Integrated Coal Ash Processing Plant
Business Feasibility Study

Report to the
Carolina Ash Products Consortium

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1.0 Executive Summary

Background

This Business Feasibility Study for an Integrated Coal Ash Processing Plant is part of a larger project to demonstrate the viability of processing coal ash from the Progress Energy power plant in Skyland, NC, into desired and marketable by-products. This project's goals are to create new industry and jobs, have a positive environmental impact in the region and take a step toward long-term, sustainable prosperity. The larger coal ash project has been in process since October 2000 using a variety of public and private sector funds with heavy stakeholder involvement from the waste generators, researchers, potential end users, technical assistance providers and others. This Business Feasibility Study is funded by an Economic Innovation Grant from the NC Rural Economic Development Center, and has been underway since July 2005.

Technology

Currently, the Skyland power plant generates and landfills in excess of 150,000 tons of coal ash annually. Through existing industrial proven processes, this ash can be broken down into several useful by-products. In many regions, coal ash has been used in concrete.

The coarse fraction, known as bottom ash, has been used as a fine aggregate in manufacture of concrete masonry units (CMU) and similar products.

The finer material, known as type F fly ash, has been used commercially to replace up to 20% of the Portland cement in concrete. The long-term strength of concrete made with fly ash substitution has proven acceptable or even better than traditional mixes. Since the Portland cement is by far the most expensive part of the concrete formulation, this practice provides considerable economy.

Since the 1990's, power plants have changed their coal burning practices to meet EPA regulations limiting nitrogen oxide (NO_x) emissions. This has resulted in ash with much higher carbon content. Higher carbon levels make the fly ash unusable in the concrete industry because the carbon interferes with chemicals added to entrain air in the concrete. One primary feature of the process developed in this project is a mechanism which removes most of the carbon from the fly ash, bringing it back into specification for the concrete industry. A traditional and proven flotation process similar to that used to refine certain mineral ores was utilized. The carbon removed comprises another marketable product.

Phase 1 Pilot Plant

Several tons of Progress Energy coal ash were processed in the NC State University Minerals Research Laboratory (MRL) in Asheville, NC. Bottom ash was separated by screening. The fine material passed through the flotation process resulted in three streams: high carbon, low carbon and medium carbon ash. The high- and low-carbon streams were dried and evaluated as product lines. The medium carbon stream was then combined with paper mill sludge, pelletized, and fired to produce lightweight aggregate. This aggregate is used to replace stone in numerous applications and products for improved engineering performance and reduced weight.

Market Potential

This Business Feasibility Study focused upon specific customers for the products described above, and upon the costs of constructing and operating a processing plant to manufacture those products. It finds that there does appear to be an ample market for carbon and for low-carbon type F fly ash within the region. Only one customer for bottom ash has been found thus far. The market for lightweight aggregate is dominated by a very efficient and high-quality producer, Stalite, located just east of Charlotte, NC. Teaming up with Stalite rather than competing with them is highly advised, and Stalite has expressed a willingness to explore this possibility.

In all cases, the potential customers for coal ash by-products require strong batch-to-batch consistency. They also require that the products compete with respect to price. This is believed to be achievable.

Business Models

As part of this business feasibility study, profit/loss models were built, detailing estimates for plant investment costs, production costs, and product selling prices. These models reflect several possible business approaches, including a fully integrated concept as well as several arrangements making more limited product lines. The returns on investment (ROI) for most of these simulations were in the 8-16% range, without placing a value on the avoidance of landfilling costs to the utility company providing the ash, or to the paper manufacturer providing sludge (where appropriate).

A plant that produces only carbon and Type F ash can be built for approximately $3 million. To include the manufacture of unfired “green pellets” to supply Stalite’s lightweight aggregate production is estimated to cost about $5 million. The cost of building a fully integrated plant that fires the pellets and produces the aggregate is estimated to be about $9.3 million. All estimates are exclusive of land costs.

Plant Configurations

Manufacturing Plant Configuration	Ash Landfilled (tons)	Capital Costs (million $)	ROI (%)
Current – no plant	100,000	0	0
Carbon & Type F Ash	33,000	3	12.8
Carbon, Type F Ash & Green Pellets	0	5	9.2
Fully Integrated	0	9.3	12.5

The anticipated yield of a manufacturing plant utilizing all 100,000 tons of waste ash produced at the Progress Energy plant in Skyland is shown in the following table:

Table I. Anticipated Annual Production

	tons/year
Carbon	7,000
Bottom Ash	20,000
Low LOI Type F Fly Ash	40,000
Lightweight Aggregate (or Green Pellets)	33,000

Assigning a value to landfill cost avoidance and paying the plant to take the waste ash can impact the economics considerably. For example, if a value of $5/ton were placed on ash delivered to the plant producing just carbon and type F ash, the estimated ROI would jump from 12.8% to 32%. We estimate typical ash landfill costs for Progress Energy to be in the range of $4 to $8 per ton.

Conclusions

This Business Feasibility Study concludes that implementing this technology through the creation of a new manufacturing plant appears to be financially feasible and that markets exist for the products it would create. Capital risk may be further mitigated through a build-out of the plant in a step-wise process. For example, a manufacturer might start by building the plant to produce carbon and type F ash. Once that system is on line and operating well, they could explore expansion through a partnership with Stalite to produce green pellets for Stalite's existing lightweight aggregate plant. Marketing of bottom ash can be pursued as a separate enterprise at any point.

2.0 Introduction

This project is based on the idea of processing coal ash from a local power plant in such a way that all of the ash becomes a useful and marketable byproduct, eliminating the need for any landfilling and creating an additional income stream for the utility burning the coal. The goal is to have a positive environmental impact in the region, while creating jobs and taking a step toward sustainable prosperity.

A consortium, eventually adopting the name Carolina Ash Products, or CAP for short, was formed with representatives from local power companies, recyclers, the Minerals Research Laboratory of NC State University and Waste Reduction Partners. Operating on grant funding from the N.C. Division of Pollution Prevention and Environmental Assistance (DPPEA) as well as contributions from some of the consortium members, initial laboratory experiments were carried out at the Minerals Research Lab in Asheville to demonstrate the technical feasibility of the basic concepts. Most of the technical concepts had been demonstrated in earlier work by other organizations, although not necessarily pulled together into a comprehensive format.

In 2005, the project moved into the first pilot stage intended to demonstrate the feasibility of the concepts on a larger scale and to produce enough of the various end products for initial qualification testing by potential end users.

Beginning in late 2005, a study began to evaluate the business and commercial aspects of the concept in more detail. Objectives of this commercial study were to:

a) Identify specific customers for the end products;
b) Identify technical and business issues of the customers;
c) Estimate the cost of plant construction;
d) Estimate manufacturing costs for the products;
e) Build a profit model for plant operation and derive from this a return on investment;
f) Explore possible business structures for plant construction and operation;
g) Identify specific environmental regulations and procedures that would need to be addressed in planning plant construction and operation.

The purpose of this report is to summarize the findings of the commercialization study and to suggest possible next steps for the CAP consortium to enable and promote some or all of the original concepts into the realization of one or more robust and successful enterprises.

3.0 The Process

Traditionally, much of the ash produced by power generation has been used as additives to concrete. The coarse material (+ 100 mesh), known as bottom ash, can be used as a filler in making concrete masonry units and other applications.

