it is used as a filler material in finished products that rely, in part, on color for their quality. Examples of such products include paint and white caulk compounds. Where the calcium carbonate does not quite meet the minimum brightness specification, it can be enhanced by using other additives such as titanium dioxide. This enhancement commonly takes place in caulk compounds production, however, the relatively high cost of the titanium dioxide is a limiting factor.

Brightness is a somewhat less important specification for white PVC pipe products, and is not a significant concern for gray or black PVC products. Similarly, brightness of the calcium carbonate is typically not a concern for rubber products and animal feed supplements.

3.2.4 Oil Absorption

Oil absorption is a measure of the quantity of oils or solvents needed to produce the desired blended material and finished product. A lower oil absorption value is desired because less oil is required in the manufacturing process, resulting in lower production cost.

3.2.5 Hegman Grind

The term *Hegman Grind* refers to a procedure that measures fineness-of-dispersion of fine grained materials. The Hegman Fineness-of-Dispersion Gage is used as the testing apparatus. The Hegman Gage is a steel block in which a wedge-shape channel is cut, tapering from 4 mils at the deep end to 0 mil at the other end. An excess of the material to be tested is placed in the deep end of the channel, and the excess is drawn to the shallow end with a scraper. At some point along the channel, coarse particles or agglomerates will become visible. The results are interpreted by reference to standard reference patterns.

The Hegman Grind is a quick and simple method of evaluating particle fineness and uniformity. It is still specified for calcium carbonate in four of the five industries surveyed; however, it is seldom used for verification of product fineness by the industry technical staff.

3.2.6 Moisture

In all cases, the calcium carbonate must be dry to avoid clumping and to maintain a flowing quality to enhance dispersion and blending in the mixing process.

3.2.7 Purity

In all cases, the calcium carbonate product must be 95 to 98 percent pure. The product may contain a small amount of magnesium carbonate, silicate and other trace impurities. The recycled lime contains both calcium carbonate and calcium hydroxide in varying proportions. The recycling process must separate these constituents, and convert any residual calcium hydroxide by exposure to carbon dioxide. The ensuing chemical conversion produces heat and excess water, which must be accounted for in the process design.

3.2.8 pH Factor

In all cases, the pH of the calcium carbonate is specified to range between 9.0 to 9.5, which is standard for a pure product.

3.3 INDUSTRIAL DEMAND AND UNIT COSTS

Representatives from each of the five selected industries were also asked to estimate the quantity of calcium carbonate their company used annually, and a typical cost range for materials that meet their specifications. This information is summarized in Table 3.

Table 3–Average Quantities and Cost Ranges for Calcium Carbonate

Industry	Company	Quantity Tons/Mo.	Typical Price ($/ton)
PVC Pipe	PW Pipe	1,400	200 - 240
Rubber	Griffith Rubber	25 - 30	80 - 100
	Valley Processing	20 - 25	60 - 80
Paint	Far West Paint Mfg	40 - 60	120 - 160

Caulk & Joint	The Biddle Co.	30-40	100 - 200*
Animal Feed	Feed Specialists	100 +	20 - 30
*Function of distance to transport and the fineness of the product.			

Several of the industry representatives indicated that the supply and availability of a calcium carbonate product is also an important consideration. Many of these industries practice just-in-time inventory methods, and next-day delivery of a predictably high-quality product is essential to avoid process interruptions.

While not a formal part of this study, the residual calcium hydroxide does have a value ranging between $35 and $105 per ton, depending on quality and quantity available.

4. LIME BY-PRODUCT CHARACTERIZATION

The viability of recycling lime by-products from the CA facilities in Central Washington depends, in part, on producing a material that meets the industrial specifications, both in terms of chemical properties as well as physical properties. The following sections discuss the sampling procedure used to obtain representative samples, the laboratory testing program used to evaluate the chemical and physical properties, and the manufacturers' tests that were conducted to evaluate suitability of the materials in various applications.

4.1 SAMPLING PROGRAM

To determine the degree of processing required for use of the lime in the targeted industries, the physical and chemical composition of the residual lime were evaluated. To accomplish this, a sampling plan was prepared and implemented for the purpose of obtaining representative composite samples of the lime by-products from the two primary producers of calcium hydroxide. These producers include Continental Lime, Inc., of Tacoma, Washington, and Chemical Lime Company, Inc., of Langley, British Columbia, Canada. The Sampling Plan and the findings and photographs of the CA facilities and storage rooms are presented in Appendix A.

A composite sample consists of several smaller samples of a common material, which are combined to produce one larger sample that is representative of the total volume of material to be evaluated. Four composite samples were prepared for this project, as described below. The objectives of defining sampling procedures were to: (1) collect representative composite samples of the spent calcium carbonate materials which accurately reflect the typical range of material properties, (2) minimize variables that could potentially lead to erroneous findings and conclusions, and (3) establish a reproducible protocol to follow (or modify) for future sampling events.

Samples of calcium carbonate were collected to reflect the following conditions:

Continental Lime: spent lime from 1995 harvest season (New);
Continental Lime: spent lime from 1994 and earlier harvest seasons (Old);
Chemical Lime: spent lime from 1995 harvest season (New); and
Chemical Lime: spent lime from 1994 and earlier harvest seasons (Old).

In each case, the New bags of lime were taken from the CA facilities, and the Old bags of lime were recovered from outside storage piles. Four bags of spent lime were collected from each of the four categories; a total of 16 bags were collected. These bags were returned to covered storage at the office of Land Technologies, and the composite sampling event was carried out. Once combined, the composite samples were further processed to a uniform consistency using Land Technologies' bench scale Micronizer. Unlike conventional grinding equipment that relies on mechanical abrasion or shearing of materials, the micronizer causes very rapid acceleration resulting in particle-to-particle collisions that pulverize and blend the materials into a uniform fine-grained powder. Observations and findings resulting from the sampling and processing event are presented in Appendix B.

Samples of the New lime from both manufacturers had moisture contents of less than 1 percent, while samples of the Old lime had moisture contents that ranged from 15 to 17 percent. The elevated moisture contents resulted from exposure to wet weather conditions prior to the field sampling event. The two New (dry) lime products were easy to mix and process through Land Technologies' micronizer. The two Old (moist) lime were also easy to mix; however, these materials required oven drying before they could be processed through the micronizer. Once processed to a uniform powder consistency, the materials were sealed in one quart plastic containers with airtight lids, and shipped to the analytical laboratory. Material Safety Data Sheets were provided prior to shipment.

4.2 LABORATORY TESTING PROGRAM

The primary objective of the laboratory testing program was to determine the physical and chemical properties of each of the composite sample materials. The primary questions to be evaluated in this laboratory study included:

What is the typical conversion rate of calcium hydroxide to calcium carbonate;
What is the degree of purity of the calcium carbonate once conversion is complete; and
What is the brightness or whiteness of the calcium carbonate.

Analytical testing of the composite samples was conducted by Chemical Lime Company, at two of their laboratory facilities, one located in Henderson, Nevada, and the second in Langley, British Columbia, Canada. The test results are summarized below, and the laboratory test data sheets are presented in Appendix B.

4.2.1 Conversion of Calcium Hydroxide to Calcium Carbonate

Tests were conducted to evaluate the percent conversion of calcium hydroxide to calcium carbonate, for the purpose of comparing the chemical characteristics of the spent lime products to the calcium carbonate specifications for industrial use. The following sections present test results for: (1) a single bag of spent lime, and (2) the four composite samples previously discussed.

