Next Generation Wood Burning:
Wood Gasification Technology

Eric Truax, Alternate Heating Systems, Inc.
Jeff Gingerich, Alternate Heating Systems, Inc.
Henry Maier, LNH Enterprises, LLC

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Executive Summary

As homeowners have begun to seek relief from high petroleum costs, there is currently a resurgence of interest in heating with wood. Indeed, a quick web search uncovers hundreds of companies offering "free heat machines" that will "save you $$$ on your heating bills" by burning wood. Much of the hype has merit - wood is markedly less expensive than natural gas or fuel oil, wood is renewable, and wood is less susceptible to political fluctuations than imported petroleum. However, the majority of wood-burning home heating devices that have inundated the market today, the most popular of which are the infamous "outdoor wood boilers," are plagued by low efficiencies and high emissions. Because of the large volume of smoke produced by outdoor wood boilers, many states, especially in the Northeast, have passed strict regulations aimed specifically at preventing the purchase and operation of outdoor wood boilers by state residents. Often, outdoor wood boilers create more problems for their owners than can be offset by the benefits of burning wood.

With the increase in regulation, the manufacturers of outdoor wood boilers are scrambling to develop "next-generation boilers," that will produce no visible smoke and operate with 80% net efficiency, a great improvement over the current "smokers" that operate at 25%-45% net efficiency. Ironically though, the "next-generation boiler" is already on the market and has been since the early 1980's. Wood gasification technology, which the next generation boiler utilizes to burn wood with no visible smoke and net efficiency of 85%, has been around since World War II. It is proven technology based on a detailed understanding of how wood burns. Wood gasification technology is the key to tapping the benefits of burning wood for the future.

Setting the Stage

The new millennium has been marked thus far by two major issues: the increase in global political instability and emerging concern for the environment. Global political instability and the War on Terror have made us realize the extent to which we have become dependent on petroleum imported from foreign nations and our vulnerability therein to interruption of supply due to localized skirmishes or tyrannical whim. Perhaps the volatility of petroleum imports could be tolerated if not for the widespread belief that current petroleum supplies are on the verge of being exhausted. Indeed, the urgency of the situation is seemingly confirmed by the skyrocketing petroleum prices – a sort of association of the high price with "rare" and "hard to obtain." High petroleum costs alone are probably sufficient to trigger a mass departure from current energy practices. Coupled with the emergence of environmentalism, however, this exodus becomes a potent energy revolution. Environmentalism, as a response to the ominous trend of global warming caused by heavy usage of now costly fossil fuels, has provided the ideology to complement the rising pressure on the purse strings. This combination is the driving impetus of the alternative energy revolution.

In the current revolutionary atmosphere, interest in all forms of alternative energy has exploded. On the large scale, sources being considered include solar, wind, hydro, geothermal, and nuclear energies. Hydrogen and fuel cells are being examined as solutions for our transportation energy needs. However, it is not the large-scale changes that will have the greatest immediate impact in the energy revolution. A national shift in energy practices will undoubtedly have bumps in the road and will certainly not happen overnight. Small changes, tiny raindrops in the bucket that combine with other tiny raindrops to produce a deluge are the starting points of this revolution.

Attitudes like that, the belief that changing the world starts by changing yourself, are behind the wave of individuals, families, and businesses examining their energy needs and searching for ways to become more efficient and less wasteful. Solutions range from simple – replacing incandescent light bulbs with more efficient fluorescent bulbs – to more complicated – constructing a windmill to produce electricity.

According to the US Department of Energy, 56% of all energy consumed by the typical household is used for heating and cooling[1]. When looking to save energy in a home or business there is no better place to start than with heating and cooling. Traditional methods of heating and cooling are heavily dependent on fossil fuels both directly and indirectly through electricity. With prices for fossil fuels hitting record levels, heating and cooling is also a great place to start to save money as well.

There are plenty of convenient, unobtrusive suggestions for reducing heating and cooling energy usage that range from installing insulation to keeping air ducts, registers, and radiators clean and unobstructed by furniture. Often, more substantial energy savings can be obtained by replacing old heating/cooling equipment with new, high efficiency models. At this point, some homes or businesses may decide to break away from petroleum heating and cooling altogether and explore the realm of alternative fuels and energy sources. For these people, often the first option they consider is wood.

