Introduction:

The cost of energy is an important concern for businesses, institutions, and people. The volatility of the fuel oil and natural market has reintroduced the desire to move away from dependency on foreign oil as well as natural gas. The price of natural gas and oil has reached such high prices that it sparked a serious interest in alternative energies. Much renewable energy, like solar, wind, geothermal, biomass and many others, have come under consideration for use in small to large scale projects.

Biomass has received serious attention in recent years. Biomass is defined as any fuel that can be extracted or created from plants. The range of plants within this category is pretty expansive, including soybeans, certain kinds of grass, trees, corn, and even algae. This project will focus on wood chips (coming from trees) as a source of biomass fuel ("FAQ").

Wood chip biomass plants are not new technology. There are wood chips plants, like the Joseph C. McNeil Station has been burning wood chips since the early 1980s. It did not gain popularity because the cost of oil was far lower than today, therefore reducing incentives to invest in a most renewable energies (Wiltsee 23).

In the New England area several wood chip burning biomass cogeneration plants have sprouted. Middlebury College is one of the notable examples of a new biomass plant. Bennington College and Green Mountain College have both employed similar wood burning biomass plants recently (Barna).

These systems are gaining popularity for a number of reasons. The first and foremost reason is that these energy producing plants are significantly cheaper than fuel oils or natural gas. They relieve these institutions from being dependent on foreign oil

(the schools mentioned do not use natural gas) and pump money back into the local economy because the wood chips are supplied locally.

The second significant reason that burning wood chips have gained popularity is the impact wood chip biomass plants can have on carbon dioxide emissions. The boilers burning wood chips come in three different burning styles but the most common one, especially among these schools, is the gasification type. The boiler turns the wood chips into a gas and catches the ash produced. Some boilers, like Middlebury's claim a 99.7% efficiency rate particulate collection during the gasification process. The claim is that provides a zero – net CO2 emissions. This means that the CO2 produced is low enough in quantity that plants can naturally absorb it. This has led to drastic reductions in CO2 emissions for schools like Middlebury that are committed to reducing their carbon footprint. In addition to reducing their production of CO2, biomass plants are significantly reducing the amount of oil bought and because of wood chips lower price, colleges are saving money ("FAQ").

Another benefit to wood chip biomass plants is that in addition to providing heating they can also provide electricity. The steam produced from the boiler can be run through a turbine to generate electricity. Middlebury is able to meet half its heating demands with this biomass plant and about a fifth, or three to five kilowatt hours of electricity per year (Mike Moser Middlebury College).

This renewable energy source is also not without its complications and difficulties. One of the major factors affecting large to medium scale wood chip biomass plant decisions is the availability of wood chips. There are not many providers of large scale quantities of wood chips in the New England region. There is a lot of wood. It is an

abundant resource in many states. Institutions like Middlebury and Bennington College must turn to brokers, like Cousineau Forest Products, to find them enough wood chips annually because mills and logging cites are not large enough to own a chipper that can supply the tens of thousands of tons needed annually (Bill Tronsen).

In addition to issues of supply there is also the issue of how far the wood chips must travel before reaching their destination. Transportation of these wood chips can have a significant impact on the cost of wood chips. Generally, it is not profitable to get wood chips from farther than forty to fifty miles away. This figure also applies only to large scale quantities like a college institution would require. It is important to note that Cousineau Forest Products will obtain wood chips from as far as seventy five miles away. This could have effects on cost if fuel for transportation rises. This also has implications on the carbon neutrality of the operation. This is area seems to be somewhat ignored in estimate of carbon footprints (Bill Tronsen).

Another difficulty associated with these systems is that they cannot totally replace fossil fuels. Because of the process used to generate energy, gasification of wood chips, these biomass plants cannot meet peak demands. They do not have issues sustaining base loads cannot meet peak demands because the boilers cannot ramp up burning fast enough to account for peak heating or energy demands. This means that some amount of fossil fuels must be burned to meet peak demands (Bill Tronsen).