Laboratory Tests Conducted on a Single Bag of Spent Lime

Prior to initiating the sampling and testing program, as described in Section 4.1, a single bag of spent calcium hydroxide (Old Continental Lime) was analyzed for distribution of converted lime within the bag, and overall percentage of converted lime. The following information was developed from this bag of lime, and is presented as general information:

Theoretical fresh bag weight = 35 pounds.	
Theoretical spent bag weight = 47.3 pounds.	Theoretical increase weight factor = 1.35.
Actual spent bag weight = 50 pounds.	Actual increase weight factor = 1.4.
Actual free moisture < 1% typical	

From this one bag of spent lime, 14 individual samples were obtained from positions within the bag that were denoted by x, y, z coordinates. Table 4 summarizes the analytical test results.

Table 4–Lime Conversion for a Single Bag			
Description	**Free Moisture**	**Calcium Hydroxide**	**Calcium Carbonate**
Low Value (%)	0.17	4.41	53.97
High Value (%)	1.04	41.65	91.56
Average Value (%)	0.63	19.97	75.08

Additional compounds, including small quantities of calcium sulfate, magnesium hydroxide and insolubles (generally silica) account for the balance of materials in the samples tested.

Laboratory Tests Conducted on Composite Samples

Wet chemical analyses were conducted on the composite samples by Chemical Lime Company, in the company's Henderson, Nevada laboratory.

The test results on the 1995 (New) composite lime samples indicated that approximately 30 to 38 percent of the Chemical Lime product was converted to calcium carbonate, with approximately 57 to 64 percent consisting primarily of calcium hydroxide. The balance was comprised of trace compounds and less than 2 percent of free moisture.

In contrast, approximately 74 to 79 percent of the Continental Lime New product was converted to calcium carbonate, with approximately 15 to 20 percent consisting of calcium hydroxide, with trace compounds and less than 2 percent free moisture.

The apparently low conversion values for the Chemical Lime product are believed to result from differences in storage and handling. Other factors, such as placement of the individual bags on the pallets and holding times within the fruit storage rooms may also have contributed to these lower values.

The trace compounds in all of the samples consisted of sulfide, calcium sulfate, and magnesium hydroxide, all of which were below 1 percent. There was no evidence of Magnesium carbonate, free calcium oxide or free magnesium oxide in any of the samples.

The test results on the 1994 (Old) composite lime samples indicated that approximately 84 to 87 percent of the Chemical Lime product was converted to calcium carbonate, with approximately 3 to 4 percent consisting primarily of calcium hydroxide. The balance was comprised of trace compounds and 7 to 9 percent of free moisture. As previously discussed, these Old materials had been exposed to the elements, necessitating oven drying before initial processing and analytical testing.

By comparison, less of the Continental Lime Old product was converted to calcium carbonate, with approximately 69 to 71 percent consisting of calcium carbonate, 21 to 23 percent consisting of calcium hydroxide, and the balance consisting of trace compounds and 3 to 4 percent free moisture.

In addition to the wet chemical analysis, two samples of the Chemical Lime Old product were tested using x-ray diffractometry. The fingerprints from these tests confirmed that calcium carbonate was the predominant mineral present in the sample, with small quantities of calcium hydroxide and trace amounts of silicon oxide also present. These test results are presented in Appendix B.

The test results indicate that the percent conversion of calcium hydroxide to calcium carbonate is quite variable, and that the locations of converted materials within the bag are also variable. This variability may be explained, in part, by the following differences:

Methods of producing, handling, and storing of fresh calcium hydroxide materials between the respective manufacturers prior to shipment to the CA facilities;

Methods of stacking the individual bags on the pallets and the corresponding amount of surface area of each bag exposed to the CA room atmosphere;

Quantity of calcium hydroxide used in CA rooms combined with variable exposure times (i.e., short-term versus long-term storage in the CA rooms);

Method of storage of the spent lime materials following removal from the CA rooms (i.e., under cover or exposed to the weather); and

Length of time in storage following removal from the CA rooms (i.e., short term vs. long term).

4.2.2 Comparative Brightness Analysis

Chemical Lime Company conducted comparative brightness analyses on each of the four composite samples prepared for this project. The results from these tests are summarized in Table 5, and the full test results are presented in Appendix C.

Table 5–Comparative Brightness Analysis

Sample	Whiteness Index (ASTM E313)
Hunter White Tile (Standard of Comparison)	84.42
Chemical Lime - 1994 (Old)	79.23[1]
Continental Lime - 1994 (Old)	59.58[1]
Chemical Lime - 1995 (New)	76.92[2]
Continental Lime - 1995 (New)	63.87[2]
Chemical Lime - Fresh June 24, 1996	81.33

[1]Average of three replicate samples
[2]Average of four replicate samples

These test results indicate that for both the Old and New lime samples, the Chemical Lime product is considerably whiter and brighter than the Continental Lime product. This is also readily apparent in visually examining the different materials. The reason for this is thought to be the method of lime production. The Chemical Lime product is produced using natural gas as the heat source, whereas the Continental Lime product is produced using coal as the heat source. It is believed that the coal introduces some residual carbon, which in turn causes a “yellowing” of the calcium hydroxide and the spent calcium carbonate.

4.2.3 Conclusions of the Analytical Test Results

The analytical test results indicate that there is considerable variability in the degree of conversion of calcium hydroxide to calcium carbonate, based on age of the spent lime, the placement of individual bags on the pallets and within the storage rooms, and the method of handling and storing the spent products. Given the difference in the molecular weight of each of these materials (calcium hydroxide with a molecular weight of 74 and calcium carbonate, 100), it is possible to separate these materials using air classification. It may also be possible to complete the conversion process by exposing the unconverted calcium hydroxide to carbon dioxide during the refining process.

The whiteness and brightness of the Chemical Lime and Continental Lime products is quite variable, with the Chemical Lime being considerably whiter and brighter than the Continental Lime. To produce high quality products for use in producing higher value products (i.e., white PVC pipe, paint and caulk compounds) it will be necessary to segregate the two products to avoid blending and discoloration of the whiter/brighter Chemical Lime product. The Continental Lime material would be well suited to those industries where color is of less concern (gray or black PVC pipe, rubber and agricultural feed supplements). The separate handling of the bagged spent lime materials will need to be incorporated in the general operations plan of the facility.

4.3 MANUFACTURER'S TESTING

The primary objective of the Manufacturer's Testing Program was to evaluate appropriate processing technologies, procedures, and economics, which in turn determine the suitability of the calcium carbonate materials for use as additives in the selected industrial applications.

As discussed in Section 4.1, the composite samples were processed to a uniform fine grained consistency using Land Technologies' bench scale micronizer. This processed calcium carbonate was packaged in water tight containers of various sizes and shipped to four manufacturing companies for further testing. The following sections present the purpose, methods, and results of these manufacture's laboratory tests.

4.3.1 Union Process–Laboratory Test Run-Dry Grind

Union Process, of Akron, Ohio, manufactures pulverizing and air classification equipment for use in a wide range of industrial applications, including calcium carbonate processing. A 25-pound sample of the Chemical Lime New composite sample was sent to Union Process. In addition, a 2-pound sample of Columbia River Company calcium carbonate that met PVC pipe specifications was also sent. This second sample was provided by PW Pipe Company to serve as the control for comparing particle-size gradation.