Benefits of Burning Wood

Wood is attractive as a fuel source because it is commonly available and inexpensive. In rural or semi-rural areas, firewood can literally be as close as your backyard. Often, enough wood is available as dead fall each year to prevent you from even having to fell a single tree. Except for an investment in a sturdy chainsaw, gathering firewood on your property is a source of free heat. For home or business owners located in less rural areas, firewood can be bought already split and ready to use and still provide substantial cost savings over petroleum heat. A cord of wood, approximately 26,000,000 BTUs of heat costs $211 delivered[2]. A gallon of #2 fuel oil, on the other hand, sold for $2.46 in March of 2007[3]. A gallon of #2 fuel oil contains about 138,500

BTUs of heat. Adjusting to an equivalent amount of BTUs reveals that the burning fuel oil, $432.50 for 26,000,000 BTUs, is roughly double the expense of burning wood.

Burning wood also contributes to national and personal self-sufficiency. Wood is available domestically; approximately one-third of the United States is covered by forested land (about 747 million acres) [4]. Unlike petroleum, there is no danger of the wood supply being interrupted because of events taking place on the other side of the world. On a personal level, burning wood harvested from your own property could enable you to live "off the grid," the ultimate in self-sufficiency.

Wood is a renewable resource. Properly managed forests can provide a continuous supply of firewood for home heating. Wood is also environmentally friendly. Burning wood is, for all intents and purposes, carbon neutral. This means that the tree sequesters a similar amount of carbon dioxide while it grows as is emitted when the wood is burned. There is no net carbon emission into the atmosphere from burning wood. It is important to note that the term carbon neutral is a bit misleading. Petroleum products are carbon neutral if viewed in a timescale of millions of years. The key is timing[5]. Petroleum is not being naturally formed at a rate equal to the rate at which it is being used. Wood, with its smaller carbon cycle of 50-100 years, can in fact be carbon neutral if it is harvested sustainably[5] – if for every tree burned, another tree is currently growing and sequestering the same amount of carbon dioxide. Even disregarding any considerations of sustainable harvesting, wood burning still produces a lower net carbon dioxide emission than petroleum products because of the timing issue. The time it takes for the carbon emissions of burning petroleum to be re-sequestered into oil is vastly more than the time it takes for a tree to grow and re-sequester carbon emissions from burning wood.

Options for Burning Wood

The use of wood as a fuel is as old as civilization itself. The first wood-burning device was no more than a fire pit, hole in the ground. Today, options for burning wood are plentiful and varied. They range from the basic, no frills fireplace to wood stoves and finally to wood fueled boilers. Today, the fireplace is used more as décor than as a device meant for serious heating. Fireplaces lose too much heat up the chimney to be of much use heating an area larger than a few square feet. For localized room heating, fireplace inserts and wood stoves are typically used. These devices generally utilize a fan to distribute heated air over a larger area. Fireplace inserts and wood stoves typically operate with low efficiency, as again, a lot of heat is lost up the chimney. Both are also typically of a small size which limits heating capacity of the device to only a single room.

In order to heat an entire household with wood, it is necessary to either use a wood fired hot air furnace or a hot water boiler system. A hot air furnace works on the same principle as a wood stove – create heat and use a fan to blow it somewhere – except on a large scale. Hot air is directed throughout a house via a series of air ducts. Burning wood is not always a clean activity. Often, soot or ash produced by burning wood will make its way into the air ducts of a hot air furnace and be blown all over the house. Besides the dirtiness of hot air systems, often the smell of wood burning is transferred throughout the house. While this smell is pleasant to some, to others it can be a real annoyance. A wood fired hot water boiler system alleviates all the problems of hot air furnaces, making it the ultimate device for heating with wood.

Hot water boilers use water as the transfer medium for heat, unlike most other wood heating devices that use air. This immediately solves the issue of transmitting the smell of wood heating throughout the house. Water is heated by the boiler and then pumped throughout the house and into radiators, baseboard heaters, or through radiant floor piping where heat exchange takes place to warm the building. Water pipes are smaller and less intrusive to install than large, bulky hot air ductwork. Also, a hot water boiler can typically be located outdoors, away from a building it heats to create further separation from the smoke, soot, and dirt produced as wood burns. This also has the effect of reducing the risk of fire caused by the heating device. Many wood fired hot water boilers come standard with a weatherproof housing allowing for the convenience of an

outdoor installation. These units have become known as outdoor wood boilers, or OWBs for short.

