DRYING FIREWOOD

PAST, PRESENT, FUTURE, AND GETTING STARTED

by Niels Jorgensen

MOTHER NATURE HAS BEEN DRYING FIREWOOD FOR CENTURIES

—make that a millennia. Unlike years past, we have been splitting firewood using bigger, industrial equipment for a few decades. In the last 5 to 10 years, we have also seen an increase in the use of firewood kilns, though in the not-so-distant past, kiln drying firewood was unheard of. But the firewood industry is changing due to regulations for eliminating bugs and the subsequent customer demand for kiln-dried firewood.

What is kiln-dried firewood? What is seasoned firewood? These are questions with a variety of answers. I am unaware of any recognized standard other than several websites that suggest 20% moisture content (MC) when listing the Btu value of one cord of firewood. While there really is no official or legal standard pertaining to dried firewood, I will use the 20% moisture content as our benchmark in this article. In a similar vein, it is not possible to truly qualify the actual moisture content of "fresh split" firewood—for obvious reasons. Still it seems that most agree that the moisture content of "fresh split"—i.e., freshly logged and immediately split—is often 60% or more.

There are countless methods for testing the moisture content of firewood. Here are a few: measuring the side using 1/4-inch-deep pins, measuring the end using 1/4-inch pins, or splitting the wood in half and testing the inside. It is our opinion that—scientifically speaking—the best, though cumbersome, way of determining moisture content is to use the oven method (for more information on this, see www.kiln-direct.com/understandfirewoodmc). The most practical approach is splitting the piece such that a core moisture content reading can be made. It is my observation that drying firewood down to an average of 20% MC most likely indicates the firewood is 14% to 17% MC on the outside surface and 25% to 30% MC in the center/core.

What Is Heat-treated Firewood?

It is firewood that has been heated to a certain internal temperature for the purpose of killing a pest, such as an insect or bacteria. It is very important to understand that heat-treating firewood does not necessarily mean it is dry or that it will not mold later. On the contrary, experience in heat-treating pallets indicates that new pallets may be more likely to mold after they have been heat-treated. Is this true for firewood as well? The USDA initially required a temperature of 160°F inside the firewood for 75 minutes. Currently this is reduced to 140°F for 60 minutes; however, some states still hold to the old 160°F standard. When selecting a firewood kiln, it may be wise to ensure it has the ability to meet the 160°F for 75 minutes standard—unless you firmly believe the government will not revert to the higher standard at some future date.

Kiln-dried firewood may be the coming standard for bundles (usually 3/4 cubic feet) and other unit-load delivery of firewood. Unit load means bundles, racks, large bags, palletized/stacked, or other non-bulk deliveries. There seems little doubt that firewood bundles have led the way, as it is surprising how far a firewood bundle is transported from the producer to the consumer. A few examples: Firewood produced in Florida ends up in North Carolina; firewood from Virginia and Tennessee is shipped to Florida; Wisconsin firewood is transported to Colorado; and producers in northern Maine send firewood to Philadelphia retailers. This magazine has run many articles about the dangers of transporting disease- or insect-infected firewood for long distances. The wide-ranging transportation is mentioned here in terms of commerce, but there are obvious cautions in terms of insects and diseases that come into play here as well (see Table 1).

Contrary to what some may think, kiln drying is not all about making firewood more expensive. Table 1 compares fresh-split and kiln-dried firewood as it

SPECIES	Btu/cord of Fresh Split	Btu/cord at 20% MC	Increase in Btu/Cord
Ash, white	16.5 million Btu	23.6 million Btu	7.1 million Btu
Hackberry	14.6 million Btu	20.8 million Btu	6.2 million Btu
Maple, red	13.1 million Btu	18.7 million Btu	5.6 million Btu
Oak, red	16.8 million Btu	24.0 million Btu	7.2 million Btu
Average increase in Btu per cord from fresh split to 20% MC: 6.5 million Btu			

Source: www.engineeringtoolbox.com/wood-combustion-heat-d_372.html
These are generic numbers and will vary greatly with actual data due to differences in fresh-split MC% due to season, region, etc., and the 20% average moisture content is probably lower than most seasoned and kiln-dried firewood.