The purpose of this testing was to determine if the recycled calcium carbonate could be processed to the specified size range. This testing would also provide necessary information regarding process operations, including appropriate equipment selection and projected processing rates, energy requirements, and alternative methods of reprocessing oversized materials.

The device that was used for the testing was a bench scale apparatus (HSA-1) that uses a grinding media for particle size reduction. This apparatus is capable of producing results that can be scaled up to desired production rates with a relatively high degree of certainty. Two dry-grind tests of the composite sample were conducted, the first using 8 pounds of sample and 1.6 liters of zirconium balls as the grinding media, and the second using 8.5 pounds of sample and 1.8 liters of grinding media. The run time and other variables were kept constant between the two tests.

Following the testing, the four samples (one unground, one control, and two processed) were analyzed for particle size gradation using a Microtrac Particle Analyzer. The Dry-Grind test was conducted on August 14, 1996.

The Union Process test results are summarized in Table 6, and the complete Laboratory Test Report is presented in Appendix D.

Table 6–Union Process Test Results

Description	10% Passing (microns)	50% Passing (microns)	90% Passing (microns)	Average (microns)
Unground	4.748	107.1	286.1	129.5
Control	0.276	3.525	10.14	4.724
Test #1	0.312	3.404	12.20	5.461
Test #2	0.305	3.407	11.70	5.231

Note: The U.S. No. 200 Standard Sieve is equivalent to 75-micron particle size.

Based on these test results, it was concluded that the recycled calcium carbonate can be processed to meet the size specifications for the selected industries considered in this study. The specific equipment recommended for processing the lime at the selected production rates is discussed in Sections 5 and 6.

4.3.2 Jet Pulverizer Company–Micronizer Test

Jet Pulverizer Company, of Palmyra, New Jersey, manufactures jet micronizers for use in a wide range of industrial applications, including calcium carbonate processing. A 250-pound sample of the Chemical Lime-New composite sample was sent to Jet Pulverizer Company. In addition, a 2-pound sample of Columbia River Company calcium carbonate which met PVC pipe specifications was also sent. This second sample was provided by PW Pipe Company to serve as the control for comparing particle size gradation.

The purpose of this testing was to determine if the recycled calcium carbonate could be processed to the specified size range. This testing would also provide necessary information regarding process operations, including appropriate equipment selection and projected processing rates, energy requirements, and alternative methods of reprocessing oversized materials.

The device that was used for the testing was a bench scale apparatus (12-inch mill) that utilizes air flow and particle impact for size reduction. This equipment is capable of providing results that can be scaled up to desired production rates with a relatively high degree of certainty. Four tests of the composite sample were conducted, each at different in-feed flow rates. The air pressure, air temperature, and other variables were kept constant between the two tests. The third test, which was conducted at a feed rate of 200 pounds per hour did not meet the product specification, and therefore test No. 4 was conducted at a feed rate of 150 pounds per hour, which did meet the specification.

Following the testing, the five samples (i.e., one control and four processed) were analyzed for particle size gradation using a Coulter Counter Model T & TA. The test was conducted on August 21, 1996.

The Jet Pulverizer test results are summarized on Table 7, and the complete Laboratory Test Report is presented in Appendix E.

Table 7–Jet Pulverizer Test Results

Description	In-Feed Rate (Pounds/Hour)	Avg. Particle Size (microns)	100% Passing (microns)
Control		3.8	13
Test No. 1	50	2.8	8
Test No. 2	100	2.9	8
Test No. 3	200	5.2	(22% > 8 microns)
Test No. 4	150	4.3	10

Based on these test results, it was concluded that the recycled calcium carbonate can be processed to meet the size specifications for the selected industries considered in this study. The specific equipment recommended for processing the lime at the selected production rates is discussed in Sections 5 and 6.

4.3.3 The Biddle Company–Sample Caulk Compound

Two of the composite samples were sent to The Biddle Company, in St. Louis, Missouri, in February 1996. One of the samples consisted of the Chemical Lime New recycled calcium carbonate, and the second sample consisted of the Continental Lime New recycled calcium carbonate. Each of these samples had been processed using Land Technologies' bench scale micronizer to produce a uniform fine-grained material.

The purpose of these tests was to determine the suitability of the recycled calcium carbonate for use in producing caulk compounds, sealants and other joint filler materials.

The Biddle Company prepared three test samples of caulk compound, following the formulation for their product called *Aqua-Crylic–Siliconized Acrylic Sealant*. The first caulk sample was prepared as the control, and included the calcium carbonate product customarily used in preparing this product. The other two caulk samples were prepared using the respective composite samples of recycled calcium carbonate.

The control sample had a uniform, stable viscosity and produced a bead of caulk that was smooth and elastic. By comparison, the two recycled calcium carbonate samples produced a caulk that had a very unstable viscosity, which required the addition of considerably more water than called for in the formulation. In addition, the coarse nature of the powder produced a bead that was abrasive and rigid.

Two factors were believed to contribute to these unsatisfactory test results, including incomplete conversion of the calcium hydroxide to calcium carbonate, and fineness of the grind. In the first case, the calcium hydroxide would be reactive to water, causing adsorption into the mineral structure as part of rehydration. It is believed that this could be remedied by exposing the calcium hydroxide to a carbon dioxide stream as part of the recycling process operation. In the second case, the coarseness of the material can be remedied through further processing, as described in Sections 4.3.1 and 4.3.2.

4.3.4 MMC Mars Mineral–Sample Pellets

Two of the composite samples were sent to MMC Mars Mineral, in Mars, Pennsylvania, in May, 1996. One of the samples consisted of the Chemical Lime New recycled calcium carbonate, and the second sample consisted of the Continental Lime New recycled calcium carbonate. Each of these samples had been processed using Land Technologies' bench scale micronizer to produce a uniform fine grained material.

Mars Mineral manufactures equipment for use in preparing pellitized products for use in a wide array of industries. The purpose of the tests conducted by Mars Minerals was to determine whether pellets of the recycled calcium carbonate could be economically produced, primarily for use in agriculture both as a soil amendment and potentially as a feed supplement. The advantages associated with a pellitized material include control of dust and an extended release time for soil amendment.

To process the pellets, the lime is fed at a constant rate onto a rotating disk which is oriented at an adjustable angle above horizontal. As the disk rotates, a liquid binder is sprayed onto the surface of the powder, and the combined materials are caused to tumble down the face of the disk, thus producing rolled pellets. The pellets roll from the lower end of the disk as new powder and binder are added at the upper end of the disk.

For this test, the liquid binder consisted of 50 percent ligno sulfate. Brew-Ex, a liquid binder by-product of the beer making industry can also be used, but is not common in the western states because of the ready availability of ligno sulfate.

The Pellet Sieve Analysis is summarized in Table 8, and the lab test data and photographs of the finished pellets are presented in Appendix G.

Table 8–Mars Minerals Pellet Size Distribution

Mesh Size	% Retained	Accumulative % Retained
4	2.9	2.9
6	3.9	6.8
10	11.0	17.8
16	40.7	58.5
20	35.8	94.3
30	2.7	97.0
Pan	3.0	100.0

The conclusion of this test was that the recycled calcium carbonate could be prepared in pellitized form for use in various agricultural applications.

