Community Assistantship Program

Biomass Gasification

Prepared in partnership with
West Central Research and Outreach Center

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Every year, small businesses spend $60 billion on energy costs (EnergyStar, 2008). That number is only going to increase with the rapidly rising prices of fossil fuels. Many small businesses are looking for more efficient ways to heat their businesses at rates that are more economical. One way some businesses are doing just that is by using biomass gasification. Biomass gasification is an existing technology that has “resurfaced” when fossil fuel prices get too large for businesses to handle. The technology of gasification has been around since the late nineteenth century and has been widely used only a few times around the world, until now. This report focuses on the process of biomass gasification and its application to small businesses in particular, a one of its kind case study in Morris, Minnesota.

Research has been done in order to determine the advantages and disadvantages of a boiler fired by wood gasification system. In doing the research, we hoped to understand the gasification process and how it benefits the environment on a small scale. The Laundromat and car wash in Morris currently run on a boiler with a wood gasification system and were previously run on a wood-fired boiler (without a gasification system). The Beyers installed the wood stove at their business because natural gas prices were skyrocketing and they could not afford to continue heating the building and water at that cost. They installed the wood stove as a cost effective and environmentally friendly way to pay to heat the building and provide hot water. The wood fuel that the Beyers are using comes from Craig Beyer’s other business and would otherwise be burned in a landfill at the end of the year. By using this gasifier, the Beyers are putting the wood waste from one business to good use at another.

I. What is Biomass?

Biomass is biological material that comes from living or dead (but not for too long) organisms. Its chemical composition is primarily carbon but usually has a few other elements in it in small amounts such as hydrogen, oxygen, and nitrogen. Some of the organic molecules that are in the biomass contain alkali, alkaline earth, and heavy metals. The carbon used in biomass energy was absorbed from the atmosphere as carbon dioxide (CO_2) by plants in the photosynthesis process. Animals then eat these plants and that is how we get animal biomass. The biomass used in most energy resources is plant biomass, which includes wood, grasses, and some crops like corn (Biomass Energy Centre, 2006). This definition of biomass does not include fossil fuels because they have been in the formation process for millions of years and are, therefore, not from a recently living organism.

The energy in biomass originally came from the sun via photosynthesis, is stored in plants and animals, and according to some writers, is therefore a form of solar energy. When these plants and animals die, their remains will eventually break down and release the carbon dioxide back into the air. According to the Australian Institute of Technology, burning this biomass is not adding new carbon dioxide to the atmosphere. It just speeds up the natural carbon-cycling process. The use of biomass for energy is one form of renewable energy, and will continue to be renewable so long as we do not use the biomass faster than plants and animals around the world produce it. As long as there is sunlight, plants and animals will continue to produce biomass that humans can use as fuel).

On a large scale, biomass energy in the United States was not used until the energy crisis of the 1970's. Wood has been used to heat homes essentially since man discovered fire. Since about 1860, wood has been used for cooking food and creating steam on trains and in factories. People stopped using wood as their main source of fuel during the early 20^{th} century because liquid fuel prices were much cheaper (and more efficient) than wood. During the 1970s, many people started to use wood as fuel again because, like today, fuel prices were skyrocketing, and it was much cheaper to use wood to heat their homes, businesses, etc. (United States Department of Energy, 2008).

II. What is Gasification?

The process of gasification was first used to produce "town gas" in the nineteenth century, for lighting and cooking. After cryogenic separation—the separation of air at low temperatures (into individual elements/molecules)—became available in the 1920s, gasification became a process that was available for the production of synthesis gas and hydrogen because of constant oxygen blast (Higman & van der Burgt, 2003). The earliest forms of gasification and most applications of the process today involve coal gasification. However, biomass gasification started being used more in the 1980s after technology of gasification of biomass more economical (Quaak, Knoef, & Stassen, 1999). About one million air gasifiers were built during World War II to operate cars, trucks, or generate power (Reed, 2002).

Gasification is the process of turning wood, biomass, coal, or other organisms into a vaporous fuel with usable heating value. Biomass gasification, more specifically, is the process of turning biomass fuels into vaporous gas that can be used as fuel for homes and businesses. Combustion is not included in this definition because the product gas of combustion has no heating value. In biomass gasification, incomplete combustion takes place and that process produces byproducts usually composed of carbon monoxide (CO), hydrogen gas (H_2), and sometimes small amounts of methane. The mixture of these gases is called a producer gas or 'syngas' (synthesis gas) (Rajvanshi, 1986).

Gasification generally converts about 90% of the chemical energy available in the fuel source into usable gas fuel. If too much oxygen is present when the gasification conversion occurs, carbon dioxide and water vapor are produced, as in the complete combustion process and the resultant products do not have very much energy in them to be used later (Frontline BioEnergy, LLC, 2008).

III. The Gasification Process.

There are two main elements in the gasification process. The first step is to heat the biomass, at a high temperature, where it forms producer gas and charcoal. The second step is to use charcoal to reduce the carbon dioxide and water that was produced in the first step to create carbon monoxide (CO) and hydrogen gas (H_2). The gasification process requires high temperatures, around 800° C (1475° F), or more, to help break down the gas, which contains a lot of tars and hydrocarbons. The gaseous product components are hydrogen (18-20%), carbon monoxide (18-20%), carbon dioxide (8-10%), methane (2-3%), and small amounts of other hydrocarbons, like ethane. If air is used as the oxidizing agent, rather than steam or pure oxygen, small amounts of nitrogen can sometimes be found in the producer gas. The gasification process is very similar to the combustion process of materials except, in gasification, there is limited oxygen. The limited amount of oxygen helps to make the product gases more useful (Frontline BioEnergy, LLC, 2008). Several different processes happen during the two main steps of the gasification process. In the first step, pyrolysis, the particles are heated up to a point at which the feedstock gives off gas, vaporized tars or oils, and char residues. After the pyrolysis step, the products are dried to evaporate all moisture that may be present. After all the products have been dried, they are then gasified. The gasification usually happens to the solid char first, and then the tars and gases go through the pyrolysis process again, depending on the gasifier unit that is being used.

