Basics of Burning Wood for Heat

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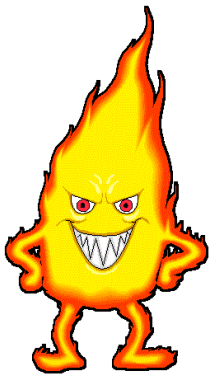
Outline

- What……
  - are the best species to use and why?
  - is better to burn hardwoods or softwoods?
  - factors affect the amount of creosote produced when burned?
  - moisture content should wood be and how should wood be stored?
  - factors can affect the heat produced when wood burns?
  - is a cord, a face cord, a rick or a pickup truck load of material and how much variation can exist for these measurements?
  - is wood ash and how much should I expect
  - insects attack firewood and how to prevent them
  - are heating values, what are they and how are they determined for different species?

What are the best species to use and why?

What Wood Burns Best?

- How much heat will a wood produce?
  - Depends:
    - Density
    - Moisture in the wood
    - Efficiency of your wood burning device
- How does density and MC affect heat?



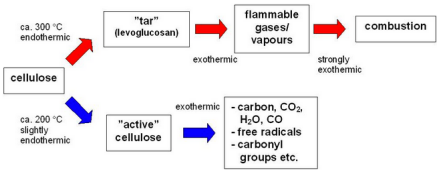
How does wood produce heat?

- Combustion of wood is a chemical reaction
- If the burning process is complete:

$C + O_2 \rightarrow CO_2 + 32.8$ MJ/kg (carbon)

$2H_2 + O_2 \rightarrow 2H_2O + 142.1$ MJ/kg (hydrogen)

- In practice the burning process is never complete
- Combustion always produces small amounts of unburned hydrocarbons (CO, C_2 H_2O)



Average chemical contents of wood fuels

Chemical Constituents of Oak:
- Cellulose – 45-50%
- Hemicellulose - 20-25%
- Lignin – 25-35%
- Extractives – 5-10%

	Share, % of dry matter weight
Carbon	45-50%
Hydrogen	6.0-6.5%
Oxygen	38-42%
Nitrogen	0.1-0.5%
Sulphur max	0.05 %

How does wood burn

- Pyrolysis
  - The thermal decomposition of materials at elevated temperatures in an inert atmosphere
  - Involves the change of chemical composition and is irreversible
  - Produces volatile products and leaves a solid residue enriched in carbon

Charring Rate

- Paralyzing wood can be considered char
  - the charring rate corresponds to the propagation rate of the pyrolysis front
    - Pyrolysis front
      - When a wood product burns at a constant rate of heat release per unit area, the boundary between the pyrolized material and the intact wood, i.e. the pyrolysis front, proceeds to the wood in depth direction
- Factors that influence charring rate:
  - Wood density
  - External heat flux (heat transfer)
  - Wood moisture content

How wood burns

- Stages of wood burning
  - Heating efficiency depends on how that wood progresses through three stages
  - 1st stage:
    - wood is heated to a point where the moisture within the wood cells can evaporate
    - After the wood has dried, it then undergoes a chemical breakdown to charcoal, volatile gases and volatile liquids (around 500 F)
  - 2nd stage:
    - is indicated by the obvious visual sign of actual flames
    - what burns in this second stage are the volatile gases and volatile liquids (approximately 1,100F)
  - 3rd stage:
    - occurs when the charcoal burns and can be seen when the embers glow
    - heat is radiated from the burning charcoal
    - different species of wood burn and expend energy differently throughout these three stages

Higher Heating Value

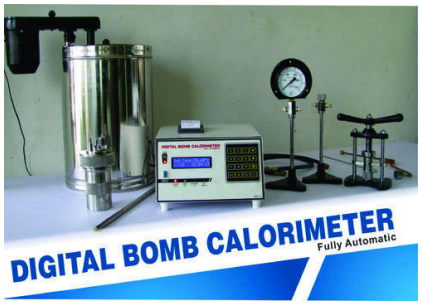
- First step for calculating effective heat:
  - Obtain an estimate of the higher heating value of the fuel
  - The higher heating value is the heat of combustion of a unit weight of dry wood fuel
- Bark is usually slightly higher than that for wood
- The small variations among different species result from differences in chemical composition