5. EVALUATION OF ALTERNATIVE REPROCESSING EQUIPMENT

5.1 PROCESS FLOW

Recycling of the lime by-product would occur in three stages, including:

Primary reduction and separation;
Secondary reduction; and
Pellitization and bagging.

The first two stages are essential to producing a high-quality calcium carbonate product for use as a filler material. The third stage does not require secondary reduction and is optional, being dependent on the value and marketability of the various pellitized end products. Examples of the equipment that may be used for each operation are shown in the Facilities Schematic Flow Diagram, Figure 1. The equipment that would be used and the three stages of processing are discussed in the following sections.

5.2 EQUIPMENT EVALUATION CRITERIA

The criteria that were used in selecting the equipment for processing the lime by-product into (1) calcium carbonate for use as filler materials, and (2) calcium hydroxide include the following:

Flow through capacity–10 tons per hour;
Debagging-minimum of 99 percent separation of lime from kraft paper bags;
Primary reduction-100 percent of the lime finer than the U.S. Standard No. 60 Sieve;
Separation-dry air classification and 98 percent separation of calcium carbonate from residual calcium hydroxide;
Secondary reduction–average particle size of 2 to 3 microns, maximum particle size of 8 microns;
Calcium carbonate quality–99 percent pure;
The capacity of the system may be increased by adding component equipment in parallel;

Capital cost plus installation and start-up not to exceed $1.2 million.

5.3 DESCRIPTION OF MATERIAL FLOW AND PROCESSING EQUIPMENT

The following sections discuss the flow of materials at each of the three stages of processing, along with a description of the individual components of the processing system. The equipment that is discussed are examples that may be used to meet the criteria presented above. The actual pieces of equipment selected for the processing system will be based on large scale testing and process validation, as described in the Section 7-Draft Operations Plan of this report.

5.3.1 Primary Reduction and Separation

Much of the lime by-product that is received at the processing facility will be stored outside on pallets. The pallets are stacked with an average of 20 to 25 bags per pallet (5 layers with 4 or 5 bags per layer). With an average weight of 50 pounds per bag, the pallets typically weigh 1,000 to 1,250 pounds. The pallets are stacked a maximum of four high, although considerable care is required in handling the pallets under these conditions to avoid toppling and the risk of injury to the workers.

The pallets are brought into the processing plant one at a time using a fork lift, and delivered to the debagging equipment. The pallets are unloaded by one or two workers who feed the bags one at a time to the debagging equipment, which separates the spent lime from the kraft paper bags. The bags are shredded and discharged into a hopper for subsequent baling and recycling. The lime consists of blocky calcium carbonate and powdery residual calcium hydroxide. The blocky material is broken down by the debagger to a size that passes through a 3/8-inch screen. The "de-lumped" material is then transferred pneumatically to a feed hopper attached to the primary reduction equipment.

From the storage hopper, the lime is then metered into the primary reduction equipment which further reduces the particle size to less than one-one hundredths of an inch (i.e., passing the U.S. Standard No. 60 Sieve). Following primary size reduction, the lime is transferred pneumatically to a set of cyclones for separation into calcium hydroxide, calcium carbonate and residual dust and paper fiber. The separation of these components is possible because of a marked difference in material densities and air flow characteristics. Once separated, the materials are placed in separate storage hoppers.

At this point in the process, each of the three materials may be sold for various uses. The calcium hydroxide and the residual dust and paper fiber may be used by the paper industry for use in making kraft paper products. All three of the materials may also be used for treatment of agricultural soils. To attain a higher value for the separated calcium carbonate, additional size reduction is required to meet the specifications for use as a filler in the various products discussed in Section 3 of this report.

5.3.2 Secondary Reduction

To attain a higher value for the separated calcium carbonate, additional size reduction is required to meet the specifications for use as a filler in the various products (refer to Section 3 of this report). As discussed previously, two tests were conducted to verify that the recycled lime could be reduced to meet the average 2- to 3-micron size requirement, with a maximum cut of 8 microns. This was successfully accomplished using (1) an Attritor ("stirred ball mill") available through Union Process, and (2) a Micron-Master Jet Pulverizer available through the Jet Pulverizer Company.

For all secondary reduction operations, additional equipment is needed, including such components as feed hoppers, metering equipment, drive motors or compressors, dust collectors, electrical controls, and duct work.

During the secondary reduction process, the finished ground product may also be coated with a stearate material to aid dispersion of the calcium carbonate in the various filler applications. Also at this point of the operation, the reduced calcium carbonate may be exposed to carbon dioxide gas to fully convert any residual calcium hydroxide to calcium carbonate. This would likely require heaters or dryers to prevent the accumulation of free moisture which results from the chemical conversion process.

Finally, the finished product would be stored in a hopper or silo prior to transfer into bulk (1-ton tote) bags. The finished bagged material would be stored inside the processing facility prior to shipment to maintain high-quality standards.

5.3.3 Pellitization and Bagging

The separated lime materials produced in the Stage 1 process may all be used in various agricultural applications. To produce a higher-value product with improved handling and dust control properties, the lime materials may be pellitized. Sample pellets were produced by MMC Mars Minerals using ligno-sulfate as a binding material, as part of this study. While this process is feasible, it is not considered essential to the main purpose of this study (i.e., to produce a high-value calcium carbonate product for the filler market).

The pellitization process recommended by Mars Minerals requires several steps and numerous pieces of equipment, including hoppers and metering equipment, a pin mixer, disc pelletizer, dryer, and screening equipment. This equipment is illustrated in the Facilities Schematic Flow Diagram, Figure 1.

6. COST EVALUATION OF PROCESSING RECYCLED LIME

An economic analysis was conducted for processing the spent CA lime, for a facility that would be equipped with the processing equipment described in Section 5–Evaluation of Alternative Reprocessing Equipment. This analysis was based on the following assumptions:

- Amount of lime received by the processing facility–Low 12,000 tons/year
- Amount of lime received by the processing facility–High 15,000 tons/year
- Process Flow Rate 10 tons/hour
- Operations Building, Leased 20,000 square feet
- Labor (no overtime, shifts added as needed) $8.50/hour
- Total labor, production plus maintenance and repairs–Low 1,400 hours/year
- Total labor, production plus maintenance and repairs–High 1,800 hours/year
- Depreciation on equipment, straight line 10 years
- Loan payment factor (N = 10 yr., I = 8%) 0.149
- Shipping FOB Recycle Facility
- Revenues
  - Calcium Hydroxide 20% @ $45/Ton
  - Secondary Grind–White Filler 40% @ $200/Ton
  - Primary Grind–Gray Filler 25% @ $120/Ton
  - Primary Grind–Agriculture 15% @ $25/Ton
  - Kraft Bags $140/Ton

6.1 LIME RECEIVED

The projected amount which could be received by a centralized recycling facility is estimated to range between 12,000 tons and 15,000 tons per year.

The costs by category are summarized in Table 9, and the complete spread sheet analysis is presented in Appendix G.

