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Heating Kodiak: A Biomass Solution

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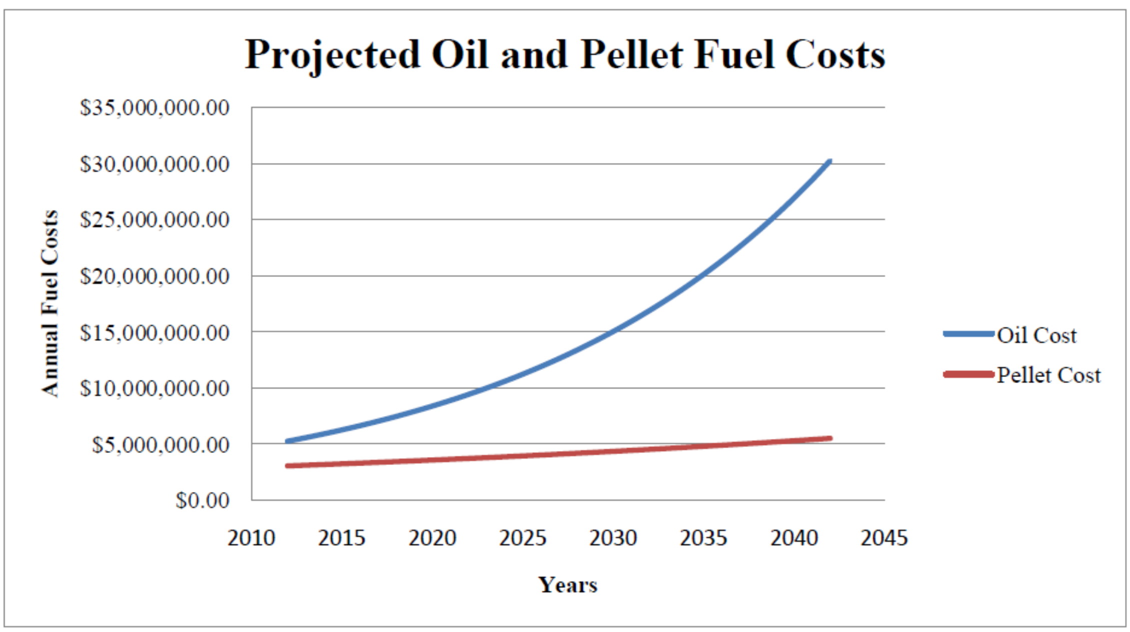
Abstract

Base Support Unit (BSU) Kodiak, Alaska is considering converting from a central oil heating system to a wood pellet biomass heating system in order to reduce cost and environmental impacts. BSU Kodiak will require a wood pellet storage system sufficient to support the demands of the unit. The bases' fuel oil demands for the past three years were used to determine the projected daily and monthly wood pellet demands. A silo storage system was determined to be the best storage option, and the wood pellet demand projections were used to estimate the necessary silo size. Three silo size options were considered: a 1000T, 1500T, and 2000T, which would have a four, six, and eight week respective wood pellet capacity. It was determined that the eight week wood pellet supply capacity would be most suitable for BSU Kodiak and the larger capacity would significantly minimize the wood pellet handling burden. It was determined that this option consist of four separate 500T silos arranged in a square cluster. Having multiple silos will enable the base to shutdown a silo for necessary repairs and cleaning without compromising the systems performance. These four silos will be constructed on the undeveloped hill directly south east of the building No. 24 (steam plant, see appendix A). It is recommended BSU Kodiak obtain soil characteristics of the recommended silo location in order to create an accurate foundation design. The base should also look into a suitable method of transporting the wood pellets from 20ft storage containers to the silo system, and technologies for automatic operation and minimum maintenance. The purpose of this project is to analyze and design the most economical method for the local storage and distribution of biomass fuel. Currently the base is using a combination of #2 fuel oil and LOWS to heat BSU Kodiak. A cost-benefit analysis of various storage and logistical options will be completed as part of the project. The objective is to analyze and design the most economical method for the storage of wood

pellet biomass, while promoting the Commandant's policy in stewardship of the environment by reducing the base's dependency on fuel oil.