The partial oxidation in the gasification process occurs because of air, oxygen, and steam (or any combination of these three reactants) that are used as gasification agents. Air gasification creates a very low density and low heating value gas that is suitable for a boiler, engine or turbine usage, but is not very good for transporting the gas via pipelines because it has so little energy. Oxygen gasification produces a medium density gas with a medium heating value.

Air gasification is most widely used because there is no need to worry about the high concentration of oxygen that is being used in oxygen gasification. Cold gas efficiency of air gasification is typically around 70%, but can range from 55-80% (European Biomass Industry Association). Gasification requires a pyrolytic step, but uses a minimal amount of air and steam to convert the char to gas in a single unit (Reed, 2002). Pyrolysis is the decomposition or transformation of a compound because of heat. Air gasification of biomass is a simple process. The gas tends to have a low energy efficiency, but is suitable for use in a retrofitted existing boiler (one that uses oil or natural gas) and can be used to drive engines for transportation (Reed, 2002).

Oxygen gasification is also a relatively simple process that produces a medium energy gas that is mostly carbon monoxide (CO) and hydrogen gas (H_2). It is good for burning, but can also be used to make methanol, ammonia, hydrogen, methane (CH_4), or gas that is called “Syngas” (Reed I1- 2). The same type of producer gas can be created by pyrolytic and steam gasification. The oxygen producer gas can be used in pipeline transportation (in small amounts, over small distances). Air gasification is most widely used because there is no need to worry about the potential of explosion with the presence of high concentrations of oxygen. It is also much cheaper to use air than to use oxygen because air is free.

IV. Types of Gasifiers

In today's market, there are four main types of gasifiers—up-draft gasifiers, downdraft gasifiers, fluidized bed gasifiers, and entrained flow gasifiers. Up-draft and downdraft gasifiers are in a larger category of fixed-bed gasifiers. Each of the four types of gasifiers produces a similar type of gas. The process is slightly different for all four types of gasifiers.

A. Up-Draft (Counter Current Fixed Bed)

The up-draft or counter current fixed bed gasifier is the simplest type of gasifier. The biomass is fed in through the top and then proceeds to move downward because of its conversion and removal of ashes." Air (that helps with the gasification process) comes in at the bottom and the gas leaves out of the top. The biomass moves in the opposite direction of the air, thus creating a counter-current movement of gases. The biomass fuel goes through a drying zone, distillation zone, reduction zone, and hearth zone. The biomass is dried and is then decomposed into volatile gases (that can be burned for fuel) and solid char. The heat for the distillation and drying process is from the upward flowing producer gas and partly from radiation from the hearth zone. In the reduction zone, carbon is converted to carbon monoxide (CO) and hydrogen gas (H_2) is produced (the main component of producer gas). In the hearth zone, the char is combusted, which provides heat, carbon dioxide, and water vapor for the reactions that happen in the reduction zone (Quaak, Knoef, & Stassen, 1999).

One advantage the up-draft gasifier has over the other three types is its simplicity. The up-draft gasifier also has high charcoal burnout and an internal heat exchange, which allows for lower gas exit temperatures and higher efficiencies. The internal heat exchange allows wood to be dried at the top of the gasifier, which in turn, allows for fuels with high moisture content to be used (up to 60%). The up-draft gasifier also is good because it is adaptable and can use many different feedstock sizes.

Some disadvantages to the up-draft gasifier include the high amounts of tar and other products that are produced during the gasification process. There is a larger amount of these products because they do not pass through the hearth zone and are therefore not combusted like the other parts of the process. If the gas is used as a direct heat component or application in which the tars will be burned, the high amount of tar is not a big concern, but if the gas is going to be used as fuel in an engine, it must be cleaned before it can be used (Quaak, Knoef, & Stassen, 1999)