The finer material (-100 mesh), known as fly ash, was often used to replace up to 20% of the Portland cement in ready-mix concrete. The long-term strength of the concrete made with such a fly ash substitution was either nearly equal to, or in some cases even greater than concrete made without the ash. The American Coal Ash Association (ACAA) records show considerably greater strength in concrete manufactured with fly ash.

During the 1990's EPA regulations limiting NO_x emissions from power plants have resulted in fly ash with increased carbon content. Higher carbon levels make the ash unusable in the concrete industry because the carbon interferes with chemicals added to entrain air in the concrete. The carbon content is generally measured by a Loss on Ignition (LOI) test which simply measures the weight loss of a sample upon heating to a high temperature. Beginning with a dried ash sample, virtually all of the weight loss can be attributed to carbon – thus "LOI" is a common industry term.

Maximum LOI limits are set by state regulations, generally around 3.5%. The LOI from power plants is now often in excess of 10%.

For this reason one of the main features of the proposed process is a mechanism which separates at least most of the carbon from the fly ash. A flotation process similar to that used to refine certain mineral ores was chosen.

Figure 1 shows a simplified flow diagram of the plant operation.

Coarse Screening and Dispersion

The incoming ash from a landfill or pond is put over a very coarse 6-mesh screen to remove the largest particles and other debris that may have found its way in with the ash. This comprises less than 1% of the material to be treated, but it is desirable to remove it so that it does not interfere with downstream operations.

The material then moves to an attrition scrubber where it is slurried with water and agitated to break apart particles which may be loosely bound together.

From there it is put through a 30-mesh screen. The plus 30-mesh fraction is collected as part of the bottom ash. The minus 30-mesh fraction (the bulk of the material) moves into the flotation process.

The Flotation Process

In the flotation process, a very small amount of a flotation agent is added to the slurry. Air is also incorporated, and the slurry agitated to create a froth. The flotation agent is generally an oil. In fact, fuel oil can be used, although more effective agents developed specifically for the application are available. The slurry progresses through a series of dams and weirs. The flotation agent, having a greater affinity for the carbon than for the mineral content of the ash, tends to float the carbon to the top while the heavier minerals settle to the bottom. The process can be done in multiple stages to achieve more complete separation.

High LOI Stream

Three streams of material emerge from this process. One is the high carbon (high LOI) fraction. This is put through a filter to mechanically remove as much water as possible and then through a drying process to bring the water content down below 3%. This high carbon stream is one of the end products of the plant.

Low LOI Stream

The second stream emitted from the flotation process is the low-carbon (low LOI) stream. The parameters of the flotation process are adjusted so that this stream consistently meets the specification for Type F fly ash.

An additional size separation is done on the low LOI stream either by screening or by hydro cyclone or a combination. The diagram shows a 100-mesh screen, but even finer screens may be required.

Like the high LOI stream, the low LOI stream is then filtered and dried to low moisture content. This stream constitutes another end-product of the plant.

Intermediate LOI Stream

The flotation process also produces a third stream of material. This fraction is intermediate in carbon content, too high to qualify as low-carbon type F ash, and too low to be of interest as a fuel or additive for steel making. This intermediate stream is combined with sludge, as, for example, sludge from a paper mill. The mixture is pelletized, dried and fired to about 2200° F, forming a lightweight aggregate. As described in greater detail later, lightweight aggregate is a desirable constituent in concrete.

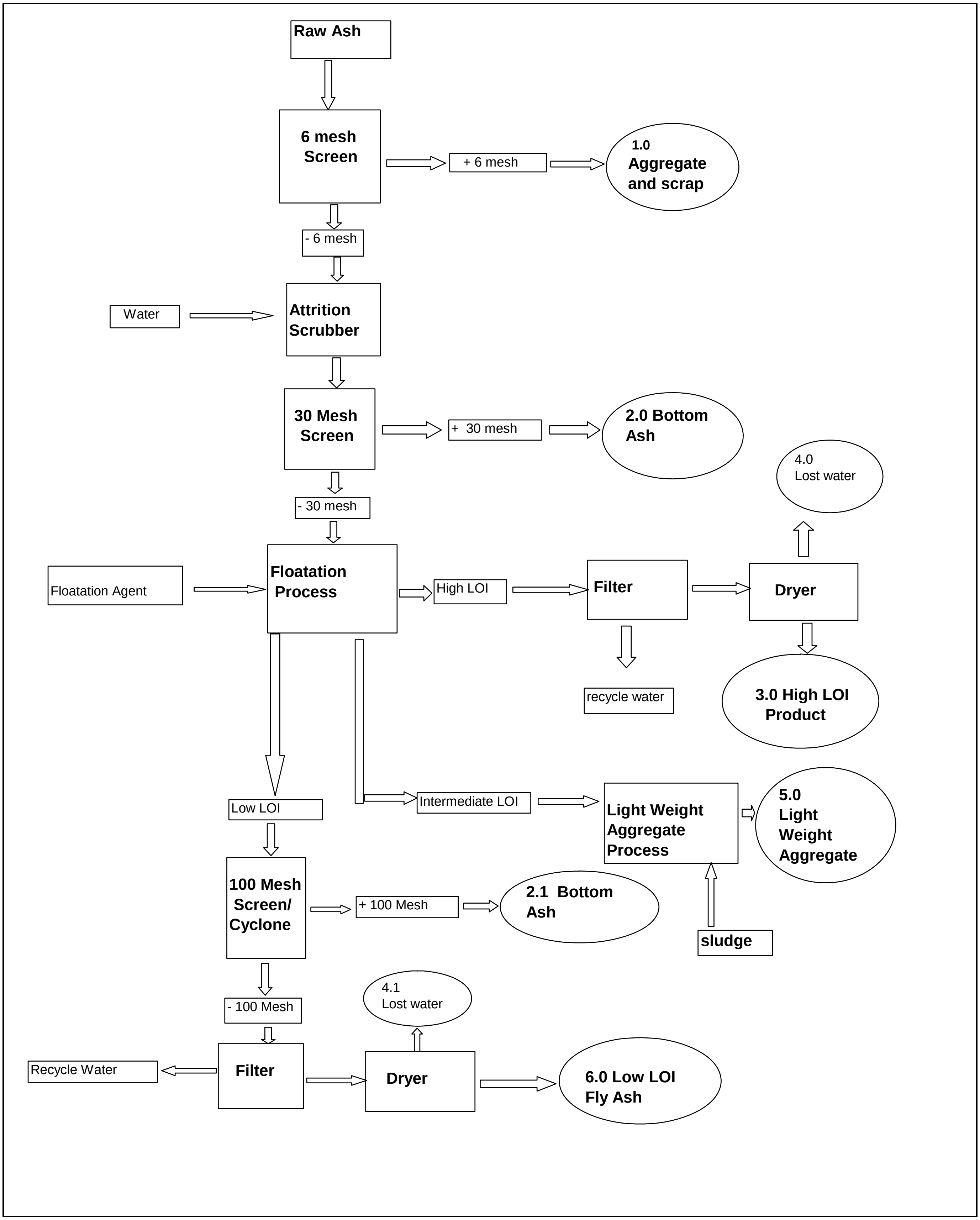

Figure 1. Simplified Flow Diagram

4.0 Parameters and Assumptions

This study focused on the Progress Energy power plant in Skyland, NC as the source of the ash. That plant produces about 100,000 tons (dry basis) of ash per year with an average LOI of about 12%.

At the beginning of the study, the source of sludge was assumed to be the landfill of the former Ecusta Paper plant in Brevard, NC. Because of some technical and business problems uncovered in the course of our work, this assumption was changed, with focus shifting to the by-product sludge from Blue Ridge Paper in Canton, NC.