Literature Review

In the coming years, oil supply will continue to diminish while the demand increases, thereby increasing the price per gallon of oil. With rising oil prices, it is becoming more cost-effective to convert to biomass heating systems, and as a result biomass has been gaining popularity throughout the country. The graph bellow represents how the price of fuel oil is likely to dramatically increase over the next few decades. The graph assumes an annual price increase of 6% for fuel oil versus a 2% annual price increase for wood pellets. The graph compares the projected cost of fuel oil and wood pellets that BSU Kodiak will pay over the next thirty years at these rates.



Graph 1.0: Projected Oil and Pellet Fuel Costs

In order to properly convert to wood pellet heating, BSU Kodiak examined several case studies of similar facilities that made the switch. Jackson Laboratories in Bar Harbor, Maine recently installed a wood pellet heating system on the same scale which may potentially be utilized in Kodiak. Jackson Labs is an appropriate comparison due to similar heating demands of 235.5 billion BTU's a year. Both the Jackson Lab's plant and BSU Kodiak are expected to use approximately 10,000T of wood pellets a year. However, the biomass system in Bar Harbor utilizes a smaller sized silo, approximately 450T, due to the ease of refilling the biomass on a daily basis (Bordzel). Since there are no wood pellet plants on Kodiak Island, this will not be an option for BSU Kodiak. Biomass is composed of living or recently dead materials which are used to create eco-friendly and sustainable energy (Renewable 5). To harvest the energy the biomass is cycled through biomass reactors which releases the energy through combustion (Clean 1). Typically these units include a hopper which cycles the fuel through a combustor. The combustor is where the energy is collected and dispersed. Ash from the burning is left behind in a separate collector unit (Free 1). Biomass heating systems are unlike oil heating systems because instead of burning petroleum based fuels it burns organic matter. Although the steam heating plants can be nearly 90% efficient, they utilize costly petroleum based fuels. The use of biomass reactors will be a cost effective and environmentally sound alternative to the central oil heating systems currently in Kodiak. (Hoffman 4).

Materials and Methods

Our team has been utilizing numerous CAD drawings provided to us by the base. These drawings include dimensions and topographic estimations of the area in question. In addition, a site visit was conducted in which we obtained photographs, an idea of the site layout, and recommendations of potential sites, as well as logistical concerns that may arise.

Identification and Selection of Alternatives

The first step in converting to a more cost effective fuel source was identifying the most practical form of biomass. There are five broad categories of biomass: industrial waste, wood, energy crops, agricultural residues, food waste. Due to the fact that BSU Kodiak is an island with limited resources energy crops, agricultural residues, and food waste biomass will not be considered. These types of biomass require numerous plants and area to make their energy into useable form ("What is Biomass?"). The first source of biomass investigated, industrial waste has two different products that were considered. The first being waste from a fish processing plant. According to the Food and Agriculture Organization in 2006, 50% of the total fish material processed became waste material, with oil content of 40% to 65% (Wiggers). The residual oil can then be turned into a usable fuel if a specific type of reactor is purchased. Currently there is a local fish processing facility that could provide the fish waste but have stated they plan on using their byproducts in the future, making it an unreliable source.

The second waste looked at was the paper and cardboard recycled locally on the base. For the 2011 fiscal year approximately 150,000 lbs of paper, plastic, and cardboard were recycled. In order to assess the viability of the paper and cardboard it was assumed 70% of that weight came from paper and cardboard and 30% came from plastic. This was done because the biomass reactors will only be able to deal with paper products, not plastic waste. The paper and cardboard would be able to supply roughly 7,100 BTU's per pound. Paper and cardboard at these estimates could potentially supply 6% of the required annual heating. Currently it is costing approximately $85,000 to recycle due to Kodiak being an island. Paper would then have to be sent to a processing plant to compact it into a more uniform, consistent product in order to be usable. The additional shipping on and off the island would incur additional expenses as well as the fee of the plant (Laurijssen).