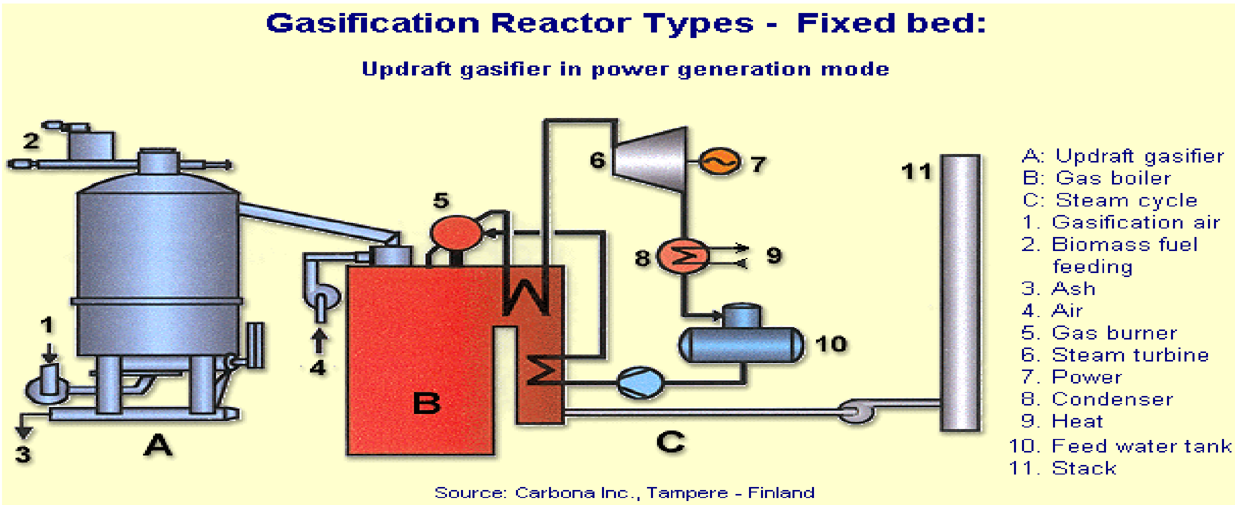


Figure 1

Up-Draft Gasifier Diagram

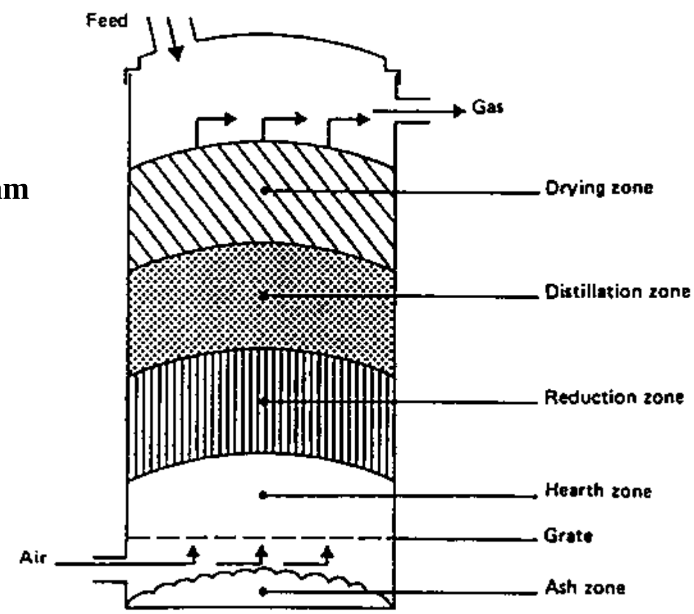


Figure 2 Source: Quaak, Knoef, and Stassen, 1999

B. Downdraft (Co-Current Fixed Bed)

The downdraft gasifier is very similar to the up-draft gasifier. The biomass is again fed in at the top, but instead of the air intake being at the bottom of the gasifier, the air comes in on the top or the sides. Another key difference between the up-draft and downdraft systems is that the gas leaves at the bottom of gasifier. The four zones are similar in a downdraft gasifier, but occur in a different order. First, the biomass is dried and then it goes to the distillation zone. These zones are mainly heated by the radiation given off from the hearth zone and slightly by convection. The pyrolytic gases are also burned in the distillation zone and the gasifier's design will determine how much of the pyrolysis gases are burned. The feedstock itself and the operator will also influence how much of the gases are burned in the gasification process. After the oxidation zone, the remaining char and the products from the combustion go to the reduction zone where they are turned into carbon monoxide (CO) and hydrogen gas (H_2).

The main advantage of a downdraft gasifier is its low tar content of the gas, which makes the gas more applicable to engines because it does not have to be cleaned before it is used. The gas is rarely tar-free because not all the gases go through the hottest zones and they may not be in the combustion zone long enough to eliminate all the tar.

Downdraft gasifiers are generally used in power production in the 80-500 kW_e range (Quaak, Knoef, & Stassen, 1999). Downdraft gasifiers are able to produce up to 1.5MW_{th} of energy and are thus generally used in small-scale applications. Downdraft gasifiers have high market attractiveness and are the system type that is most used by industrial companies (Bridgewater, 2003). The downdraft gasifier is also the most extensively researched of the four main types of gasifiers (Bridgewater, 2003).

Some drawbacks to the downdraft gasifier include the high amounts of ash and dust particles that are in the gas. Because the gas passes through the oxidation zone, where the producer gas collects the dust and ash, there is a large amount of dust and ash in the gas. Another drawback to the downdraft gasifier is that the size of the feedstock is very limited compared to the up-draft gasifiers. Feedstock can generally only be about four to ten centimeters in diameter so that the particles do not block the intake throat. If the particles are much larger than that, they will block the intake throat and allow the pyrolysis gases to flow downward and the heat from the hearth zone will flow upward. To prevent this from happening, the feedstock is usually in the form of pellets or a briquette. The moisture content of the biomass fuel also has a much stricter range. Biomass fuel sources need to have less than twenty-five percent moisture content (on a wet basis). Since the gas leaves the gasifier at a relatively high temperature, the gas has lower gasification efficiency (Quaak, Knoef, & Stassen, 1999).