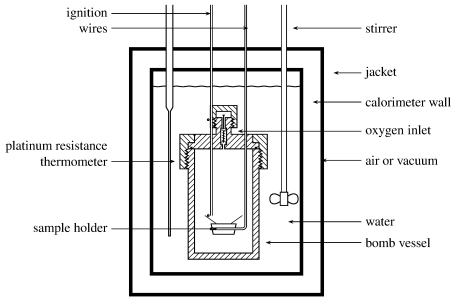
	Wood	Bark
Douglas-fir	5,030*	5,610**
Lodgepole pine	4,760**	5,960**
Western hemlock	4,790*	5,170≠
Western redcedar	5,390**	4,830**
Black cottonwood	4,690**	5,000**
Red alder	4,440**	4,670**
White birch	5,190*	5,460*
Red oak	5,200*	4,660≠≠
White oak	5,280*	4,140≠≠
Poplar	5,350*	4,890*
Beech	4,870≠≠	4,240*
Ponderosa pine	5,060**	5,340+
Sitka spruce	4,500**	—
Oregon ash	4,560**	—
White fir	4,440**	—
Bigleaf maple	4,670**	—
Oregon white oak	4,510**	—
Redwood	5,020*	—
White cedar	5,040*	—
Cypress	5,920*	—
Pitch pine	6,790*	—
White pine	5,340*	—
Yellow pine	5,770*	—
White ash	5,350*	—
Hickory	5,200*	—
Engelmann spruce	—	4,900≠≠
Western larch	—	4,860≠≠
Slash pine	—	5,320≠≠
Western white pine	—	5,040≠≠
Eastern hemlock	4,940*	5,190≠≠
Sugar maple	4,550*	4,300≠≠
Yellow birch	4,930*	5,310≠≠
Balsam fir	—	5,060*
Jack pine	4,960*	4,960*
Soft elm	—	4,220*
Tamarack	—	5,010*

1/ Sources: *, Combustion Engineering, Inc. (1); **, Corder (2); ≠, Harkin and Rowe (5) ≠≠, Grantham (3); and +, Harder and Einspahr (4).

Higher Heating Value

- A bomb calorimeter, a sealed container in which a weighed amount of ***oven dried fuel*** is subjected to complete combustion in pressurized oxygen, is used to determine the higher heating value of a wood fuel





Heating Value

- The heating value of wood is usually expressed in BTU's per unit volume, than lighter woods
  - BTU (British thermal unit)
    - Standard measure of heat that can be used for comparative purposes (one BTU is equal to the amount of heat required to raise the temperature of one pound of water one degree Fahrenheit
  - Takes into account the impact of moisture content
  - Relates directly to wood density
  - Lighter woods, such as cottonwood and willow, produce roughly the same heat value per pound as heavier woods, such as oak, but are less dense, and therefore produce less heat per unit volume

Weight per cord given a 20% moisture content and the average BTU's produced.

Species	Weight per Cord	Heating value per cord (Btu's)
American elm	3,000	20.2
Apple	4,140	26.5
Aspen	2,295	14.7
Basswood	2,108	13.5
Beech	3,757	24
Black birch	3,890	26.8
Black locust	4,200	29.3
Black cherry	2,880	19.9
Cottonwood	2,108	13.5
Hackberry	3,247	20.8
Hard maple	3,757	24
Hemlock	2,482	15.9
Hickory	4,327	27.7
Paper birch	3,179	20.3
Red oak	3,757	24
Soft maple	2,924	18.7
Sycamore	2,900	20.2
White ash	3,689	23.6
White oak	3,800	26.5
White pine	2,236	14.3

Fuel Properties

Important fuel properties of wood are:

- Moisture content
- Density
- Heating value
- Ash content and properties
- Chemical composition
- Amount of volatiles

OffGridWorld

Best firewood

Good firewood:

1. is dry
2. burns through the second stage evenly without sparks, and with a minimum of smoke production
3. spends a long time burning in the third phase
   - has good "coaling qualities"

- What else??

