# Appleton Fluidized Bed Boiler Cost Justification

**Fall 2008**

Formatted: Italian (Italy)

**Miranda Madole, Paul Sager,**
**Mike Stephenson, Scott Zastaupil**

**Introduction**

Appleton Paper is a manufacturer of carbon-less paper that has committed to increasing its use of environmentally preferable manufacturing processes in order to significantly reduce its carbon footprint over the next five years. This reduction of carbon footprint could be accomplished through the use of new technologies including Fluidized Bed Boilers (FBB) and biofuels in their West Carrollton, OH plant. The cost justification has been measured against a return on investment of two years established by company management. The focus of our project research was as follows:

- Evaluating the pros & cons of different boiler types
- Assessing currently available models of FBBs for large scale manufacturing process
- Determining the availability of biofuels in Ohio
- Funding opportunities such as grants
- Calculating a Return on Investment (ROI)

**Advantages and Disadvantages of Boiler Types**

Coal Boiler-

The largest benefit with a coal burning boiler is the low direct costs associated with burning coal. Compared to other widely produced fuels, coal is available at an extremely low price. A study by Purdue University found that coal could be burned at $1.50 per BTU of heating energy, while an equivalent amount of natural gas would cost $5.55. This price differential makes coal a very attractive fuel source for high energy use industries.

While coal can be bought for a low cost in today's market, burning coal emits several toxic greenhouse gases such as carbon dioxide, nitrous oxide, and sulfur. Greenhouse gas regulation is currently being debated in Congress and will likely be in place within the next five years. As such, the regulation of carbon emissions will impact the economic benefits of coal burning.

Natural Gas Boiler-

The largest advantage of natural gas is that it is burns much cleaner than coal. Using natural gas to generate heat produces 45% less CO2 emissions, 2/3$^{rd}$s less nitrous oxide, and one percent as much sulfur oxides compared to a similar energy output of coal.

While natural gas burns cleaner, it is currently considerably more expensive than coal. As stated before, a single kJ of heating energy for natural gas is $5.55 compared to $1.50 of coal. While future greenhouse emission standards may make burning coal more expensive, it is unlikely that natural gas will be more economical than coal.

Fludized Bed Boiler-

As with a natural gas boiler, a major advantage of a FBB is decreased emissions. Fluidized boilers use heat jets to burn fuel in the air. This tumbling allows coal to be mixed with limestone to reduce sulfur emissions. When the limestone is combined with sulfur, a dry powder called calcium sulfate is created and can be easily removed from the boiler. In addition to absorbing sulfur, the fluidized boiler can lower

nitrous oxide emissions by burning coal at a lower temperature. Nitrous oxide is emitted when fuels are burned hot enough to break up nitrogen atoms that are then combined with oxygen molecules. A FBB can burn coal at temperatures as low as 1400F, which is substantially less than a traditional boiler which burns coal at 3000F. At 1400F, nitrogen atoms are not broken up and therefore very little nitrous oxide is released. In total, the fluidized boiler can eliminate up to 90% of the sulfur and nitrogen oxide emissions. These reduced emissions will lower the economic exposure risks that coal boilers now bear with imminent regulation looming in the near future.

The other major advantage of fluidized boilers is that they allow for flexibility in fuel use. Depending on the size of the boiler, a fluidized boiler can burn nearly any solid or liquid material. Fluidized boilers can go from burning biofuels, to burning tires, to burning coal. This flexibility allows a company to search for the most economical fuel source, thereby reducing the risk of being dependent on any single fuel if prices of certain commodity fluctuate wildly.

While FBBs provide many benefits, the major obstacle with this technology is the cost. A fluidized boiler must be custom built for each plant's power and fuel needs and can therefore cost as much as 30-40% more than a standard coal boiler.

**FBB Types**

There are two kinds of FBBs: circulating FBB and bubbling FBB. For the fuel type and capacity needed to replace Appleton's current boiler, a bubbling FBB (BFB) would be the most practical. It is designed to allow a variety of fuels to be burned. These fuels include wood waste, bark, paper mill sludge, sewage sludge, tire-derived fuels, natural gas, biofuels, and more. BFBs also lower emissions such as nitrogen oxides, sulfur dioxide, carbon monoxide, and volatile organic compounds.

**Biofuels Options in Ohio**

There are a variety of biofuels available in the state of Ohio. The focus of our research, as directed by Appleton, was on solid biofuels. In general, solid biofuels work better in FBBs. In some cases there may be no cost, a cost avoidance or even the possibility of revenue generation from burning certain types of solid fuels. While there are a number of liquid biofuels readily available in Ohio, these were out of scope for this project. However, these may be considered as a backup when solid fuels are in short supply and a better alternative than coal.