Downdraft Gasifier Diagram

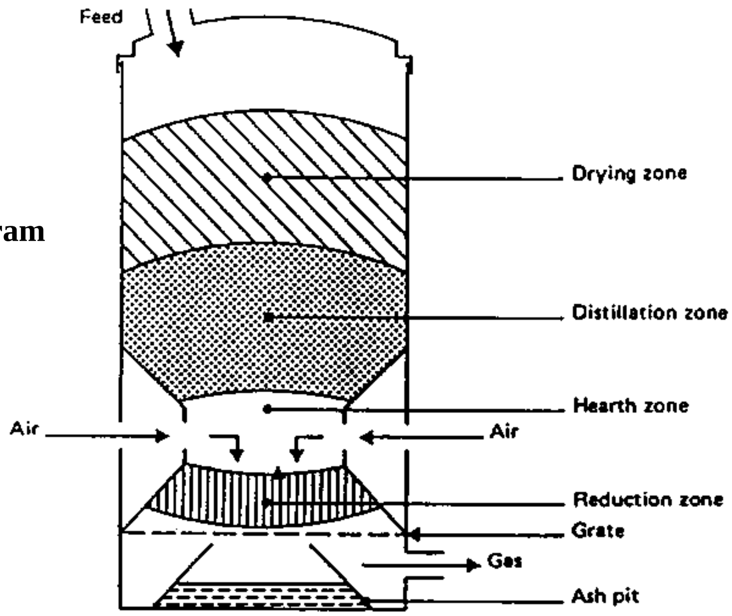


Figure 3 Source: Quaak, Knoef, and Stassen, 1999

C. Other Types of Fixed Bed Gasifiers

There are two more types of fixed bed gasifiers—the cross-draft gasifier and the open core gasifier. These two types of gasifiers are not adaptable to many different types of feedstocks. The cross-draft gasifier is made for charcoal gasification because it has such extremely high temperatures (1500°C +). The open core gasifiers are made to gasify materials that have a low bulk density, like rice husks. There is a lot of ash produced with these types of gasifiers so the ash needs to be removed continuously. Because of the limited situations in which the gasifiers can be used, there are not very many of them in use.

D. Usage of these Gasifiers

The few large-scale or commercial up-draft gasifiers around the world are all located in South America. In the 1940s and 1950s, many of the systems that were being used in Europe were up-draft gasifiers due to the different fuels and feed stocks available. The last up-draft gasifier in Europe closed because it had negative environmental effects—water pollution from the tar. Because of these negative effects from the tar, today, most fixed bed gasifiers that are used are of the downdraft type. In a 2003 survey, seventy-five percent of the gasifiers sold were of the downdraft classification and only about two and a half percent were considered up-draft gasifiers (Bridgewater, 2003).

E. Problems with Fixed Bed Gasifiers

Sometimes explosions may occur if or when the combustible gases leak through the fuel intake valve or any other places where a leak could happen. An explosion can also happen if the gasifier is restarted without venting it with fresh air. The throat of the gasifier can become blocked if there is too much ash in the system, the fuel size is too large, or the bulk density is not within the gasifier's specifications (Quaak, Knoef, & Stassen, 1999).

F. Fluidized Bed Gasifiers

The fluidized bed gasifiers were originally developed to overcome problems with the fixed bed gasifiers (high ash content). Fluidized bed gasifiers can be used on a very large scale—larger than $10MW_{th}$. Gasification temperatures of fluidized bed gasifiers are much lower than fixed-bed gasifiers, around 750° to 900° C. There are two types of fluidized bed gasifiers: circulating bed and bubbling bed fluidized gasifiers. Under most circumstances, the bed is made up of hot sand most of the time and behaves like a fluid. The fuel particles mix with the bed material quickly, resulting in rapid pyrolysis and many pyrolysis gases. In addition, as temperatures are lower, there is minimal tar output (Quaak, Knoef, & Stassen, 1999).

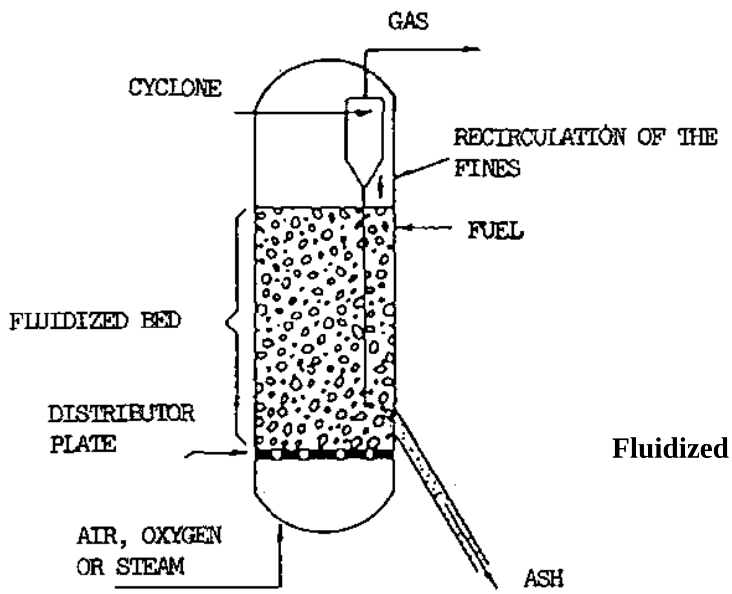
The fuel in a fluidized bed gasifier has been fluidized in oxygen and steam or air. Ash that is removed is usually dry. The temperatures involved are relatively low in dry ash gasifiers. Sometimes, the fluidized bed gasifiers produce heavy agglomerates that defluidize. The agglomerate gasifiers have slightly higher temperatures and are good for higher-grade coal. The fuel throughput is higher than for a fixed-bed gasifier but is not as good as the entrained flow gasifier. The conversion efficiencies of fluidized bed gasifiers can be low due to the purification of the carbonaceous material—materials made up of carbon (which is usually the biomass fuel). After it is cleaned, the combustion of the solids can be used to increase conversion. Fluidized bed gasifiers are most useful with fuels that have highly corrosive ash (like biomass). About twenty percent of the gasifiers manufactured are fluidized bed gasifiers (Bridgewater, 2003).

One advantage that the fluidized bed gasifier has over the fixed-bed gasifiers is that it is much more compact because of high heat exchange and reaction rates, due to intensive mixing in the bed. The gasifier is flexible to use feedstock with various moisture and ash contents, which is another advantage over fixed bed gasifiers. Usually fluidized bed gasifiers are able to deal with fuels that have high ash content, low bulk density, or both. The ash typically has a low melting point because the reaction takes place at a low temperature (Quaak, Knoef, & Stassen, 1999).