Table 1. Increased Btu Value of Kiln-dried Firewood (20% MC).

relates to the increase in burnable Btus. The average increase in heating value is 30% to 40%, so technically the firewood should be worth 30% to 40% more, which is often the case. It is also worth noting that dry firewood weighs less per cord, which means you can ship more per truckload and thereby reduce cost per cord. Dry firewood can be transported further and at a lower cost than green firewood. In the end, it is up to the individual firewood company to explain why the customer will get better-burning wood at better overall prices.

Firewood Markets

The firewood industry serves a great many markets. Let's consider the three biggest:

- Heating: firewood purchased purely for heating buildings or similar spaces (Delivery: normally bulk delivery or sometimes large unit loads).
- Ambience: firewood used for campfires, fire pits, chimneys, fireplaces, etc. (Delivery: normally bundles, some large unit loads, and some bulk delivery).
- Gourmet: used for commercial cooking and high-end private cooking (Delivery: commercial, medium to large unit loads and private by mail orders).

Like it or not, the shift toward kiln-dried and heat-treated firewood in the marketplace seems more a question of "when" rather than "if." If, due to state and federal regulations, mold prevention, customer or retailer demand, kiln-dried and heat-treated firewood emerges as the industry standard, how can those in the firewood industry prepare for such a significant shift of product?

Nature's pathogens (emerald ash borer, Asian longhorned beetle, wood wasp, etc.—with still more certain to come over time) are doing what they were designed to do, and when combined with modern conveyances, spread nonnative species at alarming rates into areas with no natural defense mechanisms. A simple Google search on the term "firewood quarantine areas" currently yields 9,870 results, a stark testament to how widespread local, state, and federal concern has developed into regulatory oversight. Consequently, it would seem that the only relevant question for those who would prefer to remain in the full-time firewood business would be: How will you position your firewood business for the future and take advantage of a changing marketplace driven by increasing regulatory oversight?

Drying Firewood

It takes a lot more to dry firewood than most people imagine. Here's how it works:

Drying happens mostly through vapor coming out of the end, but why? Look at the end of wet firewood in a fireplace when the water is bubbling out. The air in the kiln chamber transfers heat to the firewood, it evaporates water, and then this same air transports the water vapor away. This is why good airflow is so critical in a firewood kiln. But probably the most important factor in drying firewood faster is chamber temperature. This is because water moves faster from the inside to the outside of firewood when the temperature is higher, especially if the temperature is above boiling point (~212°F).

In Table 2 you see the differences in drying times as the temperatures go up. These drying times naturally assume that plenty of heat and air circulation was available. In a normal firewood kiln you will have a heat-up time and a treatment/drying time. Furthermore, when most people talk about the drying temperature in a firewood kiln, they focus on the air entering the firewood (called supply temperature), but the more important number is exiting temperature (called exit temperature). The exit temperature is the one you should consider most carefully when you review Table 2. Just to clarify, supply temperature is not the real concern in drying and heat-treating firewood. It is the exit temperature that is the concern, as that is the temperature known to be the lowest point of reference in terms of how quickly the slowest firewood is drying.

Drying times in hours and days are based on exit temperature in Table 2, plus actual experience with installed kilns. The hot water and steam temperatures are estimated. Heat-up time will vary greatly depending on the size of the heat system and start temperature of the firewood.

Table 3 compares some generic heating systems often found on firewood kilns. Basically, it is difficult to get below 36 hours in total cycle

Loading Method	DRYING TEMPURATURE 140° F	180° F	220° F
Random / loose stacking	287 hours	87 hours	29 hours
Parallel stacking	226 hours	97 hours	34 hours

Source: Kiln-Drying Time of Split Oak Firewood from Forest Products Laboratory (Research note FPL-RN-0254 – August 1987)

Table 2. Drying Times for Oak Firewood to 20% MC.