The next type of biomass considered will be wood. Wood biomass comes in many different forms. The first type, wood chips are small pieces cut into uniform chips either by a shredder or as a byproduct of a lumber mill ("Wood Chip Costs"). Wood chips are often supplied wet, meaning their moisture content is around 50%. The optimum moisture content for any biomass wood product is roughly 6-10%. Therefore, the wood chips will need to be dried out to get the optimum energy output. The first problem is that wood chips will have increased shipping costs due to their extra moisture content. They also will not provide the same energy content as other wood products of the same weight as part of their energy will be used in removing moisture. When shipping and storing the wood chips due to their high water content rot and fungus may degrade the material and its energy potential making it a potentially unreliable fuel source. The price of wood chips however, is $100 per gross ton, making it one of the least expensive options of biomass fuel. At 50% moisture, they will provide 3,150 BTU's per pound. The wood chips may also be ordered "debarked" making it the cleanest type of biomass as it will produce the lowest ash content, helping lower the maintenance cost of the boiler system ("Biomass Heating Assessment"). There is also a possibility of an Alaskan company supplying wood chips in the future however, they do not currently have the means or cost estimates of providing chips so this is not a reliable source yet.

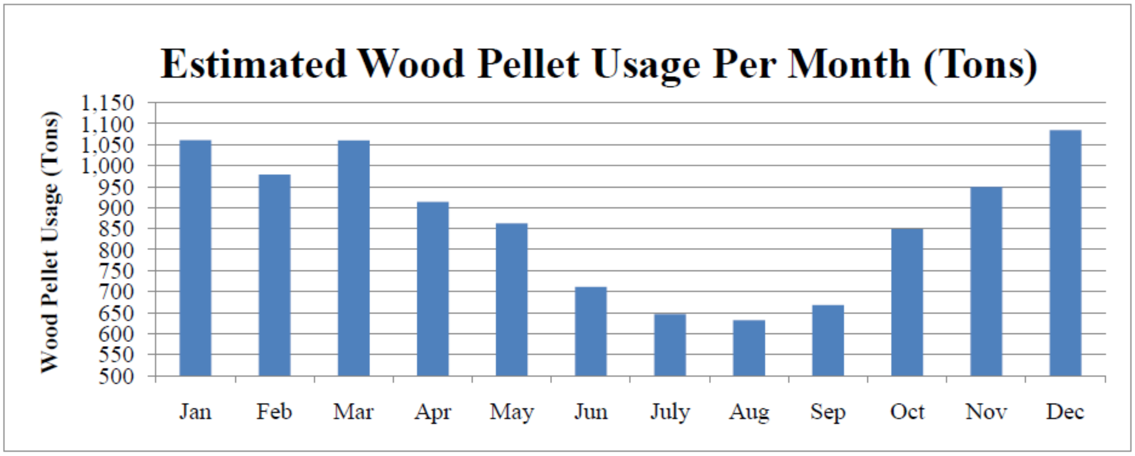
The second type of wood biomass investigated was wood powder. Wood powder is saw dust or finely ground wood. Wood powder is useful due to its very fine nature it is able to provide very efficient chemical energy release. Wood powder is also a byproduct of many timber processes making it inexpensive at roughly $100 per gross ton providing 3,900 BTU's per pound. However, due to its fine texture the material is highly susceptible to moisture in the environment. The wood powder can easily absorb water from the atmosphere increasing its water content subsequently decreasing its BTU or energy content. ("Wood Powder Products") Due to the climate of Kodiak and the possible exposure in transit the wood powder poses an increased risk of damage.

The final wood product investigated was wood pellets. Pellets are created from various wood materials including, lumber scraps, unsuitable lumber, wood chips and sawdust. To create the pellets the material will be dried to the typical moisture content of 6-10%. Then the material is compacted through either a chipper or a press to create the desired density and size of pellet. The pelleting process can be done without additional chemical or byproducts because wood contains a natural glue called lignin which binds the material. Also because of low moisture content risk of deterioration or fungal infestation is reduced. Due to the resistivity, the pellets become much easier to ship and are moved around the base either by an automated system or trucks. Pellets also can be easily stored in bulk reducing costs and emissions encountered from transportation. The ash content can vary depending on the manufacturer so the desired ash content should be specified. To help keep the system clean and maintenance costs down the lowest ash content should be attained. Currently there are no local dealers of wood pellets in Alaska but there are a few companies looking in to producing wood pellets, which in the future may reduce costs. There are however, many companies within the lower 48 states and Canada producing pellets which will help ensure fair pricing. Pellets are roughly priced at $270 per gross ton providing 8,500 BTU's per pound ("Wood Pellets"). This makes pellets a more expensive alternative but a more reliable, attainable option.