Species	*Weight (lbs./cord) Green*	*Dry*	*Heat/Cord (Million BTUs)*	*% Green Ash*	*Ease of Splitting*	*Smoke*	*Sparks*	*Coals*	*Fragrance*	*Overall Quality*
Apple	4850	3888	27.0	135	Medium	Low	Few	Good	Excellent	Excellent
Ash, Green	4184	2880	20.0	100	Easy	Low	Few	Good	Slight	Excellent
Basswood (Linden)	4404	1984	13.8	69	Easy	Medium	Few	Poor	Good	Fair
Birch, Paper	4312	2992	20.8	104	Medium	Medium	Few	Good	Slight	Fair
Boxelder	3589	2632	18.3	92	Difficult	Medium	Few	Poor	Slight	Fair
Buckeye, Ohio	4210	1984	13.8	69	Medium	Low	Few	Poor	Slight	Fair
Catalpa	4560	2360	16.4	82	Difficult	Medium	Few	Good	Bad	Fair
Cherry, Black	3696	2928	20.4	102	Easy	Low	Few	Excellent	Excellent	Good
Coffeetree, Kentucky	3872	3112	21.6	108	Medium	Low	Few	Good	Good	Good
Cottonwood	4640	2272	15.8	79	Easy	Medium	Few	Good	Slight	Fair
Douglas-Fir	3319	2970	20.7	103	Easy	High	Few	Fair	Slight	Good
Elm, American	4456	2872	20.0	100	Difficult	Medium	Few	Excellent	Good	Fair
Elm, Red	4800	3112	21.6	108	Easy	Medium	Few	Excellent	Good	Good
Elm, Siberian	3800	3020	20.9	105	Difficult	Medium	Few	Good	Fair	Fair
Fir, Concolor	3585	2104	14.6	73	Easy	Medium	Few	Poor	Slight	Fair
Hackberry	3984	3048	21.2	106	Easy	Low	Few	Good	Slight	Good
Hickory, Bitternut	5032	3832	26.7	134	Medium	Low	Few	Excellent	Excellent	Excellent
Hickory, Shagbark	5104	3952	27.5	138	Difficult	Low	Few	Excellent	Excellent	Excellent
Honeylocust	4640	3832	26.7	133	Easy	Low	Few	Excellent	Slight	Excellent
Ironwood	4590	4016	27.9	140	Difficult	Medium	Few	Excellent	Slight	Excellent
Juniper, Rocky Mountain	3535	3150	21.8	109	Medium	Medium	Many	Poor	Excellent	Fair
Locust, Black	4616	4016	27.9	140	Difficult	Low	Few	Excellent	Slight	Excellent
Maple, Other	4684	3680	25.5	128	Easy	Low	Few	Excellent	Good	Excellent
Maple, Silver	3904	2752	19.0	95	Medium	Low	Few	Excellent	Good	Fair
Mulberry	4712	3712	25.8	129	Easy	Medium	Many	Excellent	Good	Excellent
Oak, Bur	4960	3768	26.2	131	Easy	Low	Few	Excellent	Good	Excellent
Oak, Red*	4888	3528	24.6	123	Medium	Low	Few	Excellent	Good	Excellent
Oak, White	5573	4200	29.1	146	Medium	Low	Few	Excellent	Good	Excellent
Osage-Orange	5120	4728	32.9	165	Easy	Low	Many	Excellent	Excellent	Excellent
Pine, Eastern White	2780	2250	15.6	78	Medium	Medium	Few	Poor	Good	Fair
Pine, Jack	3200	2488	17.2	86	Difficult	Low	Many	Poor	Good	Fair
Pine, Ponderosa	3600	2336	16.2	81	Easy	Medium	Many	Fair	Good	Fair
Redcedar, Eastern	2950	2632	18.2	91	Medium	Medium	Many	Poor	Excellent	Fair
Spruce	2800	2240	15.5	78	Easy	Medium	Many	Poor	Slight	Fair
Sycamore	5096	2808	19.5	98	Difficult	Medium	Few	Good	Slight	Good
Walnut, Black	4584	3192	22.2	111	Easy	Low	Few	Good	Good	Excellent
Willow	4320	2540	17.6	88	Easy	Low	Few	Good	Slight	Poor

Species	Weight (lbs./Cord)		Heat/ Cord (1,000,000 BTU'S)	% Green Ash	Ease of Splitting	Smoke	Sparks	Coals	Fragrance	Overall Quality
	Green	Dry								
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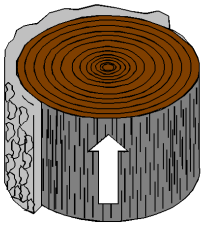
Ease of splitting

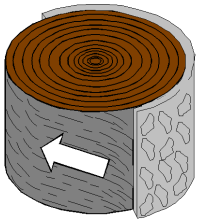
- Splitting enables the wood to dry out faster and reduces the size of the sticks
- Woods with interlocking grain, like American elm or sycamore, can be extremely stringy and are difficult to split even with a hydraulic log splitter.
- Green wood will split more easily than dry wood
- Softwoods will generally split more easily than hardwoods