HEATING SYSTEM	AVG. HEAT SURFACE TEMP.	MAX SUPPLY TEMP	EST. EXIT TEMP	HOURS	ESTIMATED DAYS
Hot water	190° F	170° F	140° F –160° F	120–200 hrs.+ heat-up time	5–10 days
Low-pressure steam	250° F	220° F–230° F	180° F –200° F	50–85 hrs. + heat-up time	2.5–4 days
High-pressure steam	300° F	260° F *	220° F	30 hrs. + heat-up time	1.5–2 days
Direct gas heating	NA direct gas flame	260° F *	220° F	30 hrs. + heat-up time	1.5–2 days
Air-to-air heat exchanger from wood waste firebox	600° F–800° F	260° F *	220° F	30 hrs. + heat-up time	1.5–2 days

* Operating a kiln at higher temperatures does increase the potential of fire. At high temperatures a kiln should have some kind of sprinkler system installed.

Table 3. Heating System Temperatures, Estimated Chamber Temperatures and Drying Times.

time if you want to dry from fresh-split to 20% moisture content. Of course letting the firewood air dry during the warmer months can help reduce both the time needed in a kiln as well as the overall cost of heating the kiln, but for the purpose of staying on point I will retain the standard of fresh-split to 20%.

The next main design parameter is to install a heat system with enough heating capacity to accomplish the drying in the time desired. Before we can begin to understand the energy needed to kiln-dry and heat-treat firewood, we must first determine how much water needs to be removed from the firewood itself.

SPECIES	Weight of Fresh-Split	Weight at 20% MC	Water to Be Removed
Alder	3,604 lbs.	2,218 lbs.	1,386 lbs.
Ash, green	4,237 lbs.	3,178 lbs.	1,059 lbs.
Hackberry	4,039 lbs.	2,938 lbs.	1,101 lbs.
Maple, soft	3,960 lbs.	2,640 lbs.	1,320 lbs.
Oak, red	4,886 lbs.	3,350 lbs.	1,536 lbs.
Average water loss per cord needed to dry from fresh-split to 20%:			1,280 lbs.

Source: www.engineeringtoolbox.com/weigt-wood-d_821.html

Table 4. Water to Be Removed When Drying Firewood. How Many Pounds Are Removed to Dry Firewood?

Table 4 shows six different species and their fresh-split weight versus their weight at 20% MC. This shows that you need to remove more than 1,270 pounds of water per cord, on average, to reach an average of 20% MC. With this much water to be removed, a lot of energy will be required. This is why it often takes so long to dry the firewood.

Table 5 notes the numbers for removing 1,270 pounds of water. The column for "Theoretical Lab Conditions" in Table 5 is basically the energy needed if there was absolutely no energy wasted in the drying process. This is not operationally possible due to transfer loss, venting, door seals, loss through walls/roof, etc. The next column is based on real firewood kiln experiences. As you read the table, it is worth noting that I have put a price on the firewood used to heat the kiln; however, much of this should be a "free" by-product of your firewood splitting operation (off-cut, crotch, nonmarketable biomass).

Choosing the Best Heat Source

The mixture of firewood kilns that have sold has changed significantly. Three to four years ago the majority of units sold were heated using wood waste. As the natural gas cost has come down over the last two years, we have seen a shift to more gas-heated kilns. LP and natural gas units now represent 60% to 70% of the firewood kilns sold by my company, Kiln-direct.

Basically, for the general firewood operation, the first choice would be natural gas heating, then wood waste, and then LP gas heating. One of our customers has chosen wood waste heat even though that customer has access to natural gas. Reason: They burn their tree service debris to fire the kiln instead of paying dumping fees for their biomass. On the other hand, several firewood companies who have purchased our firewood kilns have both wood waste heating kilns and gas heating kilns. The "best" heating system is an individual choice dependent upon what works for your situation.

Some Firewood Kiln History (Past)

Kiln manufacturers initially utilized existing lumber kiln design in the hope of drying firewood. In essence, the design was nothing more than a modified lumber kiln—the same conventional design with added airflow and heating capacity. Such modified lumber kilns tend to be on the larger size with 15+ cord capacity, which tends to reflect a larger capital investment/commitment.

A different option that entered the marketplace was the modified, insulated container/van bodies—typically using hot-water heating supplied from an outdoor stove. These insulated shipping containers had the lower price point so many smaller operators could afford them. These containers were not very efficient for multiple reasons (low operating temperature and poor air circulation, among others). Furthermore, as insulated shipping containers were originally designed for cold storage, the very hot and humid conditions of a firewood kiln led a relatively short kiln lifespan.