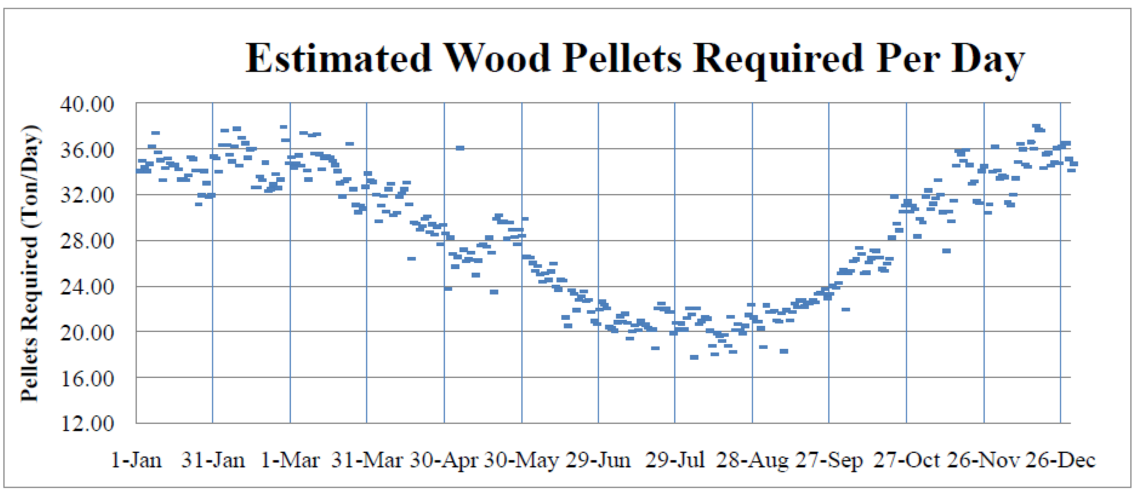
Wood chips were determined not to be the optimum fuel. They are sold at a low cost but due to their high moisture content come with hidden fees. They are required to be dried to a lower moisture content to make them usable. Because of this more of the chips will be needed to be shipped in and a larger area for storage will be needed which puts additional strain on the unit. If a local supplier were to begin manufacturing most of these issues would not be a concern and wood chips would be advantageous. As of now though, wood chips will increase costs and the carbon footprint which is not in line with the goals of BSU Kodiak. Wood powder also comes at a decreased price but will have additional expenses. The powder will very likely absorb moisture and be subject to the cold climate of Kodiak, meaning the wood powder may freeze. If the powder were to freeze it would not be able to provide BSU Kodiak with heating energy during its most demanding season which would hinder Coast Guard operations. Since the base is responsible for thirteen different operations this chance of system failure is unacceptable. Fish waste was considered as it is a local byproduct which would cut down the costs and emission of transportation. The fish waste would be valuable if a permanent set supply was available. A different type of system would be required to harvest the energy making a supply critical. At this time the local fish plant does not plan on discarding their byproduct so this option should not be considered. Paper and cardboard currently is recycled on base. The energy potential in paper could supply the base 6% of its annual heating energy. However getting the paper into a useable form would make a very expensive process which would not compensate for the cost and energy gains. If a local lumber plant wanted to add a process to create recycled paper into a usable form it would create the ideal situation as expenses and emissions would be considerably reduced.

The optimum biofuel to choose would then be wood pellets. Wood pellets will work with a wide range of bioreactors giving BSU Kodiak many additional options when choosing a reactor. The pellets are generally of standard size and characteristics providing a consistent energy supply which is critical for the base. The standardization will also help when deciding a means of storage. Cost comparison and ensuring the best product a very low ash producing pellet may be obtained reducing reactor maintenance costs. The price is more expensive for wood pellets at $270 per gross ton but can be justified in the benefits and higher energy they will provide. Lastly there are many companies producing wood pellets making finding a supplier a more competitive process and obtainable fuel source.

Based on the determination that wood pellets are the optimal biomass fuel, the next step of the project was to establish constraints and assumptions. These were researched and discussed to be; twenty foot shipping containers will be used in the shipping of the biomass, a delivery schedule of between 20 – 50 containers every 2 weeks, weather protected silo/s will be used, and the boiler will be a Petrokraft brand. The base will use approximately 10,000 tons of biomass a year. The following two graphs show BSU Kodiak's predicted wood pellet usage. Graph 2.0 gives the usage per month while Graph 2.1 depicts the usage on a daily basis.