Angled and Spiral Grain

Straight-grain Orientation



Spiral-grain Orientation



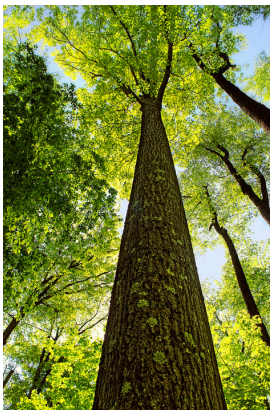
Aroma/Fragrance

"Firewood connoisseurs will assess a firewood's aroma"

- Some people attach tradition to various smells that different woods have when burned
  - According to some, aroma is best achieved through burning the fruit woods
- Apple, cherry, hickory, and pecan are examples
- If you have an efficient wood stove, how could you smell the wood smoke?

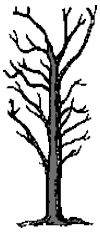
Harwood or Softwood?

Types of Woods



Hardwoods

- Classification: Angiosperms
- Seeds enclosed in fruit or shell
- Broadleaf and deciduous (shed leaves in fall)
- Broadleaf and deciduous
- Not always “hard”
- Examples: Oak, maple, ash, hickory, yellow poplar



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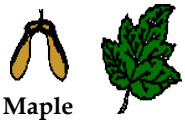
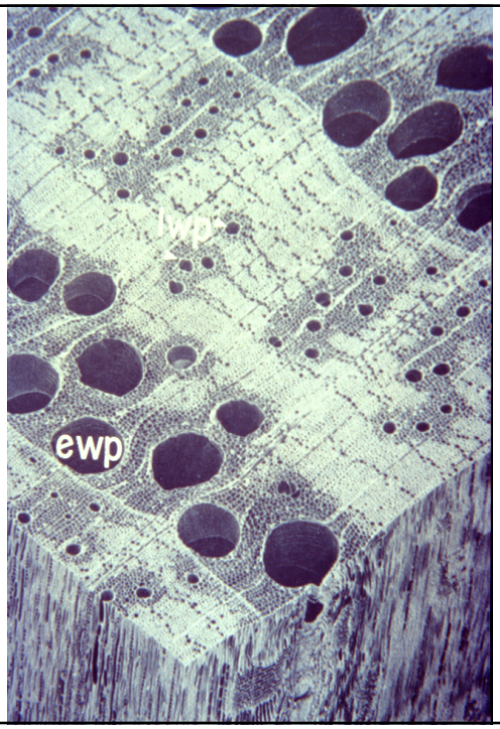


Maple



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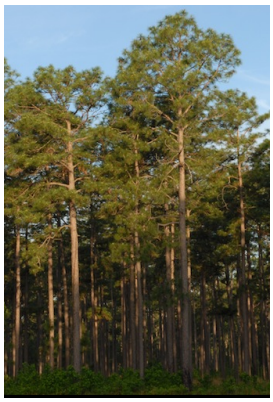
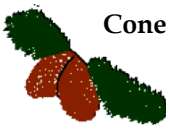


Softwoods

- Classification: Gymnosperms
- Seeds in shape of cone; leaves are needle-like
- Most are conifers (cone-bearing) and evergreens (cypress and larch are exceptions)



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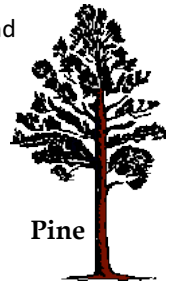
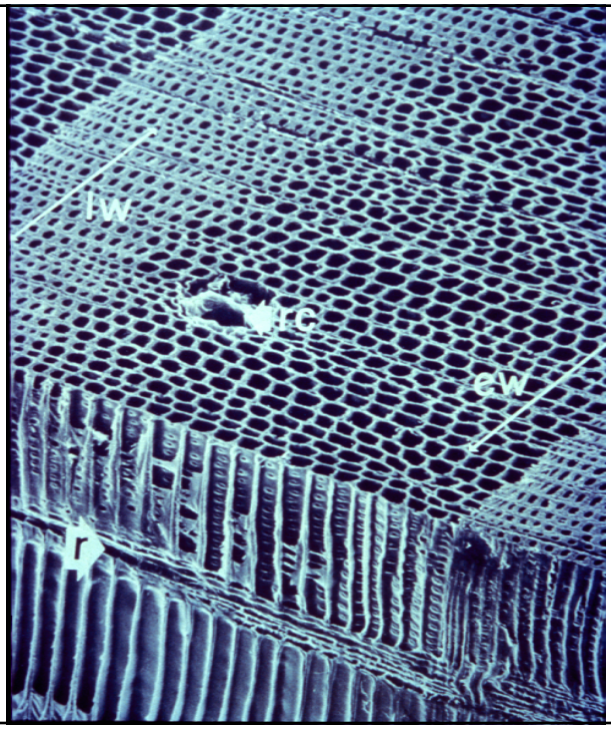




Density Differences?