Blue Ridge produces paper mill sludge which is about 35% solids coming off the belt presses. Of the solids, roughly 50% is fiber and 50% is calcium carbonate. They also process municipal sludge, but this amounts to less than 5% of their volume. Volume is about 50 tons per day, subject to considerable variability. It is trucked 5 miles to a landfill which Blue Ridge owns.

In most versions of the economic model, we assumed that all of the ash from the Skyland plant and all of the sludge from Blue Ridge would be processed by our plant.

5.0 Market and Business Findings

The previous research done for the grant proposal formed a very good foundation for this part of the economic study. Information had been gathered on uses of the products, and some information on market prices was included. One of the objectives of this part of the study was to update the market prices of products and to confirm that a local market existed for a plant of this size. In most cases, consortium members or former members provided direct market contacts.

As described above, the plant will produce four product lines:

Anticipated Annual Production
from 100,000 Tons per Year of Ash

	tons/year
Carbon	7,000
bottom ash	20,000
Low LOI fly ash	40,000
Lightweight aggregate	33,000

5.1 Carbon

The high LOI stream from the flotation process yields a product containing about 70-75% carbon, the remainder being ash. The Btu content was measured at 10,000 Btu per pound. A detailed analysis is shown in the table below.

Table II. Carbon Analysis from Pilot Run

	54-33286-06	54-33286-04	54-33286-03	mean
% moisture	1.4	0.85	1.58	1.28
% ash	22.1	26.69	31.09	26.63
% volatile	2.62	2.5	2.29	2.47
% fixed carbon	73.89	69.96	65.04	69.63
Btu/lb	10828	10306	9439	10191
% sulfur	0.4	0.39	0.44	0.41

Fuel

The high LOI material can be burned as fuel at the power plant. Both Progress Energy and Duke Energy confirmed that this would be possible. Progress Energy pointed out that their rates are based partially on fuel costs. Some discussion would be needed to work through this issue with the state so that it would not appear that they are charging twice for the same fuel.

In any case, for a fuel application the value of the carbon stream could best be estimated by equalizing it to coal on a per Btu basis. For instance, the carbon from the first pilot plant had a Btu content of 10,919 Btu/lb. Coal averages about 12,000 Btu/lb; therefore, the value of the carbon product is 90% the price of coal. At this writing, coal is selling on the spot market for $55/ton so the carbon product would have a value of about $50/ton as fuel.

Steel Industry

Another potential market for the carbon is the steel industry. For instance, Full Circle Solutions has sold a similar product as ladle topping. Coal or coke is also sometimes added to electric arc furnaces as a supplemental source of heat and to help in the metal reduction.

A meeting was held with Nucor Steel in Charlotte which uncovered two applications:

Direct Charge Carbon. This is usually coal or coke that is charged into the electric arc furnace along with oxygen. The combustion provides additional energy, thus saving on electric power.

For this application the low volatile fraction and the low sulfur content of the material made in the pilot run were especially attractive. Lower ash content would be preferred. While the ash is not especially harmful in this application, it brings no value. Therefore, material with lower ash is more valuable on a pound-per-ton basis.

The particle size is too fine. The feeding system needs particles of about one-eighth to one-half inch, which is referred to as barley-sized grain.
.
The value of direct charge carbon is about $100/ton.

Two tons of pelletized material would be needed for a commercial trial. The Beckley mill near Charleston would be the most likely customer, considering location. The exact qualification process after the first commercial trial was not specified.

Iron Production – New Process – Nucor is implementing a new iron reduction process which they were not prepared to describe in much detail. For this process they could use the material as is. In fact, they could use it without drying because they have a drying step for other materials, using waste heat. The value would be less, around $50-60/ton, but processing costs would be reduced because no drying would be needed.

Nucor could easily use all of the high LOI product of the proposed plant. In fact, the 7,000 tons per year is on the low end of being worthy of their interest.

5.2 Type F Fly Ash

Fly ash meeting the specifications described in ASTM 331 can be sold as type F fly ash. This can be substituted for Portland cement in concrete mixes in amounts up to 30%, although most producers and many state agencies limit the amount to 20% maximum.

The type F ash is referred to as a pozzolanic material, meaning that it has certain beneficial effects on concrete without having cementicious properties on its own.

Another type of fly ash used in concrete formulations is classified as type C. Type C is of even greater value to the concrete producer because it does have cementicious properties.

As shown in Table III, the biggest chemical difference between types F and C ash is the calcium content. Like Portland cement, type C has a very high calcium content. Eastern coal, including that used by the Progress Energy Skyland plant, is low in calcium. Therefore, provided that the carbon can be reduced to a low enough level, the resulting ash will be classified as type F.

Table III. Typical Ash Analysis

	Fly ash	
Typical chemical analysis (%)	**Class 'F'**	**Class 'C'**
Silica (SiO_2)	58.0	35.9
Aluminum Oxide (Al_2O_3)	29.1	18.9
Iron Oxide (Fe_2O_3)	3.6	6.1
Combined 1,2, &3	90.7	60.9
Titanium Oxide (TiO_2)	1.6	1.4
Calcium Oxide (CaO)	0.8	24.6
Magnesium Oxide (MgO)	0.8	5.4
Sodium Oxide (Na_2O)	0.1	1.9
Potassium Oxide (K_2O)	2.5	0.3
Sulfur Trioxide (SO_3)	0.2	2.3
Phosphorus Pentoxide (P_2O_5)	0.1	1.1
Barium Oxide (BaO)	0.1	0.7
Manganese Oxide (Mn_2O_3)	0.1	<0.1
Strontium Oxide (SrO)	0.1	0.4
Total Carbon (C)	1.7	<0.1
Other	1.2	1.0
Total	100.0	100.0
pH @ 25°C, s.u. (1% Slurry)	5.0	11.0
Available Alkali	0.60	1.25

Concrete Block Manufacturers

Concrete made with Type F fly ash takes longer to develop strength than concrete made without fly ash. For this reason, local producers of cement block are reluctant to use it. A large part of their profit hinges on achieving a quick turn-around in their plant. In other words, it is very important to mold the block and have it ready to ship out as quickly as possible. The need to reduce work-in-process outweighs the potential cost savings gleaned from substituting fly ash at $20-30/ton for Portland cement which sells for $90-100 ton. It is also interesting to note that the large block producers are owned by the cement companies, so, in effect, the block business is an outlet for their primary product.

It is possible that changes in transportation costs or cement cost could tip this balance the other way at some point. However, for the purposes of this study, the block manufacturers were not considered further as a market for the type F ash.

Ready-Mix Concrete – In the Asheville area there are two major producers of ready-mix concrete: Cemex and Southern Concrete.

Cemex – Cemex recently acquired Metromont. They do use a large quantity of type F ash which they buy from Santee Cooper in South Carolina. It is very high quality and they are under a long-term contract and are not interested in switching at this time.

Southern Concrete

Southern Concrete was much more receptive to using a local source of fly ash. They do not have a consistent supply of Type F ash in Asheville at this time. In Charlotte, they get fly ash from a burnout process (presumably Santee Cooper). They sometimes get fly ash from the Cliff Side plant in Forest City, but this supply is intermittent. They buy from a company called South Eastern Fly Ash. They have heard that South Eastern is putting a burnout unit on a rail car that could be pulled up to a plant site and operated to make low-carbon ash.