The solid biofuels presented in this paper are from four categories: agricultural, municipal, wood and industrial waste. There are pros and cons of each category, and these should be considered when setting up a consistent source of supply. The main factors to consider when selecting which biofuel(s) to use include availability, expense, heating value (BTU's), and moisture, carbon and sulfur content. In Appendix A, each of these factors is listed along with several different fuel types. The decision on biofuel types will directly impact the final design and cost of the FBB. Furthermore, lower moisture content translates into higher energy utilization efficiency. Our benchmark fuel source for the project was the coal which is approximately 13,000 BTUs / lb at a cost of $93/ton.

The ability to switch between the various fuel types or burn them simultaneously will help give the West Carrollton plant the ability to secure a variety of solid biofuels from multiple sources throughout the year. While even a combination of alternative fuels may not completely eliminate the need for coal, it will go a long way in reducing the current rate of consumption and the resulting carbon footprint. The

economics of biomass systems are highly dependent on transportation cost, with 50 miles being the furthest the fuel is typically transported. Therefore it is better to design a system that sources local supply and has several different sources of biofuel supply available.

Industrial Waste

With industrial waste, our research focused primarily on two fuel types: TDF (Tired Derived Fuel) and the paper sludge created on site at the West Carrollton plant. There are a number of factors to consider with TDF including availability, processing and transportation of tires. In order to use tires as fuel, they need to first be processed and turned into chips. This will add costs both for the processing of the tires and the transportation to the manufacturing plant. Another consideration with using TDF is related to emissions. It is therefore recommended that good emissions controls are built into the FBB which may add to the up-front costs. Scrubbers can reduce sulfur emissions by up to 90 percent, when working properly. Still, smaller particulates are less likely to be absorbed by the limestone, and can pass out the smokestack into the air. It is also prudent to involve the local EPA for the purposes of emissions regulations as well as community members, especially considering the West Carrollton Plant is in a highly residential area. The other issue that West Carrollton will need to contend with is the new EPA rules expected over the next five years. Right now there is no information on exactly what these will look like so there is a risk that equipment purchased today will not meet the regulatory standards when these changes are implemented.

The second industrial waste fuel source, paper sludge, has a relatively high moisture content of around 59.47% and an approximate heat value of BTU of 1,783, both of which are not ideal for use in a FBB. However, the benefit of removing approximately $2.5 million worth of sludge per year from the landfill is a cost avoidance that would help justify the purchase of a new FBB. Higher moisture content of the paper sludge will require a larger boiler.

Municipal Waste

We investigated two possible municipal waste fuel sources: refuse derived fuels (RDF) and waste water treatment sludge. Refuse Derived Fuels consist of yard waste and regular household trash. Both the moisture content and heating value of RDF varies quite a lot. The city of West Carrollton is located in Montgomery County which handles the trash hauling and disposal. They spend approximately $10 million dollars annually transporting and landfilling 360,000 tons of trash. There may be some possible revenue generation opportunities for Appleton Paper if the West Carrollton plant could establish an agreement with the Montgomery County Waste Disposal Department in which they would burn the trash in a waste-to-energy system such as an FBB. This additional revenue could help justify the high costs of the FBB. Assuming that landfill space and transportation of refuse will get more expensive in the future, the potential revenue generation from burning trash in an FBB could also increase in the future. As with other types of waste, it will be important to involve the local EPA for the purposes of emissions regulations and take a proactive approach to the local community.

Waste Water Treatment Sludge has a high moisture content (approximately 13%) which would require a larger boiler but this could be offset if West Carrollton could receive a portion of the $100,000 the City of West Carrollton spends to landfill the waste water treatment sludge each year. Still, this is a relatively small amount of revenue considering the high cost of the FBB.

Agricultural Waste

While there are many kinds of agricultural waste to choose from, the most practical and readily available in the state of Ohio include corn cobs, corn stalks, cow manure, switchgrass and wheat straw. As this is a seasonal fuel source, it should be considered as part of the total biofuel portfolio. It will be important to consider the source location of the agricultural waste so as to not offset any carbon footprint reduction by an increase in the energy required to transport in from the field to the plant.

Wood Waste

Wood waste can also be used as a source of fuel and comes from three different sources: forests, urban tree and landscape residues and waste wood from manufacturing, and wood processing as well as construction wastes. Using this type of biofuel also allows material to be diverted from the landfill and there is no net increase in CO2 emissions. Typically, the most important cost of wood is transportation. As stated above, transportation of wood waste fuels more than 50 mile may not be economical. Wood waste also has a relatively low heat value compared to coal.

Cost Justification

- *Direct Manufacturing Costs* - From a conversation Energy Products of Idaho, we determined that Appleton could install an FBB for approximately $21 million. $7 million of this cost would be related to installation of the boiler. We obtained quotes from other companies as well, and Energy Products gave us the lowest quote that would still meet Appleton's energy needs.