The producer gas usually has high ash and dust content, which is a definite drawback to the fluidized bed gasifier (when compared to fixed-bed gasifiers). The high temperatures of producer gas leave the alkali metals in a vapor state (if there are any in the biomass feedstock). There is not complete carbon burnout in the fluidized bed gasification process. Another drawback of the fluidized bed gasifier is that it is more complicated to use and run because the air supply and the fuel supply need to be controlled. Another drawback to the fluidized bed gasifier is the idea that because the gas stream is compressed in the gasification process, it uses some of the power it is creating (Quaak, Knoef, & Stassen, 1999).

In circulating fluidized bed gasifiers, the carbon burnout is much better than in the bubbling fluidized bed systems. If oxygen (pure or mixed with steam) is used in the gasification system instead of air, the producer gas has a much higher caloric value because there is no presence of nitrogen. The main drawback to using pure oxygen however, is the cost involved. Pure oxygen is expensive and is rarely economically feasible on anything other than a large-scale system (Quaak, Knoef, & Stassen, 1999). Circulating fluidized bed gasifiers are the preferred system for large-scale applications of biomass gasification because they are reliable with many different types of biomass feedstocks and are “easy to scale up” from a few megawatts (MW) to 100 MW (Bridgewater, 2003).

The commercial application of bubbling fluidized bed gasifiers has been restricted to small to medium scale applications, up to about 25MW. Bubbling fluidized bed gasifiers are more limited in size because they have not been “scaled” up to the sizes that a large-scale business would need. The gasifier itself is also larger than the circulating bed gasifier for the same feedstock capacity, but the bubbling fluidized bed gasifier is more economically feasible on the small-medium range (Bridgewater, 2003).



Fluidized bed Gasifier Diagram

Figure 4 Source: Quaak, Knoef, and Stassen, 1999

Table 1

Comparison of Fixed Bed Gasifiers and Fluidized Bed Gasifiers

Characteristics	**Fixed-Bed Downdraft Gasifier**	**Fluidized bed Gasifier**
Fuel: Size (mm)	10-100	0-20
Ash Content (% wt)	<6	<25
Operating Temperature (°F)	800-1,400	750-950
Control	simple	average
Construction Material	mild + refractory	heat-resistant steel
Capacity (MW_{th})	<2.5	Jan-50
Startup Time	minutes	hours
Attendance	low	average
Tar Content (g/Nm^3)	<3	<5
LHV (MJ/Nm^3)	4.5	5.1

(Quaak, Knoef, & Stassen, 1999)

G. Entrained Flow Gasifiers

Entrained flow gasifiers can only use oxygen as its gasification agent, in a co-current flow. The reaction takes place in a dense cloud of very fine particles. High temperatures and high pressures mean that a higher volume output can be reached. Thermal efficiency is somewhat lower with the entrained flow gasifier because the gas must be cooled before it can be cleaned. The higher temperatures are also to the reason for the lack of tar and methane in the producer gas. However, the oxygen requirement is higher than for the three other types of gasifiers. The high temperatures remove the major part of the ash as a slag as the operating temperature is way above the ash fusion temperature. Certain types of feedstocks form slag that is corrosive to the ceramic inner walls that are there to protect the gasifier's outer wall. Not all entrained flow gasifiers have these ceramic walls. Some have an inner wall that is water or steam cooled and the wall is partially covered with partially solidified slag (therefore these types of gasifiers do not suffer from corrosive slag). Fuel particles have to be much smaller than for the other types of gasifiers mentioned above.

V. The Laundromat

The Laundromat and Car Wash are located in Morris, Minnesota and have been owned by the Beyers for four years now. Prior to June of 2007, the Laundromat and Car Wash buildings and the water used at both facilities was heated with natural gas. In June of 2007, the Beyers decided it was necessary to move the wood stove they had at their home to the business downtown because natural gas prices were getting too high for the business to survive. The stove that was originally installed at the Laundromat was just a "regular old wood stove" but has since been retrofitted with equipment that makes the original boiler now a boiler with gasification system. New pieces (Figures 6 & 8) added to the boiler were not available to be installed until January 2008 because it had to undergo rigorous testing by the Environmental Protection Agency (EPA). Because the part was not available until January, the Beyer' decided to install the wood stove and then modify it once the new part was available.

The system that the Beyers currently have installed is manufactured by AquaTherm and was modified with parts also made by AquaTherm. The Beyers chose the model because the company has a good reputation and there are not very many other retailers of wood boilers around the area. They bought the wood boiler through AquaTherm directly because AquaTherm is based in nearby Brooten, Minnesota. Another key factor in choosing a specific model was the nice set of features many other companies did not have at the time.

Current operational costs associated with the Laundromat and Car Wash is not available yet since the system is so new. Jessica Beyer said that with the original wood stove, the costs were about $300-$500 per month. Before the wood stove, costs were about $1,500.00 to heat the buildings and the water each month. The installation of the original wood stove dramatically decreased costs for the Beyers, which in turn lowers the prices for their customers, as costs are easier to offset. Although current savings in terms of dollars are not available at this time, Jessica did say she has noticed a decrease in the amount of wood that is consumed by the stove. Before the gasification system was installed, the stove needed to be stocked three times per day, and now wood only needs to be added to the boiler twice a day.

VI. Costs

Installation costs of a biomass gasification system vary from company to company. Many factors to be considered when calculating the costs of the system include initial installation costs, operating costs, efficiency rates, and cost advantages versus a system without the gasification system installed.