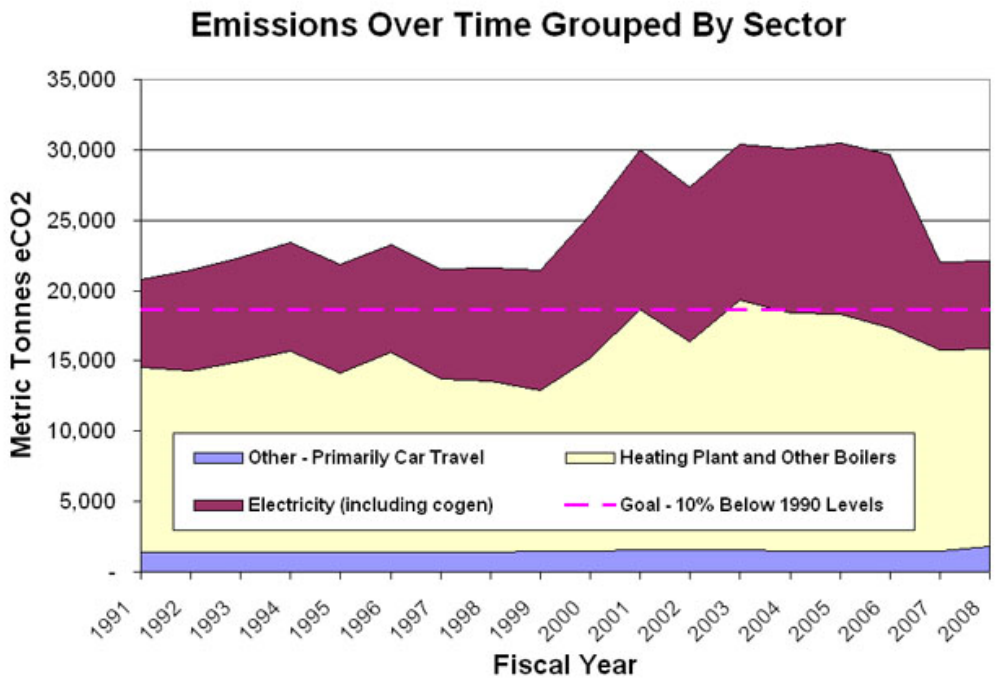
Despite these difficulties wood chip biomass is still an attractive option because of its cost and reduction in CO2 gases. This project will consider whether Williams College should consider investing in wood chip biomass as an alternative form of renewable energy. While a more in depth analysis would be required by an engineering

firm to fully understand al of the variables, this work has found that it is perhaps t in the best interest of the college to seriously investigate the benefit of a wood chip biomass plant.

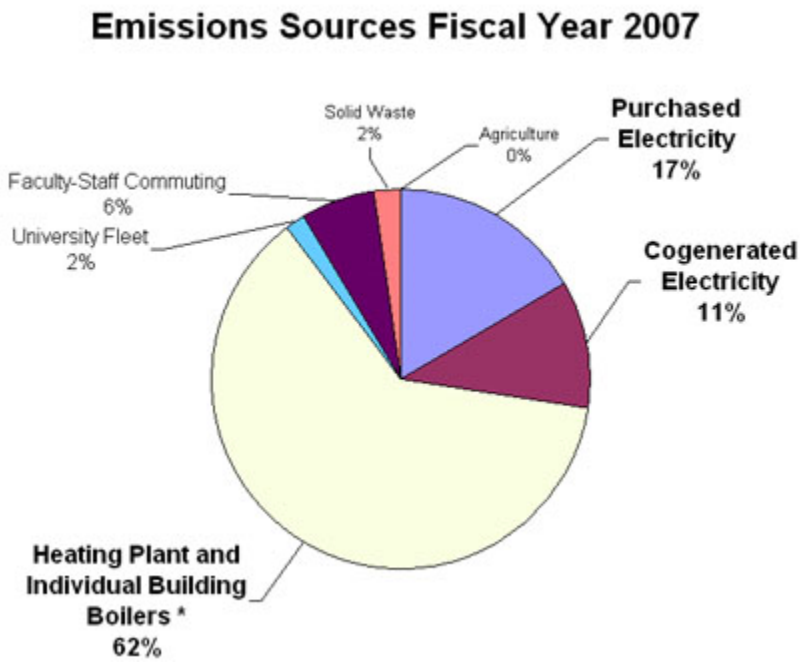
Setting:

Carbon Emission Goals

Williams, like many other schools around the nation has pledged to reduce its carbon dioxide emissions. In 1991, Williams CO2 emissions were at 21,000 metric tons. By the FY06 they had risen almost 10,000 metric tons. By FY08 emissions were reduced back down to 21,848 metric tons. This drop in emissions was achieved after Williams took a stance to reduce its emissions to pre FY90/91 levels. The table below demonstrates the trend in emissions productions until FY08 ("Report on Greenhouse Gas"1).



Because of Williams' commitment to reducing their carbon footprint the first figures to look at what functions of the college produce the most significant amount of CO2. The Table below helps illustrate identify the main source of emissions on campus.

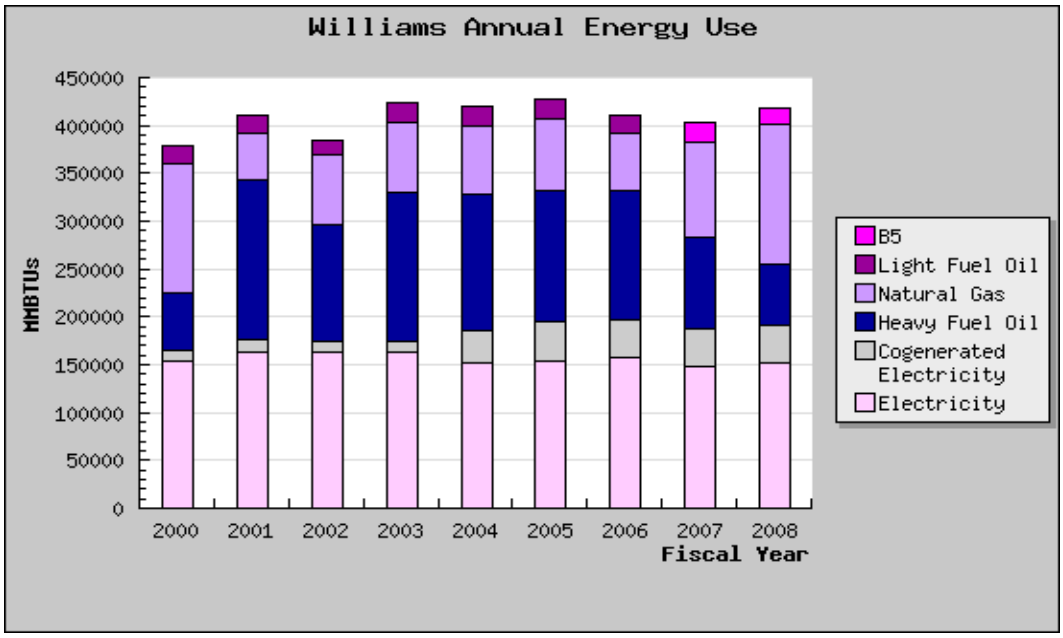


The heating plant and individual boilers are overwhelmingly the largest contributors of green house CO2. This is where efforts to reduce carbon emissions should be focused (http://www.williams.edu/resources/sustainability/co2_sources.php).

Unique fuel characteristics at Williams College

Just as the reduction of carbon emissions is a priority for Williams it was also a major priority for Bennington College and Middlebury College. It was an especially attractive feature for those two schools because they both were burning almost exclusively fuel oil. Unfortunately there is not an infrastructure set up for these schools to utilize natural gas (Bill Tronsen).