Their main quality issue with Type F ash is the carbon level -- the lower the better. Like everyone, they are concerned about the air entrainment and discoloration.

Variability is another important quality issue. It is not enough for the carbon to be less than the specification. It is also important that it be consistent. Fluctuations in the carbon content, even within specification, make it necessary to adjust the air entrainment chemicals.

They are very interested in the prospect of a plant "in their back yard." They could use all of the 40,000 tons contemplated and would like to put that under contract.

They would like to obtain type C ash, which they value at around $35 per ton. They know of no source for this in the Southeast.

Duke Energy

Duke Energy produces type F ash at some of its facilities and shared some of their experience. Consistently meeting specifications is most important. Some experience suggested that ash, when exposed to water, loses some of its pozzolanic activity, so it will be important to address that issue.

There was optimism that 40,000 tons per year could be sold, especially considering our geographical area. There is not a good source of high-quality ash in this immediate region. West of the mountains some of the TVA plants generate type F ash. To the east are Santee Cooper and some of the Duke plants. Also, there is a plant near Raleigh that uses an electrostatic process to separate carbon. Here in Western North Carolina, there is not currently a reliable producer. This perception of a market niche is consistent with observations from Cemex and Southern Concrete.

5.3 Lightweight Aggregate

The preliminary market study done for the grant application suggested that lightweight aggregate meeting ASTM C618 could be used for concrete block and for ready-mix concrete.

Various local producers were contacted to discover their particular market interests and needs. These included the block making division of Cemex, the ready-mix division of Cemex, and the ready-mix division of Southern Concrete in Asheville. Locally, lightweight aggregate from Stalite with a density of 54-56 lbs/ft^3 and from Live Lite, with a density of about 40 lbs/ft^3 are used. Of the two, most of the business goes to Stalite due to their proximity, excellent product quality, and consistency. In some cases, Stalite has long-term contracts in place.

Main concerns about using a lightweight aggregate derived from coal ash include:

- Abrasion resistance
- Staining from leachable ions
- Particle size distribution
- Particle shape
- Water absorption

The importance of consistency from batch to batch was again stressed. By all accounts, Stalite does an excellent job of this and also of custom blending aggregate to meet specific needs of customers.

Stalite's strong hold on the market, together with the cost of building and running a large rotary kiln to fire the aggregate, led to the concept of approaching Stalite to be a partner in the CAP scale-up.

It should also be noted that the density of the lightweight aggregate has an important impact on the value when expressed as $/ton. Figure 2 illustrates the potential price in $/ton assuming the price is held constant in terms of $/ft^3.

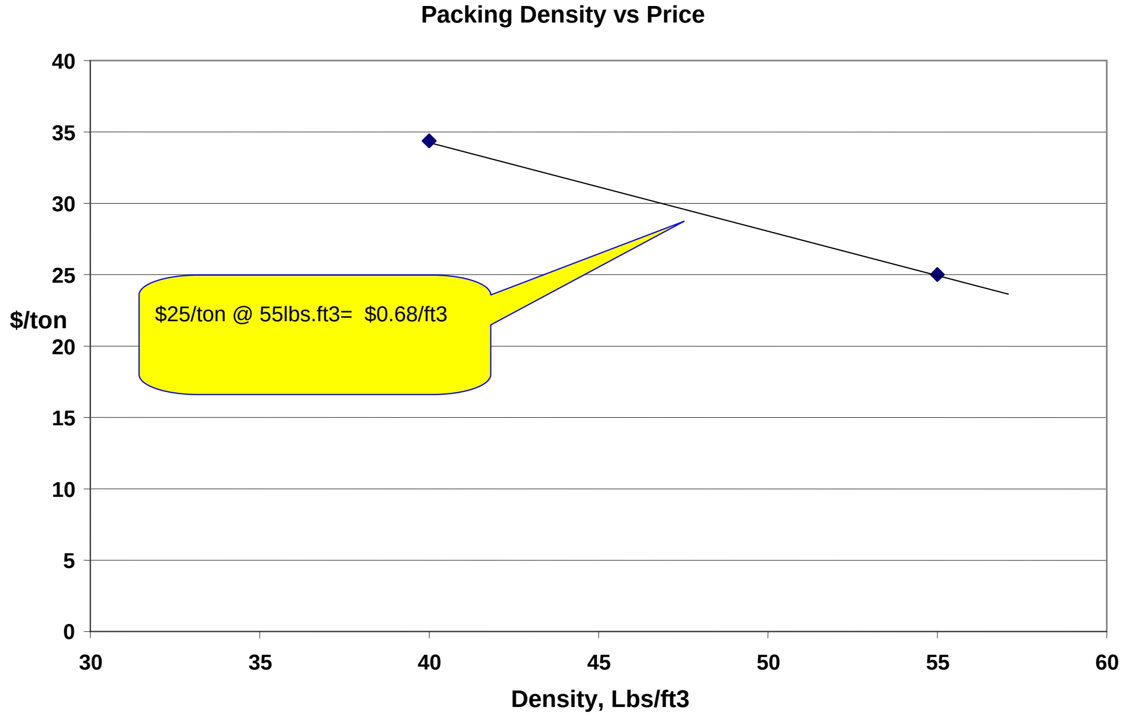

Figure 2

5.4 Bottom Ash

None of the block manufacturers or ready-mix plants mentioned above uses bottom ash in its products. Apparently, the production difficulties associated with the variability in the bottom ash quality offset the potential cost savings.

The exception to this was General Shale, an early member of the CAP consortium. General Shale does use a considerable amount of bottom ash in its plant near Johnson City, Tennessee.

General Shale confirmed they would be interested in CAP as a source of bottom ash.

The amount of 20,000 tons is small compared to their annual usage.

The most important properties are:

- FM of around 3.4 (definitely > 3.1)
- Size analysis < 7-8% in pan
- 10-12% passing 4-mesh

6.0 Potential Partners for a Commercial CAP Plant

Various business structures were discussed to put the CAP process into practice. One possibility was a joint venture or partnership between several interested companies, possibly with some outside investors. Perhaps simpler and more practical would be a spin-off company owned and operated by Progress Energy and located on the site of the power plant. In either case, the players will likely remain the same, whether they are co-owners or contractually tied with long-term commitments.

Progress Energy – As stated above, this study is focused on the Skyland plant which produces about 100,000 tons of ash per year. It is possible that this amount may increase over the next few years due to increased demand and their recent investment in scrubber technology.

Blue Ridge Paper – has sales of about $500 million per year. About 60% of this is paperboard for milk cartons; 40% envelope paper.

By-products – fall into three categories:

1) **Paper mill sludge** which is about 35% solids coming off the belt presses. Of the solids, roughly 50% is fiber and 50% is calcium carbonate. Municipal sludge is also processed, but this amounts to less than 5% by volume. They produce about 50 tons per day of this material, subject to considerable variability. This is trucked 5 miles to a landfill.

2) **Lime mud** which is calcium carbonate at 65-70% solids content. This is permitted by the state for sale as an agricultural additive. However, they do not actually sell any of this material at this time. A mixture of calcium and magnesium such as dolomite is preferred. In any case, Blue Ridge is not set up to dry and handle the material properly. They presently landfill it, where it acts to stabilize the sludge.

3) **Boiler ash** – They have two main boilers, one fired on 100% coal, the other on a mixture of coal and wood waste. Together, they produce perhaps 20 tons per day of ash which is high in carbon; LOI of 5-10%.