At the Laundromat and Car Wash, there was no initial installation cost of the wood boiler, because they already owned the boiler. (There was an initial cost of the boiler, they had to buy it, but they bought it for their home so the business experienced no installation costs). The boiler was moved from the Beyers' home when it was realized that it would be more beneficial for the business. The Beyers decided to upgrade their system to a gasification system when a neighbor of the Laundromat filed a complaint with the City of Morris. The neighbor of the Laundromat complained to the City of Morris because he did not like smelling the smoke from the wood burner when his windows were open.

At the time of the complaint, the Beyers were not able to install the gasification component to their existing boiler because the components were not available for purchase. The components still needed to pass the Environmental Protection Agency's (EPA) requirements. The component met the EPA's expectations (but not the standards they have set forth for new wood boilers) and was available to purchase in January of 2008. Once available, the Beyers purchased and installed it in their existing boiler. According to many of companies' websites, the majority of today's wood boilers can be modified to be gasification boilers. Craig Beyer himself made the modifications to the Beyer's system, so they incurred no cost because of the modifications, other than buying the parts necessary to make the modifications.

To install a new gasification system, prices depend on the size of the system purchased, based on British Thermal Unit (BTU) output. One company, TARM USA INC, reported prices to be about $11,500 for a multi-fuel boiler with a wood BTU/hour output of about 100,000. The same company also offers another system that is slightly larger with an output of 140,000 BTUs/hour, and costs about $13,125 (all prices are as of 4/1/2008). These multi-fuel boilers can be used with wood, gas, or fuel oil, and their efficiencies are above eighty percent for a stove that is fired using the wood gasification system, and not fuel oil or gas. The system works so that if the wood stock inside the boiler is too low, it will start using a back-up fuel (oil or gas) as long as it needs; this ensures that no heat is lost inside the building being heated, or the appliance that is using the fuel can operate efficiently.

TARM USA INC also has a wood gasification boiler that only operates on wood. These systems are not as expensive as the multi-fuel boilers but require more attention from the operator because there always needs to be a certain amount of fuel in the system for proper operation. The price range for these boilers is between $6,500 for a 102,500 BTU/hour output and up to $7,725 for a 198,000 BTU/hour output system.

The Beyers use a gasification boiler but have natural gas back up, which allows them to save money on natural gas usage, but also allows them to keep the energy output that they require available. On a typical day in March 2008, the Laundromat used about 142 therms of energy each day (from natural gas). This is equivalent to 14,200,000 BTUs, or about 591,600 BTUs/hour. When compared to just a year ago, the Laundromat and Car Wash used about 269 therms of energy each day, which is equivalent to 1,119,445 BTUs/hour. The wood stove has cut the natural gas usage by over half (52.8%) and the resulting savings are significant. Because the boiler with the gasification system has only been installed since January 2008, it is hard to tell if the gasification unit has made an impact on the facility's costs. The Beyers do not track the exact amounts of wood they put into the boiler so it is hard to tell if wood is saved. When the five month billing period from 10/05/2007 to 3/10/2008 is compared to the natural gas consumption of one year ago (10/06/2006 to 3/09/2007), it is obvious that the wood stove system has greatly reduced the Beyers' reliance on natural gas for heating of buildings and water. Over the most recent five-month period, the buildings used about 148.3 therms of energy per day (from natural gas), as compared to 274.1 therms per day, a year ago. This shows a savings of about 126 therms per day, about forty-five percent.

Figure 5-The Beyers Wood Stove, located behind the Laundromat and Carwash

Source: Joel Tallaksen, 2008

Figure 6- Picture of the Wood Burner and the gasification parts that were installed.

Source: Joel Tallaksen, 2008

Figure 7- The Woodstove

Source: Joel Tallaksen, 2008

Figure 8- A close-up of the parts that were added to the gasifier

Source: Joel Tallaksen, 2008

VII. Efficiency

Efficiency of biomass gasification systems differ if the gas is used hot or cold. If the gas used is hot, it has an efficiency rate up to about 95 to 97 percent. If the gas is used cold, the efficiency is reduced to about 85 percent. When the gasification system is used in combination with another type of fuel, there is typically around a fifty percent efficiency rate on a large scale. If the combined cycle is used on a small scale, the gasification rates are decreased greatly to only about 35 percent. Feedstocks used will also affect the efficiency of the system. If more dense woods are used, like oak, beech, or maple, the burn time capacity will be longer, meaning you have to stock the gasifier less often.

VIII. Environmental Impacts

There are many environmentally friendly aspects of using a wood boiler system with gasification capabilities. One of the main positive things about using a gasification system is the fact that the process does not emit any greenhouse gases, such as carbon dioxide (Reed, 2002). Biomass is also a renewable resource that will essentially be available in some amount, forever, so long as we do not overuse our resources faster than they can be produced (Reed, 2002). Biomass is available in small quantities that are dispersed over many places, essentially everywhere (Reed, 2002). The biomass production process removes carbon dioxide from the atmosphere through photosynthesis. Biomass gasification has many positive aspects over coal gasification, one of which is that biomass has a much lower sulfur content than coal (Reed, 2002). Another positive characteristic of biomass gasification is that biomass residue use or harvesting actually improves the land, whereas coal mining is destructive (Reed, 2002).

The wood that the Beyer's are using for their wood gasification system comes from Craig Beyer's other business. Craig Beyer owns a tree-trimming service and the wood remnants he has from that would usually be taken to a landfill where they would be burned. Burning it in his gasification system allows for the disposal of the wood while creating usable energy.