Williams has reduced its emissions through the use of natural gas. Natural gas has 35% less emissions than #6 oil, which was a primary fuel source for Williams previously. This is a fundamental difference from the situation that the other schools dealt with because natural gas was not an alternative and they were producing larger amounts of CO2 as a result. Natural gas is more expensive than fuel oil but because of its reduced emissions it has become a viable option for Williams. The illustration below helps illustrate Williams shift from heavy oils to natural gas ("Report on Greenhouse").



We can see that in 2006, natural gas was not a primary fuel source but that in 2007 that changed dramatically. The move to natural gas was even furthered by 20008, significantly reducing the amount of heavy fuel oil being used. This is led to a 31% reduction in emissions. Although the table is not exact the figures on the amount of fuel used are as follows: the campus used 519,007 gallons of heavy fuel, 1,670,312 ccfs of natural gas.

Compare this situation with one like Middlebury. They were burning 2 million gallons of heavy fuel oil per year. They also did not have the alternative of using natural gas. This puts into question whether the investment of a wood chip biomass plant creates enough savings when compared to natural gas. Furthermore, it questions how much the savings in CO2 will be if the switch takes place given it already has a significantly lower emissions rate than heavy fuel oils. There is also the question of how much money will be saved in comparison to natural gas since it is more expensive than heavy fuel oils.

Boiler differences

An important factor to consider when comparing Williams to schools like Middlebury is cooling. Middlebury uses its boilers to heat and cool the school. The boilers currently used at Williams are used only for heating (Mike Moser).

Another key difference is that while Williams has three boilers in its heating plant but it primarily uses only one. It uses one large boiler, roughly 2030 hp, which runs on natural gas to do primarily all of the campus heating. The other two boilers run on heavy fuels and are less efficient. They are turned to as backups. Bennington College for example has two 400 hp fuel burning boilers. They purchased a cumulatively equivalent sized wood chip boiler that is able to supply the base load. According to the facilities manager of Bennington College, Bill Tronsen, an institution should get a wood chip biomass boiler that is equivalent to the total horse power of the fuel burning boilers. Because Williams relies on primarily one boiler to do almost all the heating it changes the consideration for the size of wood chip boiler to install (Bill Tronsen; Tom Miller).

Method:

Method of research consisted of two types. The first was traditional research done online and in the library. The second, less conventional type of research, involved several personal phone calls with representatives from companies, or managers of facilities programs at different institutions.

Results/Findings:

Type of System:

The type of system is important because it determines the type of wood chips that can be used. It is important to understand the different types of wood chips. There are three types of wood chips that can be delivered. The highest quality and most expensive type of wood chips are mill chips. They have no bark and are often bought by paper mills. The other two types are bole and whole tree chips. Bole chips come from the base of the tree. The log, without branches, leaves; etc is chipped with its bark still on. Wood chips containing bark actually yield more btus but also create more ash. The last kind of wood chips, whole tree chips, come from the chipping of a tree whole. This results in pieces of leaves, branches, and bark being included in amongst the wood chips (Bill Tronsen).

Most systems that are only a boiler cannot burn chips other than mill chips because of their size. Chips that come from the other two types are often too large to be put through a gasification boiler. Both, Middlebury and Bennington, utilize wood chip biomass system that has a hammer mill. The hammer mill sorts out pieces that are too

large for the boiler and breaks them down into a manageable size. This is critical to both systems because without it the availability of chips would be significantly reduced. A system with a hammer mill allows for any chip type to be burned. In order to not create larger supply issues a system with a hammer mill would be necessary chips (Bill Tronsen).