Problems with Outdoor Wood Boilers

The benefits of using water as a heat transfer medium are undeniable. Lately, though, the wood burning technology employed by OWBs to produce heat has begun to be called into question with increasing frequency. The big problem with most OWBs lies in how the heat produced by burning wood is transferred to the boiler water. Typically, most OWBs consist of a large, boxy firing chamber that is encased on all sides by a water wall. Wood is loaded into the firebox and burned just like it would be in a typical woodstove. The surrounding water wall is designed to trap as much heat as possible from the wood fire before it can escape out the flue. Some boilers even employ a multi-pass design, routing exhaust air back through internal passageways to maximize opportunities for heat exchange. It turns out that the full water wall and multi-pass designs are too effective at exchanging heat from the fire to boiler water. The design pulls so much heat away from the burning wood that the fire basically just smolders. Smoldering fires are smoky fires. Indeed, OWBs have become infamous for their smoke and high particle emissions due to their tendency to smolder.

Smoky fires are indicative of low efficiency wood burning. Basically, most of the energy in wood is going out the flue as smoke instead of being converted into heat for your home or business. Complete combustion of wood results in only water vapor and carbon dioxide. Both water vapor and carbon dioxide are relatively colorless. The more noticeable the smoke and emissions coming from the boiler's flue, the less efficient the burn.

Inefficiency can be ignored if the price is right. For a period of time, many OWB owners simply tolerated the inefficient, smoldering performance of their units because, after all, burning a little more wood is still cheaper than burning oil or natural gas. As OWBs became more and more popular, more and more localities began to regulate them because the large volume of smoke and emissions produced was deemed a public nuisance. This trend culminated in some states and localities attempting to ban outdoor wood fired boilers altogether. Regulations have become particularly fierce in the Northeast and the northern Midwest. These states have taken a collective stand to discourage the inefficient, high emissions burning of wood via outdoor wood boilers.

Of course, the manufacturers of OWBs attempted to resist the increase in regulation, but soon found that the states were not to be dissuaded. Currently, these manufacturers are battling a wave of public disfavor, all the while spending millions of dollars[6] on research and development of the "next generation wood boiler." This "next generation boiler" is anticipated to produce no visible smoke and operate at a net efficiency of about 80%[6]. This is a marked improvement over current models that smoke incessantly and only achieve net efficiencies of around 45%.

The Next Generation Now

Ironically, the "next generation boiler" is already available and has been since the early 1980's. Wood gasification boilers use technology based on a better understanding of how wood burns to achieve 85% net efficiency[7] and produce no visible smoke. Wood combustion occurs in three stages[8]. First, the wood is heated and moisture in the wood begins to evaporate. At this point any heat produced goes to further evaporate moisture. The second stage begins when temperatures reach about 500°F. Here, wood starts to break down chemically and volatile matter is vaporized. These vapors contain between 50%-60% of the energy in wood[8]. Temperatures in excess of 1100°F mark the third stage of wood combustion. If this high temperature is maintained, efficient combustion of the vapors and the remaining wood charcoal will occur. OWBs rarely are able to maintain high enough temperatures to combust the wood gases. This means that a large portion of wood's energy is unable to be harnessed by OWBs and just goes out the chimney as smoke. Wood gasification boilers are specifically designed to operate at the high temperatures necessary to efficiently and completely burn wood vapors and charcoal. In fact, most wood gasification

boilers are capable of reaching temperatures in excess of 2000°F. These high temperatures are the key to reaching 85% net efficiency for burning wood.

How Gasification Works

The key to the whole wood gasification process is a large refractory mass that collects and holds a great deal of heat inside the boiler. When the fire is first lit, it burns identically to all other boilers. The heat produced goes to evaporate moisture from the wood charge and to bring the refractory mass up to temperature. During this initial startup phase, wood gasification boilers may produce a bit of smoke as the refractory warms up. Once the refractory reaches around 500° F, the wood charge begins to give off gases. Most wood gasification boilers are characterized as having a downdraft design because at this point, the gases are sucked through openings in the bottom of the firing chamber into secondary chambers built into the refractory. Here, the wood gases are combusted at temperatures approaching 2000° F. These high temperatures allow wood to be burned very completely resulting in very little emissions. In some boilers, the tiny amount of fly ash that is still produced is scrubbed from the exhaust air by a centrifugal ash separator before exiting the flue. Indeed, typical emissions from a wood gasification boiler are little more than a wisp of water vapor and invisible carbon dioxide.

Although wood gasification technology was developed during WWII and wood gasification boilers have been available since the early 1980's, the wood gasification industry is still relatively young. Petroleum was the fuel of choice for the last 20 years, and as long as it was cheap, wood gasification boilers were in low demand. For this very reason, there are only a handful of boiler manufacturers that produce wood gasification boilers today, although the number is sure to increase as more outdoor wood boiler manufacturers arrive at the technology and demand increases. Of the handful of wood gasification manufacturers, the majority are currently based in Europe and imported for sale in the United States. There are only one or two domestic manufacturers of wood gasification boilers, the oldest of which is Alternate Heating Systems, Inc, based out of Harrisonville, Pennsylvania.