- *Government Funding*- The Ohio Air Quality Development Authority (OAQDA) works closely with companies such as Appleton to assist in the funding of industrial projects that will reduce carbon emissions while keeping businesses running in Ohio. In order to receive funding, Appleton would have to work very closely with the OAQDA as there is obviously a very detailed and diligent approval process that the state goes through before approving funding for projects of this size. Based on preliminary discussions with the OAQDA, grants are available in amounts up to $5 million, and the department is willing to use any number of other creative measures to assist in funding Appleton with a FBB. Such measures could include interest free loans, tax exempt bonds, property tax credits, sales tax exemptions for construction of the FBB, and conduit bonds. In addition, the OAQDA would work with Appleton and other governmental departments to determine Appleton's eligibility for other state or federal funding. Information gathered from the OAQDA indicates that an FBB would generally be eligible for the $5 million maximum of grants and the remaining cost of the boiler could very likely be financed completely by loans from governmental agencies just within Ohio. Again, applying for such funding would be a lengthy process that would involve Appleton very closely, but the company could realize a great deal of savings if the government is able to help reduce potential interest and tax costs that would associated with a capital project of this size.

- *Cost Avoidance*-
    1. *Reduced Landfill Costs* - Currently the Appleton is paying $200,000 per month to landfill their industrial waste. A FBB would allow Appleton to eliminate these costs, saving $2.4 million annually.
    2. *Reduced Coal Costs* – There will be a cost savings of approximately $4.4 million each year by burning sludge and municipal waste instead of coal. From conversations with Montgomery County officials, we are confident that Appleton could reach a deal with the county to burn some of its municipal RDF waste. For the sake of determining an exact ROI, we assumed that Appleton would use 20% of the county's waste. Based on the heating values contained

in Appendix A, we were able to calculate the amount of energy that could be replaced by burning sludge and municipal waste rather than coal. See Appendix C for calculations. It also may be possible that Montgomery County would pay Appleton up to $10 million annually to take their RDF waste, however, we did not rely on this potential revenue when calculating a ROI.

- *Carbon Credit Savings*- Based on the assumptions outlined directly above in the cost avoidance section, we determined that Appleton would avoid using approximately 47,000 tons of coal each year. Using a spreadsheet provided by Appleton, we were able to translate this into a 2% reduction in carbon emissions for the West Carrollton plant. Assuming proposed cap and trade regulation in the future, we again used a tool provided by Appleton to determine that this 2% reduction would equal a savings of around $188,000 each year once cap and trade regulations passed.

- *Sustainable Marketing*- There will continue to be demand for sustainable business practices and products in the paper industry. Marketing these efforts will help keep the existing customers and attract new one's who take sustainability seriously.

  Appleton's competitors are currently taking their environmental measures seriously. Certification from the Forest Stewardship Council (FSC) is something they claim to be of increasing interest to paper buyers, users, and consumers. One example of this is Glatfelter. They market their certification to the FSC Programme for the Endorsement of Forest Certification (PEFC), and the Sustainable Forestry Initiative. They have received ISO 14001 certification for their environmental management system. In addition, they market that forty percent of the electricity they produce is generated from biomass and are considered to be carbon neutral. Another example of this is Avery Dennison. They have set six global priorities including the achievement of responsible paper sourcing through supply chain collaboration, engagement with responsible forestry organizations and third-party chain of custody certification of operations. Hewlett Packard has a social and environmental responsibility program and one of their commitments is to reduce the suppliers' environmental footprint. For the sake of calculating a ROI, we did not include sustainable marketing due to the amount of unpredictability surrounding its value.

**Conclusion**

There are a number of factors to consider before purchasing a FBB, including the cost and availability of the various fuel sources and the current and future regulation that will impact both emission and carbon credit needs. There are also a number opportunities available to help justify the cost of a FBB including revenue generation through partnerships with local municipalities as well as grants and related funding. Based on the assumptions made in this paper, we calculated an expected ROI of 2.36 years. This number relies on several estimates and assumptions and was calculated without considering a number of factors that could not be easily quantified. We therefore recommend a more detailed investigation into our findings by the Appleton Management team with respect to technical requirements, possible partnerships, local regulation and key stakeholder involvement.