Firewood Kilns Available Today (Present)

During the last five years, we have seen the arrival of "true" firewood kilns with 6 to 15 cord capacity, engineered to operate at high temperatures (~250°F–270°F) for efficient/quick cycle times, built with well-insulated chambers, and offering multiple fuel options for heating—LP gas, natural gas, and wood waste. At present, approximately 2/3 of these are sold with gas heating with the remaining 1/3 equipped for wood waste heating.

Next Generation Firewood Kilns. (Future)

We believe that making firewood kilns too large will make them less efficient and ensure longer drying cycles. We also believe it would be, in a practical sense, better to have three 6-cord firewood kilns versus one 18-cord kiln, as multiple small kilns provide a redundancy to protect production. Be it maintenance issues or fires (yes, kilns of all brands can catch fire), redundancy of kiln units clearly offers value to any operation built on delivering product with consistency. Moreover, should a fire occur, it is much easier to contain a 6-cord fire than an 18-cord fire. As a final note, sprinkler systems should always be considered on kilns, especially if using wood-waste-fired kilns.

We believe that the ideal size for a small operation is around 5- to 6-cord capacity per kiln with a 2-day drying process with either gas or wood-waste heating. This type and size of kiln is currently available in the marketplace.

Regarding the midsize to large firewood operations/companies, our experience suggests a kiln with the specifications below:

- Loading capacity of 12 cords.
- Operating at 250°F–270°F on supply side (210°F–220°F on exit side) for two-day drying.
- Short air circulation through firewood (10 feet or less).
- Wood-waste heat using wood chips/mulch/sawdust/etc. with air-to-air heat exchanger (eliminating the need for steam and expensive maintenance).
- Wood-waste storage for two to four days of operation.
- Automatic wood ignition (no manual start-up needed).
- Fire suppression system.
- Delivered in one unit to be placed on a flat, concrete slab to make installation easy, keep investment down, and ensure kiln is considered a piece of equipment.

To our knowledge, this kiln does not exist as of 2014. However, we believe it will eventually be built by someone to supply the needs of larger firewood companies.

Getting Started

Are you currently operating a processor and considering expanding into firewood drying for either bulk or bundle delivery? The smallest firewood kiln available on the market has a 5 to 6 cord capacity per load. There are "high" temperature and "low" temperature designs, with high-temp systems drying the firewood at approximately 260°F in two days or less, and low-temp systems drying the firewood utilizing hot water heat in five to seven days. In most cases, you will also need firewood baskets—preferably two sets—one set in the kiln and one set getting processed and loaded with new firewood to be dried. This is a major investment.