Conclusion

As the wood gasification industry grows and develops and regulation of outdoor wood boilers increases, there is no doubt that wood gasification boilers will supplant outdoor wood boilers as the ultimate wood heating machine. The next generation of wood heating is here and available today. The efficiency of wood gasification boilers is in compliance with the goals of reducing heating costs, reducing reliance on foreign fossil fuels, and reducing greenhouse gas emissions. Wood gasification might not be the end-all solution to the world's energy needs, but it certainly is a large drop of water contributing to the flood of the alternative energy revolution.

References

1. "Energy Saving Tips: Heating and Cooling". [Online.] US Department of Energy. (http://www.energy.gov/heatingcooling.htm). 2 August 2007.
2. "Firewood Information." [Online.] Tree Huger Farms. (http://www.treehuggerfarms.com/firewood.html). 2 August 2007.
3. "Appendix C: Residential Heating Oil Prices by Region and State." [Online.] Energy Information Administration. (http://www.eia.doe.gov/pub/oil_gas/petroleum/data_publications/weekly_petroleum_status_report/current/pdf/tablec1.pdf). 2 August 2007.
4. Smith, W.B., Vissage, J.S., Darr, D.R., and Sheffield, R.M., "Forest Resources of the United States." U.S. Department of Agriculture Forest Service. 1997. St. Paul, MN.
5. Username "adam". "Is burning wood *really* carbon neutral?" [Weblog entry.] Seacoast NRG. 30 January 2007. (http://seacoastnrg.org/2007/01/30/is-burning-wood-really-carbon-neutral/). 2 August 2, 2007.
6. Terreri, April. "In Search of Standards." [Magazine article.] Sawmill & Woodlot. March 2007. pp. 28-34.
7. "Results of Fire Tests at Arnold Greene Testing Labs." [Table.] Alternate Heating Systems, Inc. (http://www.alternateheatingsystems.com/woodboilers.htm.) 1984.
8. Vogel, Michael. "Heating with Wood: Principles of Combustion." [Online.] Montana State University Extension Office. (http://www.montana.edu/wwwpb/pubs/mt8405.pdf.) October 2005.

About the Authors

Eric Truax is a senior mathematics major at Indiana Wesleyan University. He has been a member of the Alternate Heating Systems team since 2005 and is heavily involved in developing printed and web literature, maintaining product manuals, and conducting corporate research. He is currently in the midst of his own undergraduate research involving life cycle analyses of producing ethanol from corn and biomass. His interests include alternative fuels, number theory, and cryptography.

Jeff Gingerich is President and CEO of Alternate Heating Systems, Inc. His experience in the heating industry is upwards of 25 years. He began his career in 1982 with Eshland Enterprises in Greencastle, PA. Eshland was the original designer of the products offered by Alternate Heating Systems today. In the mid 1990s, Jeff became involved in research and development of a high efficiency medical waste incinerator for Eshland. This resulted in a spin off company, Bio-Oxidation, Inc that would eventually buy out Eshland Enterprises. In 1998, Jeff purchased the Eshland boiler designs from Bio-Oxidation and incorporated Alternate Heating Systems. In 2003, Jeff and his wife Phyllis received the Fulton County Chamber of Commerce and Tourism's Excellence in Small Business Award. Alternate Heating Systems has experienced tremendous growth in recent years, fueled by the rising cost of petroleum. Alternate Heating Systems specializes in wood, coal, and waste-oil fired boilers and also provide custom engineering of heating equipment.

Henry Maier is co-owner of LNH Enterprises based in Oldtown, Maryland. Henry has served for 26 years in the HVAC industry and graduated a four-year Steamfitter Journeyman Training Program. He and his wife Nancy ran a family-owned HVAC business called Energy Systems, Inc. from 1980 until its sale in 2000. They then entered retirement in western Maryland. A few years into “retirement,” Henry and Nancy became interested in alternative ways of heating their own home. In 2003, they became authorized dealers for Mahoning Outdoor Furnace, Inc. In 2005, they were recognized by the Maryland Tree Farm System and awarded a certificate as Maryland Outstanding Tree Farmer of the year. In 2006, they were recognized by the Allegany Soil Conservation District as Allegany County Outstanding Conservation Farm of the year. Later in 2006, they began to explore more environmentally friendly ways of heating. Their interests have led them to explore alternative fuels including wind, solar, and wood gasification technologies. In 2007, they incorporated LNH Enterprises to continue their pursuit of environmentally friendly technologies using renewable energy sources.