**Appendix A: Biofuel Availability, Heating Value, & Moisture Content**

| Fuel Type | Availability | Approximate Heating Valued (BTU/lb.) | Moisture Content |
|---|---|---|---|
| Coal | High/All Year | 12,885 | 2-30% |
| Agricultural Waste | Medium/Seasonal | 4,300-7,300 | 10-40% |
| Paper Sludge | High/All Year | 1,783 | 59% |
| Municipal Waste (Waste Water Sludge) | High/All Year | 4,500 | 87% |
| Municipal Waste (Refuse Derived Fuel) | High/All Year | 8,000 | Varies widely |
| Wood Waste | Low/All Year | 7,750 – 8,200 | 12% |
| Tire Derived Fuel (TDF) | High/All Year | 12,000 - 16,000 | Low |

Sources: Biomass Energy Data Book

Penn State College of Agricultural Sciences

http://www.energyproducts.com

http://www.abe.psu.edu/extension/factsheets/h/H83.pdf

http://suncrestenergyinc.com/images/wte_presentation.pdf

**Appendix B: Contacts for Governmental Funding**

Most of the funding information we gathered from the OAQDA was from project manager Todd Nein (614-387-3062), who works with companies to organize the funding for large scale projects such as FBBs. Within the OAQDA, Bob Brown (614-466-6538) works specifically on FBBs, and he and Todd would likely work together to help Appleton assess their options. Information about grants and loans can be found on the OAQDA website here: http://www.ohioairquality.org/advanced_energy_program/

The Ohio Department of Development also offers funding for FBBs if the project will bring more jobs to the state. This did not seem to the case for this project, so we focused our attention on funding from other sources. Nonetheless, here are two contacts within the Department of Development that Appleton could work with to assess their eligibility for funding:

Kevin Carver (937-285-6185)

Michelle Miller (614-644-9759)

Appendix C

| **One Time Events** | | **Explanation** |
|---|---|---|
| Boiler Cost | 14,000,000.00 | Per Energy Products of Idaho |
| Boiler Installation | 7,000,000.00 | Per Energy Products of Idaho |
| Government Grants | -5,000,000.00 | Grant from the OAQDA |
| Total Up -front costs: | 16,000,000.00 | |
| | | |
| **Annual Savings** | | |
| Elimination of Landfill Costs | -2,400,000.00 | Per Appleton Paper |
| Cost Avoidance of Using Sludge & Not Coal | -1,249,465.79 | See Appendix D |
| Cost Avoidance of Using Municipal Waste & Not Coal | -3,118,044.24 | See Appendix E |
| | | |
| **ROI** | **2.36** | **years** |
| | | |
| **Other possible sources of cost savings** | | |
| Revenue Generation from Taking on Municipal Waste | 0-10,000,000 | Per Montgomery County Solid Waste District (927-224-3734) |
| Revenue from Future Cap & Trade Regulation | 188,255.00 | Based on a 2% reduction in coal usage from burning sludge & municipal waste instead |
| Increased Product Marketability | Intangible | |

Appendix D

| | | |
|---|---|---|
| 266 T/ day * 365 days = | 97,090 | T/year of sludge |
| 97090 T/year * 2000lbs/T= | 194,180,000 | lb/year of sludge |
| 194180000 lb/yr * 1783 BTU/lb (for sludge) | 3.46223E+11 | BTU produced from burning sludge each year |
| Divide this by 12885 BTU/ lb (for coal) | 26,870,232.05 | lbs of coal that could be avoided by burning sludge each year |
| Divide by 2000lbs/T | 13,435 | Ts of coal that could be avoided by burning sludge each year |
| * $93/T for coal | 1,249,466 | Annual cost savings from burning sludge instead of coal |

Appendix E

| | | |
|---|---|---|
| 360000 T/year * .75 (25% unusable) | 270,000.00 | 75% is usable per www.energyproducts.com/epitechpapers.htm |
| 270000 T/year * 2000lbs/T= | 540,000,000.00 | lb/year of municipal waste |
| 194180000 lb/yr * 8000 BTU/lb (for sludge) | 4,320,000,000,000.00 | BTU produced from burning municipal waste (refuse derived) each year |
| Divide this by 12885 BTU/ lb (for coal) | 335,273,573.92 | lbs of coal that could be avoided by burning municipal waste each year |
| Divide by 2000lbs/T | 167,636.79 | Ts of coal that could be avoided by burning municipal waste |
| * $93/T for coal | 15,590,221.19 | Annual cost savings from burning sludge instead of coal |

The 360,000 T/year is the amount of waste generated by Montgomery County. The Montgomery County Solid Waste District would be interested in partnering with Appleton to fuel their FBB.
Assuming Appleton could use X% of that waste each year, the cost avoidance from using municipal waste instead of coal would be:

| X% of waste in Montgomery County each year | Coal Cost Avoided Annually | |
|---|---|---|
| 5% | 779,511.06 | |
| 10% | 1,559,022.12 | |
| 15% | 2,338,533.18 | |
| **20%** | **3,118,044.24** | **For this project, we have assumed that Appleton can use approximately 20% of county's waste each year.** |
| 25% | 3,897,555.30 | |
| 30% | 4,677,066.36 | |
| 40% | 6,236,088.47 | |
| 50% | 7,795,110.59 | |
| 75% | 11,692,665.89 | |
| 100% | 15,590,221.19 | |