Size of System:

Because systems with hammer mills are almost necessary benefit, the company that supplied both Middlebury and Bennington, Chiptech Inc., with their systems was contacted. Brad Noviski, the design manager behind Middlebury's biomass plant said that each fitting of systems is a custom job. It requires an in depth analysis the current infrastructure that is already existent and what availability there is for expansion. A major component that affects the installation is the steam turbine infrastructure that is existent. For example, Middlebury's boiler is not larger than the one used at Bennington College despite the fact that Middlebury's student population is more than three times greater. Williams already existent steam turbine infrastructure would be a mitigating factor in the eventual size settled on for the project in addition to the goal of heat production. Most installations also require an additional facility to be built to house the boiler. This is determined by available space in the plant as well as available space surrounding the plant (Brad Noviski).

Peak Load Issues:

As previously discussed there are issues with peak loads and wood chip biomass systems. It is an accepted fact, at least at Middlebury and Bennington, that alternatives to wood chips are needed to meet peak demands. This is because the system cannot ramp up its burning fast enough to generate adequate amounts of heat or electricity. This is the reason that the other schools have kept their oil burning boilers.

This is problematic for Williams to some degree. The primary boiler for Williams supplies enough heat for the whole campus and the other two boilers are only backups. Keeping the large boiler and adding a wood chip burning boiler seems like it could be an option although that results in then a large capacity gas burning boiler that is largely out of use. Williams could research in a wood chip burning boiler that can also fire natural gas to meet peak loads.

Supply of Wood Chips:

Making sure that the demand for wood chips can be met is one of the most critical aspects in determining the feasibility of a wood chip burning biomass plant. Upon contacting Middlebury and Bennington it was found that they both receive their supply from Cousineau Forest Products. Upon asking managers of facilities at both institutions where the chips were coming from specifically it was revealed that neither knew. They are not told where they come from. They only know that they come from within a 75 mile radius. What they do is settle on a contract for a year with a broker, like Cousineau because it is otherwise too difficult to procure chips individually from loggers. Making matters more complicated, brokers do not like to settle on a contract that is longer than a year for a variety of reasons but primarily because of potential increases in chip price.

Cousineau would also not explain who the loggers they used were but they did say that they remained confident in their ability to meet new demands for chips (Bill Tronsen; Mike Moser).

It is not an issue of supply of wood so much as equipment. In order to produce wood chips, loggers require a large scale chipper. This is usually only possible for large scale loggers in the area because a chipper costs around $500,000. In addition, because demand is still not high for wood chips there is not an incentive for loggers to go out and purchase chippers (Paul Frederick).

While supply does not seem to be limited in the area an accurate analysis would require a survey of varying loggers in the surrounding 50 miles and an analysis of their capability in terms of wood chipping, and their current demand. There is also the issue of insecurity because there are not loggers that can singularly provide a college with the number of ton necessary per year. In addition, loggers and brokers will not sign agreements for more than a year adding to the questions of supply available. This is a largely under developed aspect of the wood market in the New England despite there being an abundance of resource available.

Cost Analysis of Wood Chips:

The cost analysis of wood chips in comparison to natural gas is promising. In order to compare the two fuel sources it was necessary to start with the comparison of heavy fuel to wood chips. Paul Frederick and Mike Moser independently gave the same conversion rate of wood chips to gallons of fuel oil. They each stated that each ton of wood chips was equivalent to about 60 gallons of fuel oil. 60 gallons of fuel oil was

found to be equivalent to about 9,120 cubic feet of natural gas. The approximate cost of this much natural gas was found to be around $103.32 based on a $11.48 cost of natural gas per million Btu (Paul Frederick; Mike Moser).

The cost of wood chips is currently around $57 a ton delivered. This is a three dollar price increase from the previous year. There is also the issue of transport. Transportation, depending on the cost of diesel at the time, can increase the cost (Bill Tronsen).

This is an almost $50 difference in cost for equivalent amounts of heat. If Williams built a facility that could eliminate half of the total natural gas used it could mean savings of over $400,000 annually.