ENERGY COST FOR DRYING 1 CORD OF FIREWOOD	THEORETICAL LAB CONDITIONS	FIREWOOD KILN CONDITIONS
Estimated weight of green firewood: (oak=4,900 lbs., maple, soft=3,960 lbs., ash=4,240 lbs., hackberry=4,040lbs., alder=3,600 lbs.) = average 4,150 lbs./cord	**4,150 lbs./cord**	
Estimated weight of dry firewood: (oak=3,425 lbs., maple, soft=2,640 lbs., ash=3,181lbs., hackberry=2,940 lbs., alder=2,220 lbs.) = average 2,880 lbs./cord	**2,880 lbs./cord**	
Amount of water extracted per cord of firewood to be dried.	**1,270 lbs./cord**	**1,270 lbs./cord**
How much energy will it take to evaporate 1 lb. of water? Starting temperature is 60° F. Raising 1 lb. of water from 60° F to 212° F = 152 Btu (1Btu = 1° F per lb.). Evaporating 1 lb. of water at 212° F = 971 Btu. Theoretical energy needed to evaporate 1 lb. of water from 60° F = 1,123 Btu. If there is a heat waste factor in any kiln, you will need much more heat due to heat energy escaping during venting, or through walls, floors, and other inefficiencies. *The rule of thumb in lumber drying is 35%–60% waste factor, which means it will cost between 1,700 to 2,800 Btu to evaporate 1 lb. of water in a kiln.*		
How much energy does it take to evaporate 1,270 lbs. of water from firewood? Theoretical: 1,270 lbs. of water x 1,123 Btu/lbs. = 1.4 million Btu (not possible). LOW Estimate: 1,270 lbs. of water x 1,700 Btu/lbs. = 2.2 million Btu. HIGH Estimate: 1,270 lbs. of water x 2,800 Btu/lbs = 3.6 million Btu.	**1.4 million Btu**	**between 2.2 million Btu and 3.6 million Btu**
How much energy does it take to raise 1 cord of firewood from 60° F to about 212° F? Average weight of firewood dry (with 20% water) = 2,880 lbs. Temperature increase is (212° F - 60° F) = 152° F increase. Approximately 1 Btu/lbs./1° F increase. Total energy needed to raise wood temperature (2,880 lbs. x 152 Btu/lbs.) = 437,760 Btu.	**approx. 440,000 Btu**	**approx. 600,000 Btu**
Total energy consumption needed to dry 1 cord of firewood: THEORETICAL: (1,400,000 + 440,000) Btu = 1.8 million Btu LOW estimate: (2,200,000 + 600,000) Btu = 2.8 million Btu HIGH estimate: (3,600,000 + 600,000) Btu = 4.2 million Btu		
Total cost in energy to dry one cord of wood in the MINIQUICK Firewood Kiln	**1.8 million Btu**	**2.8 million Btu to 4.2 million Btu**
Estimated cost of energy with wood waste: 1 cord of firewood is normally 15–20 million Btu (cost per cord = $0–$100)	**~10% of a cord up to $10**	**16%–24% of a cord $16–$24**
Estimated cost of energy using LP ga:s Each gallon of LP gas = 91,000 Btu /gal. LP gas Current gas costs: $2 per gal. (probably too low) THEORETICAL: 1,800,000 / 91,000 Btu/gal. = about 20 gal. LOW estimate: 2,800,000 / 91,000 Btu/gal. = about 31 gal. HIGH estimate: 4,200,000 / 91,000 Btu/gal. = about 46 gal.	**$40**	**$62–$92**
Estimated cost of energy using natural gas: 1 cu. ft. of natural gas = 1,000 Btu (100 cu. ft. = 1 therm) Current average cost for 1 therm of natural gas = $0.80 per therm Theoretical: 1,800,000 / 100,000 Btu/therm – about 18 therm Low estimate: 2,800,000 / 100,000 Btu/therm – about 28 therm High estimate: 4,200,000 / 100,000 Btu/therm – about 42 therm	**$14.40**	**$22–$33**

THIS CALCULATION ASSUMES THE FIREWOOD IS DRIED TO 20% AVERAGE MOISTURE CONTENT—MUCH OF THE KILN- DRIED FIREWOOD ON THE MARKET TODAY DOES NOT, IN FACT, MEET THIS STANDARD.

Table 5. Energy and Cost of Drying Firewood.

	GREEN	SEASONED	KILN-DRIED wood heat	KILN-DRIED LP gas	KILN-DRIED natural gas
Cost of one cord of firewood logs delivered to your location	120	120	120	120	120
Add 20% as total waste factor (10% for splitting + 10% shrinkage when drying)	12	24	24	24	24
Cost of splitting firewood	35	35	35	35	35
Cost of drying firewood (or seasoning) including paying for equipment	--	15	50	80	40
Total cost per cord of firewood	167	194	229	259	219
Sales price for a full cord	190	250	325	325	325
Revenue from 1,000 cord	$190,000	$250,000	$325,000	$325,000	$325,000
Total cost to produce 1,000 cord	$167,000	$194,000	$229,000	$259,000	$219,000
Net estimated profit on 1,000 cord	$23,000	$56,000	$96,000	$66,000	$106,000
Estimated profit margin	13.8%	22.4%	29.5%	20.3%	32.6%
Extra investment required to get going		Extra inventory	One 6 cord kiln + 2 sets of baskets ~ $120,000	One 6 cord kiln + 2 sets of baskets ~70,000	One 6 cord kiln + 2 sets of baskets ~70,000

This is a generic comparison based on speaking with several firewood producers. Your costs may vary, but this table should help you develop your own cost calculation to help determine if kiln-drying firewood can be profitable for you and your business. The prices and cost we received from our customer varied greatly depending on the state and closeness to a metropolitan area. You must..... (author—missing sentence here?)