History – They did not join the consortium originally because at the time they had their own lightweight aggregate project ready to go. When Champion Paper (the previous owner) pulled out, their source of capital was gone and the business was thrown into a "survival mode," so the project was never executed. However, the project planning was fairly far along. They had done cost estimates of the plant and had produced some extrusions with the help of a company near Statesville. They had not advanced as far as a detailed plant design.

The only income from this project was to be the sale of lightweight aggregate. They were not counting much on the Btu value of the sludge.

Stalite

This is a very well-established business which produces about 1.2 million tons of light-weight aggregate a year, most of which is shipped to the 12 closest states.

The main plant is located in Gold Hill, North Carolina, next to the quarry where the slate is mined. The slate is crushed to two different size ranges and then fired in one of seven large rotary kilns. The kilns range from 9 to 14 feet in diameter and are 160 feet long. They are constructed with steel shells lined with insulating brick and castable refractory. The tilt is ½° and rotational speed is 1 rpm.

Small amounts of sulfur in the mineral are oxidized to SOx, tending to create non-connecting bubbles in the matrix softened at that temperature. The bed is about 2300° F and air temperature about 2100° F.

As the fired mineral leaves the kiln, it passes through a cooling section where fresh air is blown. The heated air is blown through the coal mill and used to inject the pulverized coal into the exit end of the kiln.

Stalite designs and builds their own kilns which cost about $4 million each. This puts them at an advantage since it would cost around $8 million to have an outside firm build one. Feed rates are up to 17 tons per hour of aggregate with 1.5 tons of coal per hour. After firing, the material is crushed and classified into seven different size brackets. Subsequently, these are recombined in specific ratios to create custom blends for their customers. This part of their operation is one of the most sophisticated in the industry and helps them deliver a very consistent product to their customer. Their product also has a low water absorption, which is desirable.

7.0 Business Options

At the beginning of the project, the focus for business development was a fully integrated plant. By this is meant a plant that processes all the fly ash from the Progress Energy Skyland plant, adding sludge from a paper mill and producing four products:

- Bottom ash
- Type F fly ash
- High LOI (carbon rich material)
- Lightweight aggregate

During the conversations with the various stakeholders, many different scenarios were brought up for consideration. These included almost all combinations of the above, such as:

a) Producing only fly ash and high LOI product – This reduces the initial investment and operating costs. It reduces, but does not eliminate, landfilling.
b) Making lightweight aggregate from all the ash – This would eliminate the flotation part of the plant, take away issues of carbon, and would eliminate landfilling, assuming all the aggregate could be sold.
c) Producing all products except for firing the aggregate pellets – This would be a variation of the integrated plant concept. Green pellets would be produced from the paper mill sludge and that portion of the ash with intermediate LOI. The green pellets would be shipped to Stalite, which would fire, size, and market them. This reduces investment and operating cost. Just as importantly, it would use the expertise and market strength of Stalite rather than competing against it.
d) Option (a) with a higher carbon ash – Some smaller sources of ash have even higher carbon contents than those of the power producers. Producing more carbon (the product with the highest dollar per ton value) could make an interesting business possibility.

Estimates for plant construction and operation were done primarily for the original concept (a fully integrated plant). However, the data are compiled so that other options may easily be assessed as well.

8.0 Production Plant Costs

The first step in estimating plant cost was to determine the processing rates for each of the major pieces of equipment. Subsequently, cost estimates were obtained for each piece of equipment by queries to suppliers of equipment. In some cases, multiple quotes were obtained. In almost every case, the suppliers emphasized that the quotes were approximate. In most cases, the suppliers suggested that some testing on the actual material would be required for them to make a firm recommendation and quote. This was especially true of the filtering and drying equipment where transport of water and heat through a bed of material is highly dependent on particle size and packing density.

Table IV shows a summary of findings of this process. In a few cases, no supplier was found who was willing to make even a rough estimate. To fill in numbers for these items, estimates from people who had bought similar equipment in the past were used. Those numbers are shown in a separate column.

For future reference, a list of the contacts is provided in Appendix 1.

Table IV represents a fully integrated plant and suggests that such a plant might be constructed for about $9.3 million, exclusive of land and utility costs. The assumption behind this exercise was that the plant would be located at a site which already had basic infrastructure like rail sidings and steam boilers.

From this spread sheet, it is fairly easy to estimate the plant capital costs for the other business scenarios described above. For instance, Table V shows the estimate for a plant which would produce only bottom ash, type F fly ash and carbon. This eliminates some of the most expensive equipment, dropping the investment to a little over $3 million.

Table IV. Estimate of Plant Capital Costs – Integrated Plant

machine	function	capacity	cost, $	cost,$
		tons/hr	supplier	other
			estimate	estimate
conveyer	car to stockpile	14	18800	
conveyer	stockpile to screener	14	10800	
screeneer, #6		14	30,000	
conveyer	plus 6 mesh	0.3	8900	
conveyer	minus 6 to scrubber	14	15800	
attrition scrubber		14		50,000
water pump	add water to scrubber	2		5,000
slurry pump	scrubber to #30 screen	16	13,033	
screener, # 30		16	30,000	
conveyer	plus 30 to bottom ash pile	2.5	8900	
slurry pump	minus 30 to floatation	14	13,033	
float station		14	110,000	
metering pump	flotation chemical		300	
tank	floatation chemical	100		5,000
slurry pump	high loi	1.5	13,033	
bed filter	high loi	1.5	222,000	
dryer	high loi	1.3	350,000	
loader	high loi	1.1		35,000
bag house	high loi	0.1		25,000
slurry pump	low loi	7	13,033	
screener ,#100	low loi	7	30,000	
conveyer	plus 100 to bottom ash	0.5	8900	
slurry pump	minus 100 to bed filter	7	13,033	
bed filter	low loi fly ash	7	342,000	
dryer	low loi fly ash	5.5	500,000	
silo	low loi fly ash	4.4		100,000
cyclone/bag house	low loi fly ash	1		25,000
pnumatic transfer	load trunks from silos	5		50,000
slurry pump	medium loi ash	6	13,033	
bed filter	medium loi ash	6	342,000	
conveyer	paper sludge	6	16400	
dryer	reduce to 15% moisture	11	750,000	
converyer	mixture to mixer	7.5	10200	
mixer		7.5	50,000	
conveyer	mixed compound to extruder	7.5	7700	
roll compactor		6.5	250,000	
dryer	dries extrudate to > 2%	6.5	500,000	
converyer	dried extrudate to feeder	6.5	10400	
feeder		6.5		25,000
kiln		6.5	4000000	
cyclone/bag house		0.5		25,000
conveyer	kiln to screener	5.3	10200	
screener, classifier	classifies 3 sizes of aggregate	5.3	20,000	
conveyer	coarse	2	11400	
conveyer	medum aggregate	2	11400	
conveyer	fine aggregate	2	11400	
total integrated	equipment		8,110,698	
engineering & design			500,000	
Installation cost			750,000	
toal plant			9,360,698	