Heat and Electricity:

The electricity produced by a wood chip boiler is dependent on the number of turbines in use. Middlebury has three turbines already in place and generates from three to five kilowatt hours. Electricity produced from this could be a major benefit given Williams already existent cogeneration facility that produces just over five million kW/hrs (Don Clark).

As far as heat produced we can calculate that for every 9,120 cf of natural gas that is equivalent to one ton of wood chips. If we look at how the total load cubic feet used in the FY08 it is 167,031,200 cf. Treating one ton of wood chips as a 9,120 cf we find that it would only require 18,300 tons of wood chips in a year to provide an equivalent amount of heating. It is important to remember that there is still the issue of peak loads that would have to be handled but this data is still relevant. With less tons per year than Middlebury, Williams could, theoretically, offset its entire usage of natural gas for heating. It is also

important to remember that the Williams heating facility does not cool in addition to heat unlike Middlebury. Despite this difference we can see that a boiler of comparable size to Middlebury's could have a drastic impact on the use of natural gas.

Emissions:

If we work under the assumption that a wood chip gasifying boiler is carbon neutral we only need to figure out the impact total carbon footprint for each natural gas equivalent of a ton of wood chips. For every ton of wood chips there are 9,120 cf of natural gas. 9,120 cf of natural gas is roughly equivalent to 9 million Btu, assuming about 1,000 Btu per cubic foot of natural gas. There are 52.94 kg of CO2 emitted per million Btu. This means that each ton of chips used saves 482.81 kg of CO2. Imagine now that Williams were to use 10,000 tons of wood chips in a year. That would reduce the amount of carbon emitted by about 5,300 tons per year. This means that Williams could reasonably reach its FY90/91 goal of carbon emissions with a wood chip burning biomass plant (Amy Johnson; http://bioenergy.ornl.gov/papers/misc/energy_conv.html; Tom Miller).

Conclusions:

Evaluating the feasibility of erecting a wood chip burning biomass plant has many variables that are not easily accounted for. Wood chip availability is difficult to assess largely because as this market develops more loggers may become involved potentially increasing supply but the reverse could also happen. The use of brokers to find wood

chips for an institution demonstrates the complexity behind finding the necessary amount of fuel. However, burning wood chip biomass seems to be an attractive option. Even compared to natural gas it has significant savings in cost of heating and in CO2 emissions. These are the two most attractive aspects behind this increasingly popular form of energy production. That in mind, there are many uncertain variables that could rule this option out at Williams College. The most important is the availability of loggers within 50 miles who offer wood chips. The next issue is what to about the current boiler situation if a wood chip burning boiler is installed. These concerns make the final answer to the question of wood chip biomass for Williams not a definitive one but given its cost saving potential and ability to reduce emissions significantly it would seem that this is definitely a technology worth investigating.

Appendix I:

Calculations

Givens:

Cost of natural gas - $11.48 per million Btu

Btu/cubic foot of natural gas = 1000

1 Gallon of fuel oil = 152,000 Btu = 152 cf

60 gallons of fuel = 1 ton of wood chips

Calculation of 1 ton of wood chip equivalency

$11.48/MBtu * 1.52 = 17.45/1.52 mmbtu

1 gallon of fuel/152,000 btu = (z) gallons /1.52 mmbtu

z = 10 gallons

(10 gallons of fuel = 1520 cf of natural gas) *6 => 60 gallons = 9,120 cf

Multiply by 6 to get 60 gallons and thus equivalent of 1 ton of wood chips

Cost of 1 ton equivalent of natural gas

10 gallons of fuel = 1520 cf = 1.52 million btu

(1.52 mmbtu of natural gas = $17.45)*6 = $103.32 equivalent Btu for 1 ton of wood chips

Emissions Calculations

9.12 MBtu * 52.94 kg CO2/mmbtu = 482.81 kg CO2

482.81 kg * (2.205 lbs/ 1 kg) * (1 ton/ 2000 lbs) *10,000 = 5322 tons of CO2

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