Graph 2.0: Estimated Wood Pellet Usage Per Month



Graph 2.1: Estimated Wood Pellets Required Per Day

Both of the above graphs are based off of the fuel oil usage provided by BSU Kodiak for fiscal year '09 -11. The peak load months are November through March. During the peak loading months, the base will use, on average, 35 tons of biomass a day (approx. 1.5, 20ft containers). All estimations and storage calculations are based off of the peak load projections to ensure during all times the demand will be met. The base also requested that at a minimum a three month supply be on the base. In case of inclement weather it was decided that at a minimum there will be a two week supply near the biomass boiler system in the silos.

The next item will be to decide on the most effective silo size, and how much storage is needed near the biomass boiler system. The three design considerations will be a four, six, and eight week capacity silo system.

4 Week:

This design assumes the construction of a single silo that is capable of holding enough biomass to last the base approximately four weeks (28 days). This will require the construction of a 980 ton capacity (36 container equivalent) silo. At a minimum, the silo will need to be replenished every two weeks in order to maintain a two week supply of biomass fuel (490 tons/18 containers) in the silo at all times. An additional two and a half month supply (10 weeks) of biomass is recommended to be stored at a separate location on base to meet a three month minimum supply on base. This will require having approximately 100, 20ft containers in storage on base at all times.

6 week:

This design will assume the construction of two separate silos, each with a storage capacity of approximately 3 weeks biomass. These silos will be designed to hold a total of 1470 tons, 734 tons each, of biomass fuel (54 container equivalent). A two week minimum supply of biomass will be maintained in either silo at all times, and at a minimum the silos will need to be replenished every four weeks. This option will require a two month (8 week) supply of biomass stored on base, or approximately 72, 20ft containers.

8 week:

This design will assume the construction of four separate silos, each with the storage capacity of approximately 2 weeks of biomass. This silo system will be designed to hold a total of 1960 tons, 490 tons each, of biomass fuel (71 containers). A two week minimum supply of biomass will need to be maintained at all times; therefore, at least one silo will always remain full. This will require that at a minimum, the silos will need to be replenished every six weeks. This option will require one and a half month (6 week) storage of biomass fuel on base, or approximately 54, 20ft containers.

The next item researched was what material the silos should be made out of. There were two types of materials considered, steel and concrete. Kodiak, AK is a cold and damp location over a large part of the year, and a silo needed to accommodate for these tough weather conditions. Concrete silos are lower in cost than metal silos. In addition to a low initial build cost, concrete silos do not require expensive painting and maintenance costs. Concrete silos eliminate the opportunity for the biomass to be exposed to the harsh environment through corroded bolts, welds and cracks that might occur on a metal silo. Metal silos are susceptible to deformations within their walls that can cause uneven flow and an increase in pressure buildup.

The next item to be considered is the location of the silos relative to the boiler plant. There were three options that were investigated. See appendix A.

Alternative 1: Building No. 48 (Haz Waste Storage)

This alternative would require moving the hazmat building. In addition, this option would require relocating the street in between the heating center and the hazmat building or incorporating a screw or belt conveyor over the road. There are also many underground utilities located in that area so they would have to be diverted to construct the silo foundation.

Alternative 2: Unimproved Area East of Building No. 24 (Steam Plant)

This alternative would require the leveling of the area next to the steam plant building. There is approximately 300ft x 300ft of area available for this project. This is an ideal location due to its close proximity to the steam plant. There are no underground utilities in this area so no existing utilities will have to be diverted. This location will allow room for operations associated with filling the silo and the system. This location would be a suitable elevation above the tsunami line.

Alternative 3: Field below Building No. 24 (Steam Plant)

This alternative would require further research into the soil profile. This site is also located below the tsunami line. A retaining wall would also be required to maximize space and get the silos as close to the heating building as possible.

The next item in consideration is how the material from the silo/s will be transported to the boiler. Two types of conveyors were considered, screw and belt.

Screw Conveyor

Screw conveyors are able to handle various types of loads and would work well with biomass pellets. This option allows for there to be numerous inlet and outlet points for the biomass which will help feed the material into the silos. Screw conveyors are completely enclosed which will eliminate the possibility of exposing the material to the environment. . The screw conveyors also function extremely well in the vertical, horizontal or sloped position.