Table 9–Economic Analysis Summary Tons Per Year (TPY)		
Description	**12,000 TPY**	**15,000 TPY**
Facility	70,000	70,000
Utilities	45,000	55,000
Equipment	744,000	744,000
Equipment Installation	186,000	186,000
Depreciation	74,400	74,400
Equipment Maintenance & Repairs	74,400	74,400
Annual Equipment Loan Payments	124,713	124,713
Insurance on Facility & Equipment	20,000	20,000
Payroll plus Benefits	135,072	151,392
On-Call Consultation	10,000	10,000
Total Annual Operating Cost	553,585	579,905
Total Annual Revenue	1,517,400	1,896,750
Total Annual Revenue/Ton Lime Sold	126	158
Cost of Sales	581,264	608,900
Cost of Sales/Ton Lime Sold	48	41
Net Annual Revenue	936,136	1,287,850
Net Annual Revenue/Ton Lime Sold	78	117

7. DRAFT OPERATIONS PLAN

Research conducted as part of this project has identified the extender and filler markets as the most viable to justify a recovery process for spent lime recycling. To best utilize all of the resources, other processes as sidelines are discussed as part of this Operations Plan. Bag baling and separation of the residual calcium hydroxide is essential to an efficient operation and are described as part of the Process Flow diagram. Some of the spent lime, because of brightness, may not reach its highest potential value as a filler, so a pelletizing and bagging plant is discussed as an alternate use for the non-bright spent lime.

The Process Flow is illustrated within Figure 1 of the Facilities Schematic Flow Diagram, and is broken down into the following phases or stages:

1. Spent lime receiving and raw material storage.
2. Bag removal and primary reduction of spent lime.
3. Bag baling and paper recycling.
4. Separation spent lime into components.
5. Secondary reduction of calcium carbonate.
6. Conversion of residual calcium hydroxide.
7. Use of calcium hydroxide.
8. Pelletization
9. Bagging
10. Bulk storage or warehousing of finished product.

The vendors for the equipment described in this section can be found in Table 10.

Table 10–Equipment Vendor List Calcium Carbonate Recycling Project			
Equipment	**Company**	**Telephone**	**Contact Person**
Scott Debagger	Scott Equipment Co.	(612) 758-2591	Mr. Jim Lucas
Rotormill	International Process Equipment Co.	(609) 665-4007	Mr. Ronald Miller
Micron Master - Jet Pulverizer	The Jet Pulverizer Co.	(609) 235-5559	Mr. Daryl Bear
Dry Grind Attritor	Union Process Dlr.: Thurlow-Collins, Inc.	(330) 929-3333 (206) 771-5904	Mr. Larry Hess Mr. David Collins
Micro Jet	Fluid Energy Aljet	(215) 766-0300	Mr. Larry Flahart
Cyclone Collectors	Clean Gas Systems, Inc. Dlr.: Enright & Assoc.	(516) 756-2474 (206) 488-0766	Mr. John Enright
MMC Pelletizers	MMC Mars Mineral	(412) 538-03000	Mr. Bill Pattini
Hunter Colorimeter	Hunter Lab Dlr.: Sales & Engineering Assoc.	(703) 471-6870 (206) 883-4999	Mr. Eric Zivarts

7.1 SPENT LIME RECEIVING AND RAW MATERIAL STORAGE

Calculations by various methodologies and by general industry knowledge estimate the spent lime quantity in Washington at about 20,000 tons per year. Of this, it is expected that 12,000-15,000 tons would be delivered to a site in the Yakima region if a receiving facility was available. The spent lime would be delivered on pallets with 20 to 25 bags per pallet.

The spent lime bag weight is about 50 pounds, thus each pallet weighs at 1,000 to 1,250 pounds. Each pallet would occupy about 16 square feet of space and could carefully be stacked four high in the open without bracing. Stacking the pallets four high, the maximum safe limit when stacked in the open, would give 2 to 2.5 tons per 16 square feet, or 0.125 tons per square feet.

Of the surge release of material from the warehouses, storage should be provided for at least 25 percent of the volume of the expected receivables. That would require a pad area of 30,000 square feet for open space storage. This storage area requirement could be reduced by building bracing that would allow the pallets to be stacked more than four high. Raw material storage could also be reduced by issuing delivery dates to the CA Facilities, therefore putting the burden of temporary storage on generators. Most of these facilities have enough available space to manage some temporary storage. Minimum receiving and storage facilities should provide at least 15,000 square feet of pad space, preferably asphalt. Construction costs would be about $2 per square foot.

It would be desirable, but not essential, that the raw materials be stored under cover or inside. Outdoor storage may increase the moisture content, but does not appear to effect the quality of the calcium carbonate when left in the bags. The only essential equipment for receiving and storage of the raw materials is a forklift for moving pallets. The minimum specifications for the fork lift is a capacity to lift at least 1500 pounds and have a lift height of at least 12 feet. A higher lift capacity would allow for movement of more that one pallet at a time. Forklifts cost as low as $7,500 used, and upwards of $30,000 for new, higher-capacity models.

If finished products are stored in bulk in hoppers outdoors, the processing facility would have to be in a building and would require a minimum of 10,000 square feet. If a bag plant and pelletizing machinery are part of the facilities, 20,000 square feet should be the minimum building size. This would allow for some bag storage, but would not be adequate if all the lime goes to bagging. The focus of this report is on filler products which are generally sold in bulk. Construction costs of this type of building are about $100 per square foot. Leases, if an existing building can be found, would generally between 25 and 40 cents range per square foot per month.

7.2 BAG REMOVAL AND PRIMARY REDUCTION OF SPENT LIME

The first step in the reprocessing of spent lime is separating the lime from the bag. For each 50 pound bag, there is about one quarter of a pound of kraft paper, equating to 10 pounds of paper per ton processed. With 12,000-15,000 tons of spent lime processed per year, 60 to 75 tons of kraft paper would be available to bale and sell.

Separating the paper from the lime could be accomplished by several methods. Debaggers are manufactured by several companies. The Scott debagger is a manufactured product designed specifically for removing products from paper containers. This debagger, while efficient at paper removal, has several draw backs for the production of some products. The paper is shredded into small pieces that make it difficult to bale and undesirable to the kraft mills. Because of the fine shredding, more paper fiber would end up in the lime stream. While this fiber contamination is not important for agricultural uses, it is not desirable in filler products. The Scott debagger sells for about $50,000.

In trial operations, the bags were separated by hand over a screen. The forklift-fed pallets of bags to a platform where two laborers picked, cut, and emptied the bags on a vibrating screen. The bags were placed in a bin. After being shaken, the bags were hauled by the forklift operator, who then also operated the baling station. Production with two cutters and the forklift was 10 tons per hour. The benefit of this method is low up-front capital costs: screens and a platform could be put in place for less than $20,000. The drawback is the exposure of the laborers to the lime dust for extended periods of time. Occupational safety protection will likely be required, and could be expensive.

Other more mechanical processes can be designed and fabricated to custom specifications. Companies like R. A. Hanson in Spokane, Washington, can design and build a custom system for about the same cost as the Scott debagger. There are likely other debaggers on the market, but this project did no further research on this subject.

The spent lime would be carried by auger or belt conveyor to primary reduction. Primary reduction is necessary because calcium hydroxide powder solidifies while absorbing carbon dioxide in the storage facilities. Any of the uses for spent lime identified during this project would require a reduction of the lumps back to a powder. Agricultural use requires a minimum 60-mesh size. For use as fillers, reduction has to be to a maximum of 15 microns for lesser-quality calcium carbonate. The high-value calcium carbonate has to be reduced to an average of 2 to 3 microns with a maximum of 8 microns.