Table V. Estimate of Plant Costs – Aggregate Pellets Not Fired

machine	function	capacity	cost, $			
		tons/hr				
conveyer	car to stockpile	14	18800			
conveyer	stockpile to screener	14	10800			
screeneer, #6		14	30,000			
conveyer	plus 6 mesh	0.3	8900			
conveyer	minus 6 to scrubber	14	15800			
attrition scrubber		14		50,000		
water pump	add water to scrubber	2		5,000		
slurry pump	scrubber to #30 screen	16	13,033			
screener, # 30		16	30,000			
conveyer	plus 30 to bottom ash pile	2.5	8900			
slurry pump	minus 30 to floatation	14	13,033			
float station		14	110,000			
metering pump	flotation chemical		300			
tank	floatation chemical	100		5,000		
slurry pump	high loi	1.5	13,033			
bed filter	high loi	1.5	222,000			
dryer	high loi	1.3	350,000			
loader	high loi	1.1		35,000		
bag house	high loi	0.1		25,000		
slurry pump	low loi	7	13,033			
screener ,#100	low loi	7	30,000			
conveyer	plus 100 to bottom ash	0.5	8900			
slurry pump	minus 100 to bed filter	7	13,033			
bed filter	low loi fly ash	7	342,000			
dryer	low loi fly ash	5.5	500,000			
silo	low loi fly ash	4.4		100,000		
cyclone/bag house	low loi fly ash	1		25,000		
pnumatic transfer	load trunks from silos	5		50,000		
slurry pump	medium loi ash	6	13,033			
bed filter	medium loi ash	6	342,000			
conveyer	paper sludge	6	16400			
dryer	reduce to 15% moisture	11	750,000			
converyer	mixture to mixer	7.5	10200			
mixer		7.5	50,000			
conveyer	mixed compound to extruder	7.5	7700			
roll compactor		6.5	250,000			
dryer	dries extrudate to > 2%	6.5	500,000			
converyer	dried extrudate to feeder	6.5	10400			
feeder		6.5		25,000		
kiln		6.5	4000000			
cyclone/bag house		0.5		25,000		
conveyer	kiln to screener	5.3	10200			
screener, classifier	classifies 3 sizes of aggregate	5.3	20,000			
conveyer	coarse	2	11400			
conveyer	medum aggregate	2	11400			
conveyer	fine aggregate	2	11400			
total integrated	equipment		8,110,698			
ash and carbon only	equipment		1,996,565			
engineering and design			300,000			
installation costs			750,000			
total for ash&carbon plant			3,046,565			

This section removed to exclude aggregate production

The original Excel spread sheet is included with this report so that partners may update information or experiment with different business scenarios. Figure 3 graphs the estimates of the various plant configurations we have discussed, showing a considerable range.

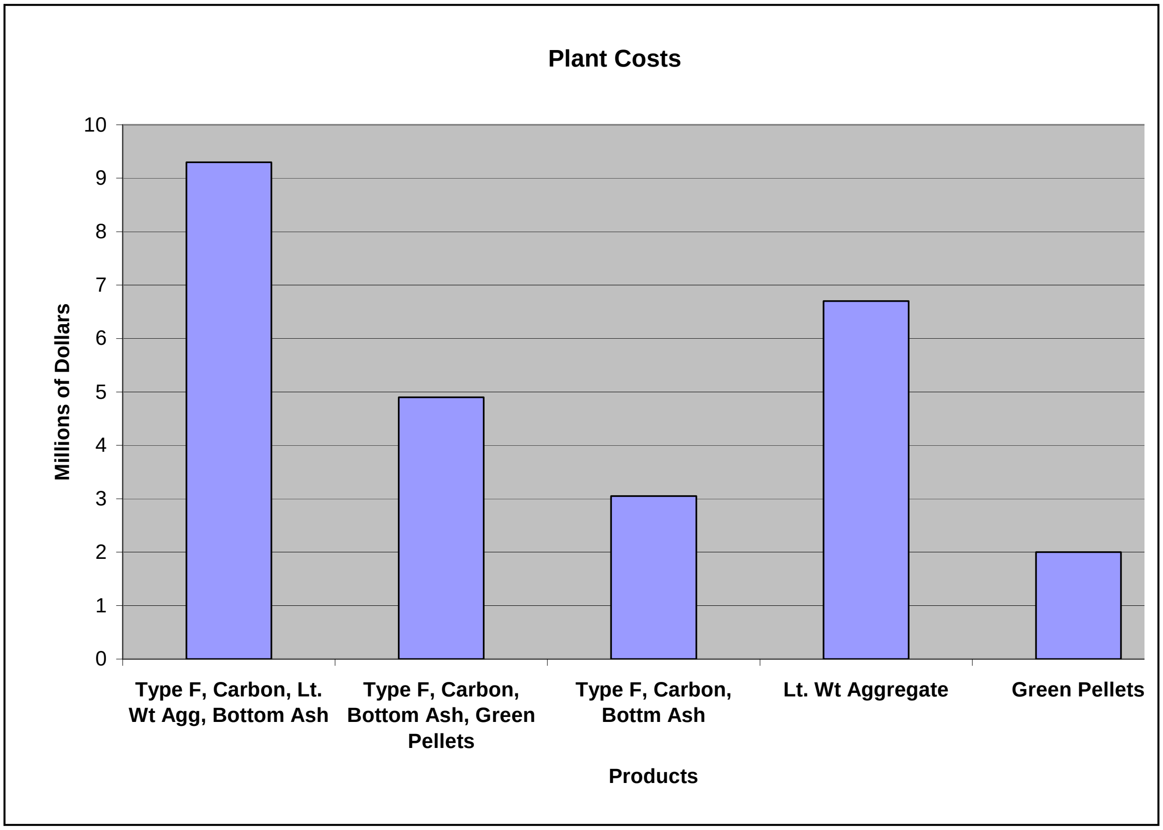

Figure 3

9.0 Estimate of Profit and Return on Investment

Accompanying this report is a set of linked Excel spread sheets used to estimate the profit/loss and return on investment of an ash processing plant. The intention of this is to make it easy to update with new information and to quickly model different sets of assumptions and conditions. As an example, the following sheets represent some typical results for a fully integrated plant.

Sheet 1 is a summary page showing the results brought together from other detail pages.

Income – In this example, the income lines reflect mid-range market prices that we gathered from the various sources. A fuel price, rather than a steel industry price, is used for the carbon.

The other source of income is fees that might be charged to the ash and sludge producers. In this example, $4/ton is shown. This is not an agreed upon or negotiated price, just pro forma.

Expenses – The labor is brought forward from detail sheet 3.

The expenses for energy refer specifically to the heat required to dry the incoming materials and to operate the kiln. In the cases where the kiln is operated on site, as in this example, the assumption is that waste heat from the kiln will be used to dry the sludge and ash products. (Calculations showed this to be feasible.) In cases where the kiln is not operated, it is assumed the energy to dry the products must be supplied separately. In this case, the number is derived from sheet 2.

The flotation process necessarily produces wet products, and the energy demand to dry these products is the objection most often cited against the process. For this reason, the issue of drying received some special attention as detailed in sheet 2.

The electrical power demand shown in sheet 1 is brought forward from sheet 4.

The overhead expense line is based on 20% of the labor number. This number might vary widely depending on the specific business arrangement, but this number is typical of manufacturing enterprises. Note that this overhead number does not include fringe benefits, which are already covered in the labor calculations in sheet 3.

Investment – In this case, the plant expense of $9.3 million was rounded up to $10 million to allow for development, planning and other expenses.

Return on Investment – This is a simple ratio of yearly income to investment expressed as percent. No attempt was made to refine this into detailed discounted cash flow analysis.