Belt Conveyor

Belts have a continuous motion, driven by a roll which is underneath the belt and positioned at one end of the conveyor. Belts are typically used in a production line and can be very flexible. Belts are advantageous when dealing with small delicate parts and operate very quietly.

Design Work

In order to meet the required 500T capacity, each of the four silos must have an internal volume of 25,000 cubic feet. This is based off of a wood pellet unit weight of 40.5 lb/ft^3 (Leaver). At 40.5 lb/ft^3 pellets are about 50 ft^3/Ton. To meet the 25,000 ft^3 a rough silo dimension was determined based off of similarly sized silo dimensions. Using the equation or volume of a cylinder, it was determined that each silo would have an external diameter of 24 ft, an internal diameter of 23 ft, and a height of 66 ft. A rough design based on the recommended size and number of silos was conducted to determine the size and shape of land that will be used for construction of the foundation. It was determined the silos will be arranged in a square formation. The wind load, seismic load, dead load, and ice loads were calculated for a single silo using the load specifications in ASCE 7-05. Dead load (D) for a fully loaded concrete silo was determined to be 1772.3 K. The seismic load (E) was determined to be 620.3K. The wind load (W) was determined to be 84.18K, and the Ice Load (Wi) was determined to be the same as W. Based on factored load analysis the worst case load combination was determined to be load combination seven, 0.9D + 1.0E + 1.6H (ASCE 7-05 2.3.2) This resulted in a factored load of 2392.6K. Based off the design specifications, an estimated reinforced concrete two way slab foundation was sized to be 68' x 68' x 5', which can be referenced to the CAD drawing (appendix A). The design was also done to create a general construction and material cost estimate. Google Sketch-Up was also utilized to create a 3-Dimensional image of the existing boiler plant with the silos built next to it in the proposed geographical area (appendix B).

Conclusion and Recommendations

It is proposed that the eight week, four silo option be chosen for this project. This option allows for the most pellets to be stored in the silo as opposed to storage in shipping containers. The larger silo option also allows for less frequent silo filling operations, thus minimizing silo refilling during inclement weather. Having multiple silos enables the base to take a silo out of operation for routine maintenance and cleaning without compromising the storage capacity. In addition, the automatic wood pellet feed from the silo to boiler system could be switched from any of the four silos. Overall, this is the best silo option due to material logistical handling and maintenance concerns. Although this option would require higher initial costs, it will pay for itself through saving money on man hours due to the less frequent filling of the biomass. In order to reduce building costs, it is recommended that the silos be constructed out of concrete. The concrete also offers significantly better weather resistance compared to a metal silo, and requires lower maintenance costs.

The unimproved area next to the Building No. 24, appendix A and B, is the most ideal site for the silo option chosen. This is an ideal location due to its close proximity to the steam plant. There are no underground utilities in this area so no existing utilities will have to be diverted. This location will allow room for operations associated with filling the silo and the system. This location is also well above the tsunami flood plain elevation.

Screw conveyors are the top choice for this project. Screw conveyors are able to handle various types of loads and would work well with biomass pellets. This option also allows for there to be numerous inlet and outlet points for the biomass which will help feed the material into the silos. Screw conveyors are completely enclosed which will eliminate the possibility of exposing the material to the environment. The screw conveyors are an economical and practical solution for transporting the biomass fuel from one location to another.

Construction costs were estimated using RSMeans and Building Construction Cost Data 61st, 2003. Table 1 estimates the total cost of approximately $9.8 million.

Construction Cost	
Item	**Price**
Foundation	
Concrete	$160/CY
-Winter Protection	$.38/SF
Forms	$7.15/SFCA
Site Clearing	$4,425/ACRE
Piles	$2175/each
Borings	$76/LF
Fill	
Material	$.84/CY
Equipment	$4,830/week
Site Excavation	
Excavation	$7.65/CY
Rubbish Handling	$440/Week
Silo(s)	$90,000/each
Conveyor	
Screw (Per Foot)	$400/ft
Fill Station	
Pre-Fabricated Building	$24/SF
Pit	$8,400
Conveyor	
Biomass reactor	$5,000,000
Container Storage	
To Purchase	$2800/each
TOTAL	**9,800,000**

Table 1, Construction cost estimate of biomass boiler system.

Table 2 shows the estimated life cycle cost and expected pay back. The biomass system, using wood pellets, will generate a payback period of approximately seven years versus the cost of oil.