As with everything, biomass gasification can have some negative environmental effects. The main concern with any type of burning of wood or any other combustible products is the smell associated with the process. Therefore, the wood burning process may not be well- suited for a residential or downtown business area. There are things, however, that can be done to offset some of the smell associated with gasification burning of wood. The Beyers have had one major complaint regarding their system: a resident filed a complaint with the city of Morris; and as a result, the Morris Planning Commission is writing an ordinance that businesses and residents must comply with. Since the gasification system was installed, Jessica says that she has noticed a definite reduction in odor when driving past the Laundromat and Car Wash.

According to the, the Morris Planning Commission first thought of "creating an ordinance in June 2006" after a former city employee urged the commission to look into the heath concerns that are associated with smoke *Morris Sun Tribune* from wood burners. During the review of the commission's research, they found it showed "'fairly severe' health effects from wood smoke, especially for the elderly, small children, and those with asthma" (Ukura, 2007). The ordinance will require any new outdoor furnaces that are to be installed "meet specifications for Environmental Protection Agency emissions standards, setbacks, chimney height, fuel materials, and fuel storage" (Ukura, 2007). The ordinance that will been set forth does not include fires that are for recreational use, such as bonfires or in fireplaces. The ordinance only applies to those wood burners that are to be used to heat a home or business. The proposed ordinance says, "any existing burners would be grandfathered in, unless the owners wanted to replace it" (Ukura, 2007).

The city of Morris Planning Commission researched outdoor wood boilers extensively, with their main source of information being Northeast States for Coordinated Air Use Management (NESCAUM). NESCAUM has done a lot of research on outdoor hydronic heaters, which is another name for an outdoor wood boiler. When asked why the ordinance was considered being imposed, commission member Margaret Kuchenreuther said that because smoke has a lot of particulate matter, it is harmful to the residents of the city of Morris, especially those with respiratory health problems such as asthma or emphysema. According to Kuchenreuther, the EPA does not regulate the amount of particulate matter that is released into the air by these outdoor heaters and that is where the health issues come into play.

The EPA has voluntary regulations that have been established, but none of the currently manufactured wood boilers are required to follow those regulations.

The ordinance will go into effect as soon as the Planning Commission has completed their research of the new generation wood boilers and completed an ordinance that will suit the community the best. One problem the commission has been faced with is dealing with the issue of where to draw the line regarding what is considered an outdoor wood boiler as opposed to a fireplace or just a wood stove to heat the house during the winter months. Another concern the Planning Commission has to deal with are the alternative fuels that people can use in outdoor hydronic boilers, such as corn stover. One question the commission is faced with is if different types of boilers should have different regulations. The commission is working on writing an ordinance that will be the most beneficial to the City of Morris and its residents. One main concern with not having an ordinance is if every business in Morris decided to heat the water and business with an outdoor wood boiler, how much would that affect the air quality for the city of Morris, and thus, endanger the residents. When writing the ordinance, the Planning Commission is using examples that NESCAUM has provided and other Minnesota cities' ordinances as examples/guides.

If the Beyers' Laundromat and Car Wash were in a different location, Kuchenreuther said that the wood boiler might not be as much of an issue. Currently, the Laundromat and Car Wash are zoned under the highway business district because highway 28 used to run through this section of town. If the business were located in an area zoned as "heavy industrial," it would be less problematic because the industrial zoned areas already have more strict regulations and there are not residents living around in the industrial park.

The Beyers' wood burner is the first of its kind for AquaTherm. The company informed Craig Beyer that they were the first "to use their product for energy generation" (Larson, 2007). The AquaTherm Company had its doubts about how the Beyers were going to use the wood burner, but the Beyer's "always had faith the systems would work."

Prior to the gasification system being installed at the Laundromat and Car Wash, the Beyers had to put about five to six "good-sized logs" in the burner. The AquaTherm machine does not require the wood to be completely dried and putting in five or six logs a day "keeps the system going for 24 hours" (Larson, 2007).

The burning of biomass in a system with a gasification unit does not necessarily mean that it is better for the environment. The system, however, is not any worse for the environment than a wood stove without a gasification system built in. Both units require wood to be burned at extremely high temperatures, but a wood boiler system with gasification will burn more efficiently than a system without it. Over time, a wood stove with gasification will save on fuel as it burns wood or biomass much more efficiently, but in the short term, it is hard to see such differences.

When comparing carbon emissions of a wood stove system with gasification to a system without, there is no difference when considering the amount of fuel consumed. There is a difference, however, when comparing carbon emissions over time. This difference is because a system with gasification burns the wood/biomass more efficiently and therefore burns the wood more slowly, thus creating less carbon emissions over the same amount of time. If the environmental effects are compared between a biomass gasification system and an ordinary wood stove, there is a difference. Because biomass is burned at a considerably higher temperature in a gasification system, there is a significantly smaller amount of ash created. Less ash is created because the biomass is burned at higher temperatures, which allows for more of the carbonaceous material to be burned.

On a small scale, the biomass gasification process is more “green” than a regular wood stove, but is not more efficient or “green” than when compared to large-scale gasification. Small-scale gasifiers tend to require much more attention from operators than a large-scale gasifier does (Inproheat Industries, Ltd, 1982).

The fuel used during the biomass gasification process includes many different carbonaceous materials. Some materials that are used in biomass gasification include wood, forestry residues, straw, livestock residues, sugar, grains, and black liquor from paper manufacturing. In some places, sewage wastes are also used for biomass gasification (Austalian Institute of Technology). Wood and bark from sawmills and plywood plants are the most appealing feedstocks for gasification for smaller scale operations as they are the cheapest and most available types of fuel (Reed, 2002). Just about anything that is carbon based can be used in the gasification process, depending on how flexible the gasifier is. Some gasifiers are only able to use a single feedstock as the biomass feedstock.