Sheet 1. P/L Summary Page

Configuration: Fully integrated Plant			
Income			
	tons/year	$/ton	toal
carbon	7000	50	350000
bottom ash	20000	8	160000
low LOI fly ash	40000	25	1000000
Light Wt. Aggergate	33,000	25	825000
			0
fees to take materials			0
coal ash	100,000	4	400000
sludge	6387	4	25548
toal income	100,000		2760548
expenses			
labor	workers		expense
	21		982800
energy	therm/year	$/therm	expense
coal	1,051,200	0.23	241776
electric	kW hr	$/kW	expense
	2,533,248	0.035	88663.7
overhead	$/$ labor	labor	
	0.2	982800	196560
total expenses			1509800
net profit			1250748
investment		10,000,000	
ROI,%		12.5	

Sheet 2. Dryer Calculations

drier work sheet						
Product	high carbon	bottom ash	low LOI	medium LOI	sludge	
			Fly Ash	ash for LW	for LW	
				aggregare	aggregate	
Beginning water, fraction	0.20	0.20	0.20	0.20	0.50	
Water after drying, fraction	0.01	0.20	0.01	0.02	0.02	
water evaporated, lbs H20/lb raw material	0.19	0.00	0.19	0.18	0.48	
latent heat of water, btu/lb	970.20	970.20	970.20	970.20	970.20	
heat to vaporize water lost, btu/lb raw material	184.34	0.00	184.34	174.64	465.70	
delta T during drying process, F	152.00	0.00	152.00	152.00	152.00	
specific heat of water, BTU/lb	1.00	1.00	1.00	1.00	1.00	
specific heat of ash ,BTU/lb	0.22	0.22	0.22	0.22	0.33	
energy to heat up materials, btu/lb raw material	57.15	0.00	57.15	57.15	101.08	
total heat for drying, btu/lb raw material	241.49	0.00	241.49	231.79	566.78	
drying efficiency , %	75.00	75.00	75.00	75.00	75.00	
design heat for drying, BTU/lb raw material	321.99	0.00	321.99	309.05	755.70	
design heat for drying, BTU/ton raw material	643973.33	0.00	643973.33	618101.33	1511402.67	
dry tons of raw material per year for each product	7000	20000	40000	33000	4950	
wet tons of raw material per year	8750	25000	50000	41250	9900	
total btu/year	5634766667	0	3.22E+10	2.5497E+10	1.4963E+10	
total therms/year	56347.6667	0	321986.67	254966.8	149628.864	
total thems for plant						782930

Sheet 3. Labor Calculations

labor										
						wages		direct wages		
positions	days	shifts	positions/shift	number	adjusted	$/hr	hrs/year	$/year		
operator	7	3	3	12.6	13	14	2000	364000		
maintenance	7	3	1	4.2	6	23	2000	276000		
operations	5	1	1	1	1	30	2000	60000		
management	1	1	1	1	1	40	2000	80000		
total direct					21			780000	average:	37142.86
	fraction									
social security	0.153									
workmans comp	0.035									
health,$/person	6000									
life										
total fringe	0.26									
toatal labor	982800									

Sheet 4. Electric Power Calculations

Electric Power Worksheet						
rate						
$/kWh	0.035		(from Duke Power)			
1 kW	equals	1.341 hp				
motors						
	hp	hrs/day	days/year	up time	hph/year	kWh/year
incoming conveyer	25	24	365	0.8	175200	154907.2
scalper screen, 6 mesh	10	24	365	0.8	70080	61962.86
over converyer	15	24	365	0.8	105120	92944.3
under conveyer	20	24	365	0.8	140160	123925.7
attrition scrubber	15	24	365	0.8	105120	92944.3
slurry pump	12	24	365	0.8	84096	74355.44
screener/30 mesh	10	24	365	0.8	70080	61962.86
over conveyer	15	24	365	0.8	105120	92944.3
screw classifier	25	24	365	0.8	175200	154907.2
conditioner	3	24	365	0.8	21024	18588.86
rougher float	5	24	365	0.8	35040	30981.43
scavenger float	5	24	365	0.8	35040	30981.43
slurry pump	10	24	365	0.8	70080	61962.86
surge tank impeller	5	24	365	0.8	35040	30981.43
slurry pump	5	24	365	0.8	35040	30981.43
hydrocyclone	15	24	365	0.8	105120	92944.3
100 mesh screen	10	24	365	0.8	70080	61962.86
plus 100 mesh dryer	25	24	365	0.8	175200	154907.2
slurry pump	5	24	365	0.8	35040	30981.43
settling tank	3	24	365	0.8	21024	18588.86
slurry pump	10	24	365	0.8	70080	61962.86
belt filter	25	24	365	0.8	175200	154907.2
sludge dryer	25	24	365	0.8	175200	154907.2
mixer	15	4	365	1	21900	19363.4
extruder	25	4	365	1	36500	32272.33
drying conveyer	15	4	365	0.8	17520	15490.72
kiln blower	15	24	365	0.8	105120	92944.3
kiln rotation	25	24	365	0.8	175200	154907.2
scrubber blower	15	24	365	0.8	105120	92944.3
heat xchange blower	15	24	365	0.8	105120	92944.3
kiln feeder	15	24	365	0.8	105120	92944.3
product cooling converyer	15	24	365	0.8	105120	92944.3
high loi conveyer	12	24	365	0.8	84096	74355.44
high loi dryer	12	24	365	0.8	84096	74355.44
lights	3	24	365	0.8	21024	87600
sum					2865104	2533248

10.0 Stepwise Implementation of Technology

Using the cost model developed above, several different plant configurations were considered.

Perhaps one of the lowest risk ways to implement the concepts of this project would be building a plant in incremental steps.

The first step could be the installation of the flotation system with associated dryers, screeners and handling equipment. Such a plant would produce only Type F ash, a high carbon product, and bottom ash. The portion of the ash that is intermediate in LOI would still be landfilled. This would reduce the landfilling from 100,000 tons per year to about 33,000 tons per year.

Sheet 5. Light Weight Aggregate Excluded

Configuration: Light wt aggregate excluded			
Income			
	tons/year	$/ton	total
carbon	7000	50	350000
bottom ash	20000	8	160000
low LOI fly ash	40000	25	1000000
Light Wt. Aggregate	0	25	0
			0
fees to take materials			0
coal ash	67,000	0	0
sludge	0	0	0
toil income	100,000		1510000
expenses			
labor	workers		expense
	17		841680
energy	therm/year	$/therm	expense
coal	378,334	0.23	87016.89667
electric	kW hr	$/kW	expense
	1,784,531	0.035	62459
overhead	$/$ labor	labor	
	0.2	841680	168336
total expenses			1159491
net profit			350508.54
investment		2,746,565	
ROI,%		12.8	

Sheet 5 shows an estimated return on investment (ROI) of 12.8%. Note that the labor, energy, and electrical requirements are all reduced from the fully integrated plant described earlier. Note also that the investment is much lower, about $2.7 million.

The return of 12.8% is probably a conservative number for two reasons. One is that a low selling price is assumed for the carbon. More importantly, this estimate does not reflect any value of avoidance of landfill costs. Sheet 6 shows another estimate for this kind of plant, only assigning a value of $80/ton for the high carbon product and a value of $5 per ton for the avoidance of landfilling 67,000 tons of material.

Sheet 6. Light Weight Aggregate Excluded – Favorable Assumption

Configuration: Light wt aggregate excluded			
Income			
	tons/year	$/ton	total
carbon	7000	80	560000
bottom ash	20000	8	160000
low LOI fly ash	40000	25	1000000
Light Wt. Aggregate	0	25	0
			0
fees to take materials			0
coal ash	67,000	5	335000
sludge	0	0	0
toil income	100,000		2055000
expenses			
labor	workers		expense
	17		841680
energy	therm/year	$/therm	expense
coal	378,334	0.23	87016.89667
electric	kW hr	$/kW	expense
	1,784,531	0.035	62459
overhead	$/$ labor	labor	
	0.2	841680	168336
total expenses			1159491
net profit			895508.54
investment		2,746,565	
ROI,%		32.6	

Under these assumptions, the return on investment is much more compelling at 32.6%.