Table 6. Costing and Profit Estimated for a 1,000 Cord Annual Production.

It is sound practice to consider the questions below in order to choose the best long-term firewood kiln:

- How many cords do you need to dry in a certain period?
- How many cords do you want to heat-treat/dry per charge?
- Do you need to heat-treat and to what standard?
- What fuel do you want to use (gas, wood waste, or something else)?
- How dry do you want your firewood to be?

Begin by talking with companies that sell firewood kilns. Be sure you get several references and ask pointed questions. If a company promises three-day cycle times with a maximum temperature of 180°F chamber temperature in a 6-cord kiln with a 250,000-Btu hot water stove, then there is good reason to be suspicious. First, 180°F is the supply temp (meaning the hottest temperature in the kiln); the exit temperature will be significantly lower (15°F or more). If this is the case, then the numbers cannot be reconciled to Table 2 drying times. Second, to dry 6 cords of firewood to 20% MC will require between 16.8 and 24 million Btu. At 250,000 Btu/hour, a heating system with 80% efficiency creates approximately 200,000 Btu/hour—suggesting a drying time of 84 to 120 hours. Visit several of the references provided by the kiln company, making sure the company you are visiting is more than four to six hours away so they are not future competitors. You will find distant operations more open to sharing information, as they are not threatened by you as a competitor. During your visit, ask for a few firewood samples that have recently come out of the kiln so you can test moisture content later. Better yet, if possible, try to have a look at the records from a regular run to make sure the kiln can actually reach the temperatures that the salespeople are promising. They may refuse, but it is worth the asking.

Most importantly, before investing in a kiln, be sure you can make a profit. If you are within three to four hours of major metropolitan areas, you can expect around $325 to $375 per cord for thoroughly kiln-dried firewood picked up at your yard. For bundles of thoroughly dried and heat-treated firewood, the average rate seems to be somewhere between $2.25 and $3 per bundle picked up at your facility. Please see Table 6 for a generic overview of firewood economics. Furthermore, you can literally log on Monday, split on Tuesday, kiln-dry on Wednesday to Thursday, and then deliver on Friday. This approach would mean you have reached three standards unobtainable by traditional seasoning: consistent moisture content, you have satisfied heat treatment requirements and provided consistent production.

How Might New Heat Treating and Drying Standards Influence the Industry?

It used to be that all a person needed to start a firewood business was a splitter, chain saw, and a pickup truck. This model seems to have

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created many "low bidders" in the marketplace and often disturbs genuine full-time operations because their infrastructure costs prohibit them from matching the unsustainable low price offered by the fellow who cuts for "beer money."

Heat treating and kiln drying has separated the full-time firewood producers from the "hobbyists." The current firewood regulations do not really stop the "nickel and dime" producers, as most of these deliver close to home. However, it does require a substantial investment to move from hobbyist to full-time production, probably in the realm of $200,000 to $400,000 to cover a bigger processor, firewood kiln, skid-steer, inventory, and working capital. Practically speaking, once people go full-time they need to produce a minimum of 500 to 1,000 cords annually to make a profit. Realistically, the long-term volume to stay in business is more likely above 2,000 cords annually. In the end, to be a full-time firewood operation, you likely end up with a mixture of local bulk delivery at lower prices and more profitable kiln-dried firewood in bundles and/or bulk delivery.

The nature of the firewood industry has changed. A clear division between hobbyists and full-time firewood producers has been a healthy development for the industry, and the establishment of additional small to midsize operations (2,000–5,000 cords annually) has stimulated improved operational efficiencies for smaller-scale operations through innovation. ●

Niels Jorgensen started Kiln-direct in 1994 by selling lumber kiln components. Kiln-direct matured as the demand for pallet kilns grew and it became one of the primary suppliers to the pallet industry. Kiln-direct later diversified into small to midsize lumber kilns and more recently into firewood kilns specifically designed for drying and heat-treating firewood.