Life Cycle

Biomass

ITEM	COST
Pellets	4,000,000
Maintenance	640,000
Construction	9,831,000
Inflation	2%
TOTAL/ YR (w/o construction)	4,640,000

Life Expectancy 40 years

Oil

ITEM	COST
Oil	5,100,000
Maintenance	780,000
Construction	0
Inflation	6%
TOTAL/ YR	5,880,000

Life Expectancy 20 years

Table 2, Life cycle cost of wood pellets and oil.

The 30 year savings is estimated to be $264 million. This is based on the projected price increase of 2% per year for wood pellets and 6% per year for oil.

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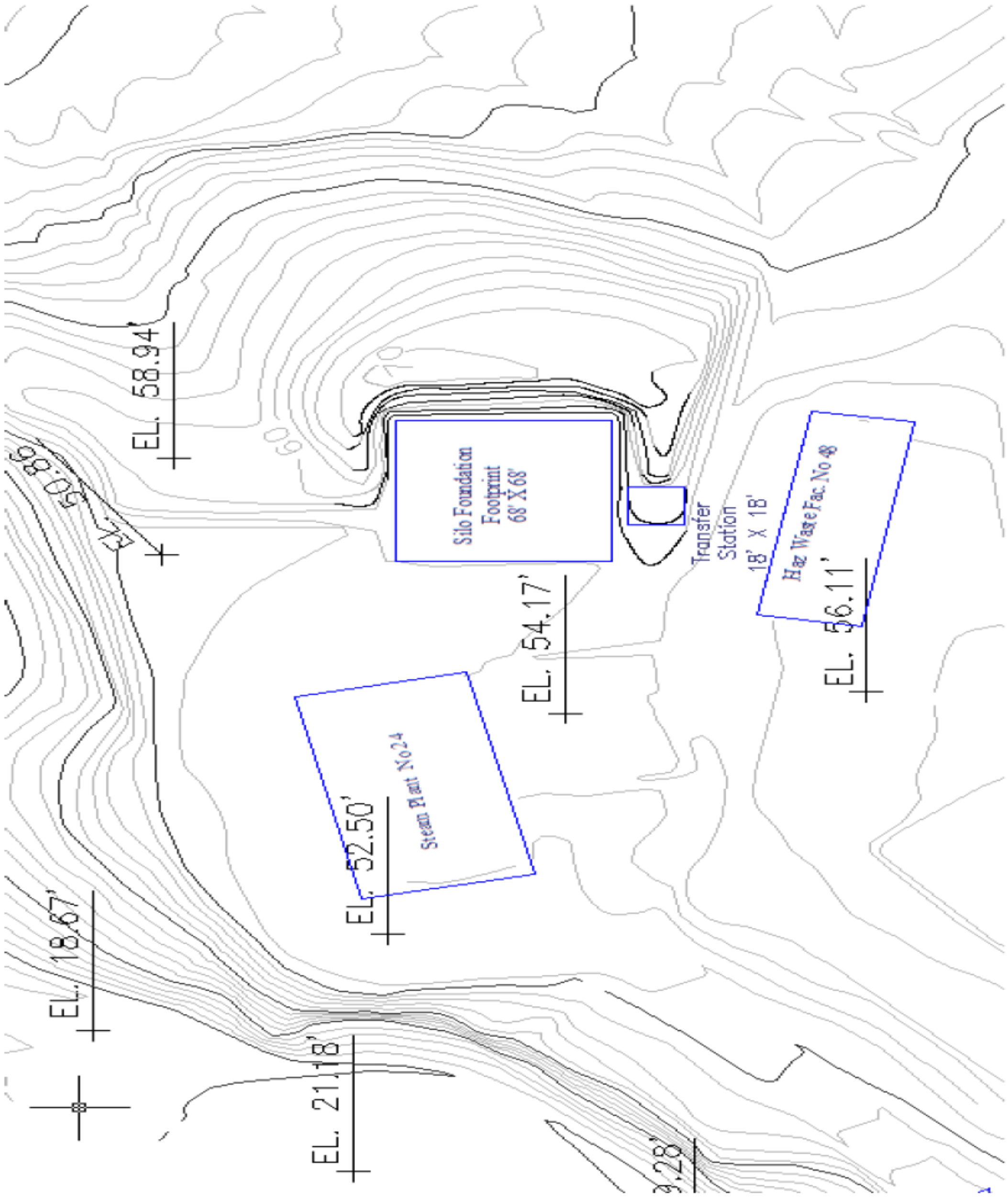
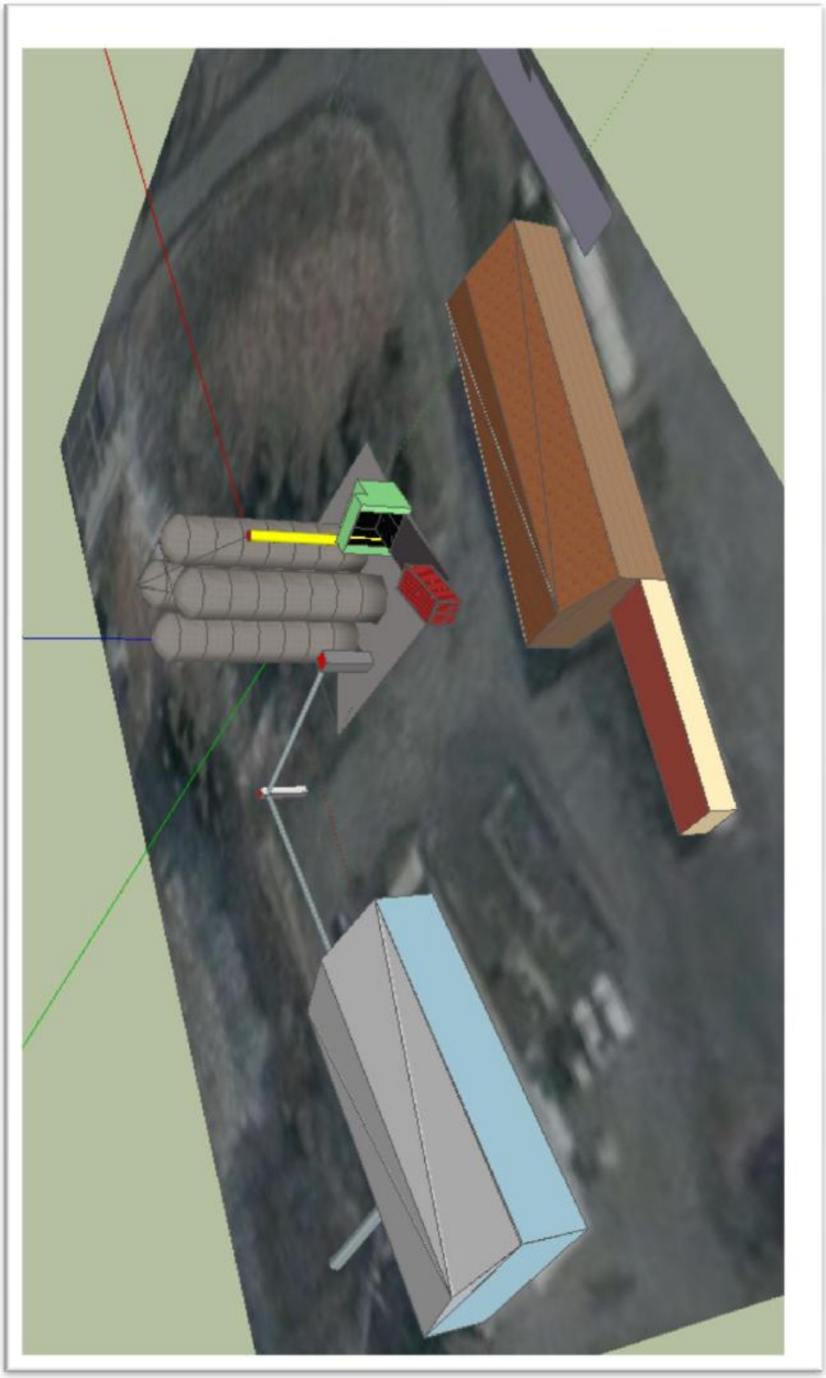
Appendix A


EL. 58.94'
Silo Foundation Footprint 68' X 68'
Transfer Station 18' X 18'
Haz Waste Fac No 48
EL. 54.17'
EL. 56.11'
Steam Plant No 24
EL. 52.50'
EL. 18.67'
EL. 21.18'

Appendix B



Proposed site of four silos next to building 24, steam plant.