A second step in implementation might be to add the production of green pellets for the production of lightweight aggregate. These pellets would be sold to Stalite who could fire, size and distribute the aggregate.

Sheet 7. Green Pellets for Aggregate with $5/ton Landfill Fee

Configuration: green pellets for aggregate			
Income			
	tons/year	$/ton	total
carbon	7000	80	560000
bottom ash	20000	8	160000
low LOI fly ash	40000	25	1000000
Light Wt. Aggregate	33,000	5	165000
			0
fees to take materials			0
coal ash	67,000	5	335000
sludge	6387	5	31935
total income	100,000		2251935
expenses			
labor	workers		expense
	21		982800
energy	therm/year	$/therm	expense
coal	782,930	0.23	180073.8994
electric	kW hr	$/kW	expense
	1,851,657	0.035	64808
overhead	$/$ labor	labor	
	0.2	982800	196560
total expenses			1424242
net profit			827693.11
investment		4,985,898	
ROI,%		16.6	

Under these assumptions, the ROI would actually go down compared to a plant that does not process pellets at all. However, if market factors were to shift such that landfilling became more expensive, this situation could easily shift to more favorable. For instance, Sheet 7 shows the ROI for landfilling costs of $10/ton.

Sheet 8. Green Pellets for Aggregate with $10/ton Landfill Fee

Configuration: green pellets for aggregate			
Income			
	tons/year	$/ton	total
carbon	7000	80	560000
bottom ash	20000	8	160000
low LOI fly ash	40000	25	1000000
Light Wt. Aggregate	33,000	10	330000
			0
fees to take materials			0
coal ash	67,000	10	670000
sludge	6387	10	63870
total income	100,000		2783870
expenses			
labor	workers		expense
	21		982800
energy	therm/year	$/therm	expense
coal	782,930	0.23	180073.8994
electric	kW hr	$/kW	expense
	1,851,657	0.035	64808
overhead	$/$ labor	labor	
	0.2	982800	196560
total expenses			1424242
net profit			1359628.11
investment		4,985,898	
ROI,%		27.3	

At or above these landfilling costs, the total profit exceeds the plant without pellets while the ROI is still very attractive.

11.0 Issues for Future Work

At this point, the basic technical and commercial feasibility of the concept looks favorable. Some of the issues that should be addressed in the next phase of the project include:

11.1 Analysis of trace elements – Mercury and ammonia are of special interest. Analysis is needed to understand how they are distributed in the by-products.

11.2 Estimation of variability – It would be interesting to run the process on ash from several locations in the landfill to establish that product consistently meets specifications.

11.3 Qualification with customers – This will follow whatever quality procedures they have established.

11.4 Environmental issues – Permitting and testing issues must be understood and addressed.

11.5 Incentives from local or state government – This type of project may qualify for incentives associated with job creation and/or favorable environmental impact.

Appendix 1. Contacts and Sources

CAP Contact List

first name	last name	with	phone	email						
Ken	Butcher	Shining Rock	828 606 2655	krbutcher@juno.com						
Terry	Albrecht	Waste Reduction Partners	828 251 6622	Terry.albrecht@ncmail.net						
Charles	Hughes	Progress Energy	919 546 4002	charles.hughes2@pgnmail.com						
Matt	Ewadinger	NC DENR	704 264 2980	matt.ewadinger@ncmail.net						
Robert	Mensah-Biney	Minerals Research Lab	828 251 6155 xt 224	mensah@eos.ncsu.edu						
Bob	Waldrop	Full Circle Solutions	770 517 7017	bwaldrop@fcsi.biz						
Bill	Ashbrook	Ecusta Business Dev. Cnt.	828 884 5544 ext 233	washbrook@nappcollc.com						
Bob	Carland	NC State-MRL	828 251 6155	bob_carland@ncsu.edu						
Charlie	Gardner	Blue Ridge Paper	828 454 0160	gardnc@blueridgepaper.com						
Tom	McCullough	WRP	828 6990985	tommccullough@mchsi.com.						
Al	Keiser	WRP	864 313 8787	Al@alkeiser.com						
Jerome	Chambless	EZBLOCK	828 626 3999	jeromechambless@charter.net						
Elaine	Marten	WRP	828 645 3546	marhoff4@buncombe.main.nc.us						
Larry	McGill	API	423-622-2105	appprod94@aol.com						
Mark L	Baker	Duke	(704) 363-9116	mlbaker@duke-energy.com.	704 382 1196 - office					
Ron	Townley	Land of Sky	(828) 251-6622	; ron@landofsky.org						
Ginny	Farrow	Progress Energy	919 n546 7483	ginny.farrow@pgnmail.com	919 219 4590 - cell; 919 546 2590 fax					
Jay	Garrett	ESI	615 218 2379							
Chris	Nicholes	Cemex	864 423 1502	block manufacture						
Brad	TRUE	Nucor	704 366 7000	btrue@nucor.com	2100	Rexford Rd	Charlotte	NC	28211	
Brian	Hill	Nucor	705 366 7000	Bhill@nucor.com	2100	Rexford Rd	Charlotte	NC	28211	
Charles	Freemen	Stalite	704 906 7636							
Jody	Wall	Stalite	704 279 8614	jwall@stalite.com	PO box 186 Gold Hill NC 28071					
			cell- 704 279 8614		815 Old Beatty Ford Road					
Larry	McSweeney	Cemex	864-423-1559	General Manager						
Chris	Heins	Cemex	864 415 6072	redimix						
Terry	Fletcher	General Shale	423 282 4661							
David	Williams	Southern Concrete Materials	828 253 6421							
Jim	Combest	Southern Concrete Materials	828 253 6421							
Cecil	Jones	NC DOT	919 733 7411	cljones@dot.state.nc.us	State Materials Engineer					
Allen	Elliot	RPI (independent investor)	704 896 7300	recycledpaintinc@earthlink.net						
Virginia	Farrow	Progress Energy	919 546 7483	ginny.farrow@pgnmail.com						
Tom	Robl	Universtiy of Kentucky	859 257 0272		Associate director- Center for applied energy research					
Lee	Griffin	Sweeco	770- 591 2117							
Richard	Peaker	Metso	717 849 7465							
John	Orava	Orava Materials Systems inc	757 560 2901							
George	Reynolds		828 553 6445							
Bill	Wescott	Orava Materials Systems inc	828 281 3381	828 712 9552 - cell						

Source list for equipment

Equipment	company	contact	phone
Driers & Kilns	FEE Minerals		610 264 6900
	Weysomont	Bruce Carpenter	201 947 4600
	Drytech		949 262 1222
	Metso	George Fletcher	520 271 7627
Floation cells	Metso	Process Techology	717 843 8671
Screeners	Sweeco	Lee Griffin	770 591 2117
Conveyers	Hoover Converyer	Dave Thompson	270 251 9111
pilot plant	U. of Kentucky	Tom Robl	859 257 0272
Crushers	Thyssen Kraft Robins		303 770 0808
Installation	Bildon	Jim Crafton	828 693 1761
bed filters	Larox	David Ziegelhofer	301 543 1200
kilns	Stalite	Jody Wall	704 279 8614