To obtain 60-mesh material, most any pulverizer or hammer mill would be adequate. Air swept milling machines can also dry any residual moisture from the spent lime. For lower grade filler markets that can accept 8- to 12-micron average particle size, several mechanical pulverizers are available that will reduce the material to this size in one step. The IPEC model 4500 Rotormill can mill 10 tons per hour and remove up to 15 percent moisture. This equipment costs about $260,000 as an installed package. Land Technologies has developed a pulverizer that may be able to perform at close to the above standards. It has not been tested on a production scale but theoretically is reliable and would cost under $100,000. Union Process makes an attrition dry mill for both primary reduction and secondary reduction. This equipment was one of the pieces tested for the very fine grinding of the high-value fillers. The Union Process primary milling machine sells for $100,000 plus installation.

The calcium carbonate has to be pre-ground to at least a 200 mesh before feeding into the attritor, and this requirement will drive the choice of the primary grinder. Use of this grinder will require an additional pneumatic pump as the grinder does not create its own discharge air stream. Selection of the primary grinder has many variables and is dependent on final product specifications. For the agricultural market, an inexpensive one-step mechanical pulverizer would be adequate. For filler, a more expensive milling machine is needed. The high-value fillers demand excellent dispersability, which requires a 3- to 5-micron size or the use of a dispersion agent such as calcium stearate on 8-to 12-micron size material. The 3- to 5-micron particle is more acceptable to the market. Because of the molecular and crystalline structure of the calcium carbonate, it is very difficult to reduce the particle size below 8 microns, and nearly impossible with mechanical milling. Any method requires primary reduction to an extremely fine particle size (less than 200 mesh) before secondary reduction to 3 to 5 microns. Any one of the three pulverizers mentioned will work for primary reduction as a precursor to micronizing to the high-value filler specifications targeted in this report.

7. 3 BAG BALING AND PAPER RECYCLING

The empty bags would be transported from the debagging station by conveyor, or in bins by forklift, to a bale compactor. There is about 10 pounds of kraft paper per ton of spent lime. Based on 12,000-15,000 tons of reprocessing, there would be 60 to 75 tons of kraft paper. Some paper reprocessors prefer this paper dusted with the lime and have paid as high as $200 per ton for the bales. The current price is approximately $130 per ton. While the income stream would be small, about $10,000 per year, it does provide 100 percent recycling of the spent lime. Balers are readily available on the used market and can be found for under $10,000. This study did not test this stream, but an earlier trial run conducted by Mr. Dave Nagle of Lime Technology, Inc., did use a paper baler. Mr. Nagle found the paper easy to market. The forklift operator was able to operate the baler and handle the bales with the forklift.

7. 4 SEPARATION OF SPENT LIME INTO COMPONENTS

Lime is a catchall name for several forms of an alkaline material generally made up of different molecular forms of calcium. The spent lime, as removed from the CA storage warehouses, is made up of calcium carbonate and calcium hydroxide (the first is commonly referred to as limestone or ag-lime, the second as hydrated lime). When used for agriculture, the combination is excellent for pH adjustments of acidic soils, as the hydrate reacts quickly but is soon gone, and the carbonate reacts slowly and lasts for long periods. When used for most other purposes, it is not desirable to have the hydrate mixed with the carbonate, especially in fillers. The reactivity of the hydrate causes adverse reactions in most formulas that use calcium carbonate as a filler (refer to section 4.3.3). It is absolutely essential that the carbonate and the hydroxide be either separated, or the hydrate is converted to carbonate, as discussed in section 7.1.6, below. The combined chemicals have a value restricted to what agriculture is willing to pay, which is generally lower than what the chemicals can be sold for when separated and processed.

After primary reduction, the spent lime would be pneumatically conveyed to air classifiers or cyclones. With air-swept pulverizers, such as the IPEC or the Land Technologies model, pneumatic conveyance is provided by the aerodynamics of the equipment. The Union Process Dry Mill Attritor would need an air classifier that can be mechanically fed. The air classifier or cyclone should be designed specifically to separate materials from a gas stream based on densities and aerodynamics of the particle shapes and not by size of particle. The pulverized spent lime will have similar particle sizes on both fractions. While the carbonate has a molecular weight of 100, the hydrate's molecular weight is 74. This 26 percent difference in density should theoretically allow efficient separation by a properly designed air classifier. Fisher-Klosterman, Inc. has provided the best data for density separation of this material. Separation was not tested as part of this project, and should be conducted before designing or building a separation system. Sound theories and manufacturer's information lend reasonable confidence that density separation on the spent lime is feasible.

The spent lime sample tests show a range from 5 to 40 percent hydrate, with an average of 20 percent. From the 12,000 to 15,000 tons available for processing, 2,400 to 3,000 tons will consist of hydrate. This hydrate has good value, and depending on its reactivity, would sell in bulk straight from the separator for $40 to $60 per ton. The hydrate could also be rebagged and used in the CA warehouses, and would generally sell for around $90 per ton. If carbonate marketing creates a better demand, the hydrate can be converted before secondary reduction, as described in section 7.6.

Pneumatically driven cyclones can be purchased for under $30,000, while mechanical air classifiers can cost up to $100,000. Used cyclones are very inexpensive, but it may be difficult to find the configuration required for this density separation of two solids in a gas stream. Cyclones require almost no maintenance and do not require an operator.

7.5 SECONDARY REDUCTION OF CALCIUM CARBONATE

The extender and filler markets have been identified as the best alternative uses for the spent lime as a raw material resource. These markets represent a 4.3 billion dollar industry, with plastics, paint, rubber, sealants and paper dominating the market. Of all the mineral fillers, calcium carbonate supplies over one-half of this entire market.

In Central Washington, Pacific Pipe Company, a PVC pipe manufacturer, uses approximately 10,500 tons of processed calcium carbonate per year, and currently pays about $240 per ton. Pacific Pipe's specifications call for a 2- to 3-micron average particle size, and a maximum cut of 8 microns.

In researching alternative processing methods, mechanical processes were eliminated after discussing specification requirements with manufacturers that had experience with lime reduction. A Jet Mill process was successfully tested, as was a high-speed dry media grinder (attritor). Both of these tested processes yielded a product that met the specifications provided by Pacific Pipe.

The Jet Mill proved to be very expensive, both to purchase and to operate. To achieve the particle size specification, compressed steam would be required for production processing. This would require a steam compressor and expensive technical labor (Boilermaker). The Manufacturer's cost estimate for equipment to produce 10 tons per hour was $950,000. The high capitalization costs, the high energy costs, and the technical expertise that is required make this process option undesirable.

The second tested process was the dry mill media grinder built by Union Process. This process uses a dry media accelerated to a high speed in a cylindrical container. The pre-ground calcium carbonate is fed into the media container consisting of small 1- to 3-mm grinding beads circulated at high speeds in a continuous circular motion, and the calcium is reduced by inter-particle collisions. The ultra fine powder is discharged by centrifugal force toward the bottom of the mill. The selected machine, the HSA-100 Attritor, can produce 5 tons per hour of 2- to 3-micron size particles, and costs $117,000. To achieve a targeted production rate of 10 tons per hour, it would take two units operating in parallel.

7.6 CONVERSION OF RESIDUAL CALCIUM HYDROXIDE

The spent lime, as described above, is a mixture of calcium carbonate and calcium hydroxide. By air classification, 96 to 99.9 percent of the hydrate can be separated from the carbonate. Some filler uses may require that the carbonate be free of any hydrate. If the use demands pure carbonate, this stream should be bathed in a carbon dioxide bath. This can most effectively be done in a turbulent air stream while being pneumatically conveyed to secondary milling. If the carbonate faction of the products has the better economic return, the process could also pass the hydrate through the carbon dioxide stream for conversion before secondary reduction.