In many cases, the biomass that small companies use to “create” energy to heat their businesses is supplied locally. If biomass must be brought in from an outside source, it adds to the cost of the fuel. In the case of the Beyers Laundromat and Car Wash, the fuel they use—wood—does not need to be brought in from anywhere else. The wood that the Beyers use is remnants from Craig Beyer’s other business—Craig’s Tree Service. Because the Beyers do not have to pay for any of the wood they are burning for fuel, they save a lot of money and time.

The Beyers wood gasification system does not require the Beyers to trim the wood into very small pieces. The fuel the Beyers use is typically in the form of small logs that Craig trimmed while working for his other business. By burning the wood at the Laundromat and Car Wash, the Beyers are using the energy that is released by the wood for a useful purpose, rather than just releasing it into the atmosphere (Beyer, 2008).

Biomass is available almost everywhere. Different types of biomass are available in different areas of the country and biomass obviously varies around the world. In the Midwest, the access to grains, straw, and forestry residues, is greater than compared to the southeast area of the United States. In the Southern United States, the gasification of sewage wastes is much more common than in the Midwest.

The environmental impacts of gasification's byproducts can usually be easily dealt with. The main byproducts are tars, char, and ash. The ash that is evolved during the gasification process contains a lot of salt, especially in biomass or wood gasification. Because most biomass contains the elements potassium, calcium, phosphorous, sodium, magnesium, iron, silicon, and other elements in even smaller traces, the ash has a relatively low melting point (Higman & van der Burgt, 2003). Because the ash has a low melting point, it is easier to get rid of the ash and the process creates less of it. Biomass ash is easy to dispose of because the components of it are naturally occurring elements, so it can be used as fertilizer to help restore the elements back in to the soil. When compared to coal gasification, biomass has much lower ash content and can be used for synthesizing chemicals, along with being able to be used as a fertilizer. Coal ash is much harder to dispose of and cannot be used as a fertilizer (Reed, 2002).

IX. Equipment

There are many places around the United States where an interested consumer or business may purchase a wood boiler with a gasification system. In my research, I found many manufacturers located in all areas around the United States (Table 2). Most wood boilers have to be bought directly through the manufacturers because there are so many different specifications that need to be discussed with the potential purchaser. When I contacted TARM USA, they informed me that they had boilers in stock and ready to be shipped to the next buyer (Table 3). In the Midwest area of the country, AquaTherm, GARN, and Central Boilers were all found to have the products, and are all located in Minnesota. In the Western part of the United States, I found one dealer—Greenwood Furnaces—that is able to sell gasification systems directly to customers. TARM USA, Alternative Fuel Gasification Boilers, and Alternate Heating Systems, are all located in the Eastern U.S. and all deal directly with consumers.

Tab le 2

Table of Suppliers

Company Name (Supplier)	Location	Phone Number	Website
Mid-West			
AquaTherm	Brooten, MN	1-800-325-2760	www.aqua-therm.com
Central Boiler	Greenbush, MN	1-800-248-4681	www.centralboiler.com
GARN	St. Anthony, MN	1-612-781-3585	www.garn.com
Eastern United States			
TARM USA	Lyme, NH	1-800-782-9927	www.tarmusa.com
Alternative Fuel Gasification Boilers	Dunkirk, NY	1-866-818-5162	www.alternativefuelboilers.com
Alternate Heating Systems	Harrisonville, PA	1-717-987-0099	www.alternateheatingsystems.com
New Horizon Corporation	Sutten, WV	1-877-202-5070	www.newhorizoncorp.com
Western United States			
Greenwood Furnaces	Bellevue, WA	1-800-959-9184	www.greenwoodfurnace.com

Table 3

Downdraft Gasifiers by Company

	Econoburn					
Model	EBW-100	EBW-150	EBW-200	EBW-300	EBW-500	EBW-1000
Water Capacity (US Gallon)	28	32	44	80	custom	custom
Fire Box Size	17" x 28" x 23"	18" x 28" x 23"	24" x 30" x 23"	25" x 32" x 25"	custom	custom
Max. Log Size	23"	23"	23"	25"	35"	48"
BTU Output/hour	100,000	150,000	200,000	300,000	500,000	1,000,000
	TARM USA					
Model	Excel 2000	Excel 2200	HS Solo-Plus 30	HS Solo Plus 40	HS Solo Plus 60	
Water Capacity (US Gallon)	64	72	41	54	60	
Fire Box Size	4.0 ft³	6.6 ft³	4.01 ft³	5.35 ft³	6.01 ft³	
Max. Log Size	20"	20"	20"	20"	20"	
BTU Output /hour, wood	102,500	140,000	100,000	140,000	198,000	
BTU Output /hour, oil	120,000	150,000				
BTU Output/hour, gas	120,000	1,640,000				

X. Conclusions

After performing the research that has gone into creating this report, the process of how biomass gasification works has become clearer. In doing this research, I discovered there are many types of gasifiers that can use biomass as their main source of fuel. I also found that biomass gasification on a small scale is not as “green” as it is on a larger scale. The process is not as “green” because the savings on a small scale make a difference in the amount of money saved, but does not make a large difference in the amount of biomass that is consumed. The process of biomass gasification is a simple, especially when the process is compared to combustion in a regular wood stove.

At the Laundromat and Car Wash, the installation of the wood stove has dramatically lowered energy costs for the business; it is hard to tell if the gasification system has increased savings on energy costs over a regular wood stove. The process of gasification at the buildings is so new that there is little to no data available describing the savings.

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