Land Technologies has conducted limited tests on this stage of processing. The recommendations here are based mostly on theory and conversations with the National Lime Institute. The original test with the Biddle Company, using the pulverized spent lime, showed the effect of the hydrate when used in their caulking compound. The heat of hydration, caused by the hydroxide, solidified the caulk in the container. This test material had no previous separation of hydroxide, so it is estimated some 20 percent of the sample used was hydrate. Perhaps most processes can be tolerant of trace amounts; however, this should be thoroughly tested before being used as a filler.

When the calcium hydroxide is bathed with the carbon dioxide gas, calcium carbonate and water will be formed as an exothermic reaction (heat will be released). This free water will likely have to be driven off before secondary reduction. Based on principles of chemistry, for every 100 pounds of calcium hydroxide that would be converted, a minimum of 59.45 pounds of carbon dioxide would be needed for complete conversion of the hydroxide to calcium carbonate. This is the minimum carbon dioxide required in an ideal reaction, and actual quantities would be larger depending on various efficiencies of the process. The reaction would yield 135 pounds of calcium carbonate and 24.5 pounds of water (18 percent). This water would have to be removed before secondary reduction. In an air-swept system, this could be accomplished in a cyclone. Minimal amounts of heat could be added to assist in water removal.

The above scenario is based totally on chemical reaction formulas. This study did not completely test these theories for actual application; however, they are based on accepted and sound chemistry principles.

7.6.1 Conversion Costs

The economics of the calcium hydroxide conversion process will depend on the cost of carbon dioxide. It will likely not be economically feasible for conversion of the bulk calcium hydroxide, especially using imported carbon dioxide. The 1 to 3 percent that may be retained in the carbonate stream will require conversion, although the volume of carbon dioxide will be comparatively low. While importing the carbon dioxide is possible, onsite generation of carbon dioxide may be a preferred alternative.

To generate pure calcium carbonate, a more passive means of conversion may also be developed. Exposure of the hydroxide to the atmosphere during storage will, over time, convert it to carbonate. More research should be applied to this step if all calcium carbonate is desired.

7.7 USE OF CALCIUM HYDROXIDE

There were considerable variations in the actual portions of non-reacted calcium hydroxide in the samples evaluated, however, the average volumes were about 20 percent hydroxide and 80 percent carbonate. This average proportion indicates that 2,400 to 3,000 tons of calcium hydroxide would be a by-product of the separation process. This stream may be converted to carbonate as discussed in section 7.6 or it may be sold as a product itself. Its ultimate value would depend on its reactivity. At the very least, the hydroxide is worth approximately $40 per ton to the Boise Cascade paper plant outside of Wallula, Washington, based on hydroxide purchased during an earlier pilot phase. In the paper production process, calcium hydroxide is used to neutralize acidic process materials. The Wallula plant has bought the screened hydroxide in bulk with heavy contamination of calcium carbonate, and paid only for that portion which is tested to be hydroxide.

As a solidification and stabilization agent for soils and sludges, calcium hydroxide is also worth $40 per ton, however, usage of this material in stabilization projects is usually seasonal as it is tied to the construction industry.

Theoretically, the calcium hydroxide could also be rebagged and sold back to the CA warehouses for use in preserving fruit. The viability of this use would depend on the reactivity of the reclaimed hydroxide and confirmation testing the economics of re-bagging the hydroxide would also weight (heavily) on the viability of this use. In bags, the newly produced hydroxide sells for $90-$130.

Formal reactivity tests on the separated calcium hydroxide have not been completed as part of this project and should be further researched before process design is implemented. From an economic standpoint, this stream could yield $200,000 to $300,000 gross dollars as a by-product to the calcium carbonate process. If rebagging and selling the hydroxide back to the CA warehouses proves to be viable, a fairly captive market would already be in place.

7.8 PELLETIZATION

For most agricultural uses, it is most desirable to pelletize the lime because the pellets are dust free, thereby eliminating excessive free lime, which drift during application. With some animal feeds, the calcium carbonate serves as a mineral supplement, and is better accepted as a pellet.

Because there had been some interest in the use of the spent lime for agricultural use, Land Technologies did preliminary testing on the viability of producing pellets. The typical pelletizer used in the agricultural industry is the disk pelletizer (also known as a pan granulators). Mars Minerals, of Mars, Pennsylvania, is one of the manufacturers of disc pelletizers and has extensive experience with lime pelletization. A sample of finely processed lime was sent for manufacturer's testing. Cost information of the equipment, along with process costs, were also provided. The tests produced a stable, functional pellet, however, the apparent costs for equipment and operations was excessively high for the projected size of this lime recycling operation.

Based on the Mars Minerals equipment cost proposal, the cost of new equipment would be approximately \$750,000 plus roughly \$600,000 to install. Operational costs would also be high, requiring a binder (Lignin Sulphate or BrewEx) and heat for a rotary dryer. The purchase of used equipment or use of an alternate process may make pelletizing more cost effective, but at the projected volumes it does not appear to be practical based on standard pelletizing processes. The pellitized agricultural lime has a worth of only \$60 per ton. To reduce the cost per ton to an acceptable price, it would require in excess of 50,000 tons per year to be processed. Despite the apparent high cost of pelletization, a pelletized product is easier to market to the agricultural industry.

7.9 BAGGING

If the calcium hydroxide was found to be suitable for reuse on the CA storage warehouses, it would have to be re-bagged. Bagged calcium carbonate for agricultural use wholesales for about \$60 per ton. Based on industry standards, powdered materials cost between 30 and 50 cents to bag (i.e., on a per bag basis). For 50-pound bags, this equates to \$12 to \$20 per ton. For 35-pound bags, bagging costs would be \$15 to \$25 per ton. The variances cover a range in bag costs and other efficiencies related to volumes.

The hydrated lime is usually bagged in 35 pound bags, especially for CA Storage. Calcium carbonate is often sold in 50-pound bags.

Bagging and pelletizing equipment can be bought new for about $30,000. This equipment is also relatively easy to find used at a fraction of the cost.

7.10 BULK STORAGE OR WAREHOUSING OF FINISHED PRODUCTS

Whatever product is produced will require some storage before sale. Bulk powder will have to be stored in silo type hoppers and bags will have to be warehoused on pallets. The volume or area requirements will differ depending on type of market to be served.

Most agricultural lime markets have seasonal demands, and therefore lime is typically bagged during the winter for spring deliveries. Spring has the biggest demand followed by a small surge in demand for fall applications. For bagged agricultural products, warehousing would have to be available for an entire season's sale volume. CA storage requirements also come in surges, the hydrated lime would have to be bagged and stored for this fall market.

The filler market, on the other hand, usually has a daily demand. Pacific Pipe Company, a filler user in Sunnyside, Washington, requires 30 tons every day of the year with little tolerance for missed or delayed deliveries. As such, the lime recycling facility should have hopper storage installed, and equivalent to a one month supply to insure a daily supply in case of delay in production. Allowance for about 1,000 tons of hopper storage should be built in to ensure a steady supply to the filler industry.

8. CONCLUSIONS

This evaluation has demonstrated that the spent lime can be reprocessed to meet stringent industry product quality specifications. Economically, filler markets also represent an outstanding opportunity, given that calcium carbonate is currently being purchased for upwards of $200 per ton for use in making various PVC pipe products. The primary marketing focus should therefore be to demonstrate that a high-grade recycled calcium carbonate product(s) can be produced for specific filler markets in quantities that are sufficient to match industry demand. Other markets also exist for both the residual calcium hydroxide and kraft paper bags, both of which contribute to the project revenue stream.

Several potential end use industries are located in close proximity to the controlled atmosphere warehouses that generate the spent calcium carbonate. A centralized lime recycling facility could easily be located in the same geographic area, thereby minimizing the cost of transport of the finished product More distant markets also exist and the processed lime could be transported by road or rail, although this is less favorable because of the cost of transportation.

This project further demonstrated through actual manufacturer's testing that processing equipment is readily available to reduce the particle size of the lime to meet the industry specification of 2 to 3 microns (average size range), and 8 microns (maximum). As part of the recycling process, residual calcium hydroxide would likely be separated as a separate product, and the remaining minor quantities of calcium hydroxide would be converted to calcium carbonate with carbon dioxide.

The economic analysis conducted for this project relied upon conservative assumptions, and the result of this evaluation was that calcium carbonate recycling is economically feasible given the projected costs and anticipated revenues. In addition to the exciting economic opportunities, this project also represents an opportunity to convert a problem "waste material" into a range of products that are 100 percent recycled, and that reduce the demand placed on natural limestone resources at the quarry.

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APPENDIX A

SAMPLING PLAN AND PHOTOGRAPHS

APPENDIX B

LABORATORY TEST RESULTS

APPENDIX C

COMPARATIVE BRIGHTNESS ANALYSIS

APPENDIX D

MANUFACTURER'S TESTING

Union Process–Laboratory Test Run-Dry Grind

APPENDIX E
MANUFACTURER'S TESTING

Jet Pulverizer Company–Laboratory Micronizer Test

APPENDIX F
MANUFACTURER'S TESTING

MMC Mars Minerals -Test Data

APPENDIX G

ECONOMIC ANALYSIS SPREADSHEET

CA LIME RECYCLING PROJECT			
ECONOMIC ANALYSIS			
ASSUMPTIONS	Low Rate	High Rate	
Annual Lime Received (Tons)	**12,000**	**15,000**	
Operations Bldg. / Wrhs. Area - Leased (Sq Ft)	20,000	20,000	
Labor ($ / Hour)	8.50	8.50	
Peak Production	Add Shifts	Add Shifts	
Total Production Hours / Year	1,400	1,800	
Straight Line Depreciation (Years)	10	10	
Loan Payment Factor (@ 10 Year Payoff & I = 8%)	0.15	0.15	
Alternative 1			
CaCO3 (2-6 micron range) sold in bulk			
Ca(OH)2 (air classified powder) sold in bulk			
Description	**Cost**	**Cost**	
Facility:	**70,000**	**70,000**	
Lease Amount / Sq. Ft. (@ $2.00 / Sq. Ft. / Yr.)	40,000	40,000	
Lease Hold Improvements (Lump Sum)	10,000	10,000	
Building Dust Control & HVAC (Lump Sum)	20,000	20,000	
Utilities:	**45,000**	**55,000**	
Electricity Cost @ $25 / Production Hour	35,000	45,000	
Other Utilities (Lump Sum)	10,000	10,000	
Equipment:	**744,000**	**744,000**	
De-Bagger (1)	45,000	45,000	
Paper Bailer (1)	10,000	10,000	
Hopper (1)	5,000	5,000	
Auger Type Conveyor (1)	5,000	5,000	
Primary Particle Reduction (1) - LTI Impact Pulverizer	75,000	75,000	
CGS Cyclone / Air Classifier (Quad Set)	10,000	10,000	
CGS Bag House	30,000	30,000	
Pneumatic Conveyors	10,000	10,000	
Hopper (CaCO3)	5,000	5,000	
Hopper (Ca(OH)2)	5,000	5,000	
Auger Type Conveyor (1)	5,000	5,000	
Secondary Particle Reduction (2) - Union Process Attritor	434,000	434,000	
Cyclones (Quad Set)	20,000	20,000	
Pneumatic Conveyor	0	0	

Pneumatic Conveyor	0	0	
Bagging Plant	25,000	25,000	
Pelletizer	0	0	
Hopper for Finished Pellets	0	0	
Fork Lifts (2)	20,000	20,000	
Front End Loaders	40,000	40,000	
Equipment Installation	**186,000**	**186,000**	
Depreciation	**74,400**	**74,400**	
Equipment Maintenance & Repairs (@ 10%)	**74,400**	**74,400**	
Equipment plus Installation Loan Value (@ 90%)	**837,000**	**837,000**	
Annual Equipment Loan Payments	**124,713**	**124,713**	
Insurance on Facility and Equipment (Lump Sum)	**20,000**	**20,000**	
Payroll Plus Benefits:	**135,072**	**151,392**	
Number of Production Managers	1	1	
Production Manager Annual Salary	40,000	40,000	
Number of Administrators	1	1	
Administrators Wage / Hour	12	12	
Annual Administrative Hours	2,080	2,080	
Annual Administrative Cost	24,960	24,960	
Number of Laborers	4	4	
Production Labor Wage / Hour	8.50	8.50	
Production Hours per Year	1,400	1,800	
Annual Labor Cost	47,600	61,200	
Total Payroll	112,560	126,160	
Benefits, Fringe & FICA @ 20% Salaries)	22,512	25,232	
On-Call Consultation & Professional Services	**10,000**	**10,000**	
Total Annual Operating Cost	**553,585**	**579,905**	

Revenues	**1,517,400**	**1,896,750**
Lime Processed (Tons / Year)	12,000	15,000
Tipping Fee ($3.00/ Ton)	36,000	45,000
Lime Sales - Alternative 1 - Bulk		
Calcium Hydroxide - Air Class. @ 20% @ $45/ton	108,000	135,000
Secondary Grind - White Filler (40% Total @ $200 / Ton)	960,000	1,200,000
Secondary Grind - Gray Filler (25% Total @ $120 / Ton)	360,000	450,000
Primary Grind - Agriculture (15% Total @ $25 / Ton)	45,000	56,250
Kraft Paper Processed (Tons / Year)	60	75
Kraft Bag Sales ($140 / Ton)	8,400	10,500
Total Annual Revenues	**1,517,400**	**1,896,750**
Total Annual Revenues / Ton Lime Sold	**126**	**158**
Cost of Sales		
Facility	70,000	70,000
Utilities	45,000	55,000
Depreciation on Equipment	74,400	74,400
Maintenance & Repairs on Equipment	74,400	74,400
Annual Equipment Loan Payments	124,713	124,713
Insurance on Facility & Equipment	20,000	20,000
Payroll & Benefits	135,072	151,392
On-Call Consultation & Professional Services	10,000	10,000
Subtotal Cost of Sales	553,585	579,905
Other Costs @ 5 percent Subtotal Cost of Sales	27,679	28,995
Total Cost of Sales	**581,264**	**608,900**
Cost of Sales / Ton Lime Sold	**48**	**41**
Net Sales	**936,136**	**1,287,850**
Net Sales / Ton Lime Sold	**78**	**117**