Hardwoods

- Balsa wood
  - 10 lbs./cu ft
- Hickory
  - 45 lbs/cu ft
- Hard Maple
  - 44 lbs/cu ft

Softwoods

- White Pine
  - 23 lbs./cu ft
- Loblolly Pine
  - 37 lbs/cu ft
- Western Red Cedar
  - 21 lbs/cu ft

What is better to burn hardwoods or softwoods?

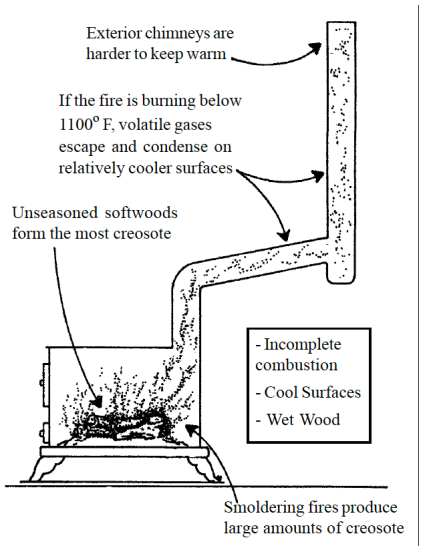
- Some generalizations:
- Softwoods
  - Pines are are easier to ignite because they are resinous
  - Tend to burn rapidly with a high, hot flame and burn out quickly, requiring frequent attention
  - Species like redcedars and hemlock can contain moisture pockets which can be hazardous.
    - Trapped gases in these pockets can explode when heated causing “pops,” which throw sparks
    - These “pops” can present a significant fire danger, especially in open fireplaces with improper screens.
  - Typically, the heat content of softwood is little more than half as much as hardwood by volume
- Hardwoods
  - burn longer and less vigorously
  - tend to produce more coals that last longer
  - tend to be more difficult to ignite (varies by density)

Creosote production?

- When wood burns, the combustion process is never complete
- The smoke produced usually contains a substance called creosote
- Creosote consists primarily of methanol (wood alcohol) and acetic acid
  - The acid tends to trap carbon from smoke which dries and bakes inside pipes and flues
  - Very flammable

Creosote and Temperature

- Temperatures below 250ºF
  - creosote will condense on the surfaces of stove pipes or chimney flues
- The amount of creosote condensing varies according to the:
  - density of the smoke and vapor from the fire
    - less smoke means less creosote
  - temperature of the surface on which it is condensing
  - MC% of wood being burned



Creosote Control/Prevention

- Often suggested " the best way to control creosote buildup is to maintain a hot fire
  - Keeps flue temperatures above 250°F
- How's that feel?
- An alternative:
  - Open the dampers and deliberately have a hot fire for 15 to 30 minutes once or twice each day the stove is used
  - "clean out" fire will burn off creosote in very small amounts, thus reducing buildup problems
- Using "clean out" fires along with a regular chimney maintenance program (chimney cleaning and inspection) can prevent creosote problems

Creosote

- Wait, use a hot fire?
  - A hot fire in the stove with the air control wide open may allow hot oxygen into the chimney, where it can ignite the creosote, causing a chimney fire!
- Assumption is that you are:
  - Doing this with a clean, properly maintained chimney with a good draught
  - Inspecting your chimney at least once a year
  - Cleaning creosote as needed

Creosote Control

- Chemical cleaners:
  - Intended to be used after chimneys are cleaned or are new
  - Use the chemicals as directed
    - approximately 1 ounce per week
- If not used as directed
  - the chemicals can cause intense chimney fires
- The only efficient and effective method of cleaning is to use a chimney brush
  - A brush scrubs the entire surface uniformly

Creosote Prevention

- The moisture content of firewood matters more than the species!
  - Do not burn green, wet wood!
  - Season at least over the summer, to dry to 20-25 % MC
  - Why?
    - Boiling off excess water from wet firewood literally cools the chimney, helping gases condense into creosote
  - A telltale sign of a slow fire?
    - a smoky chimney
    - a good, hot fire produces no smoke.

Creosote: Softwood vs Hardwood

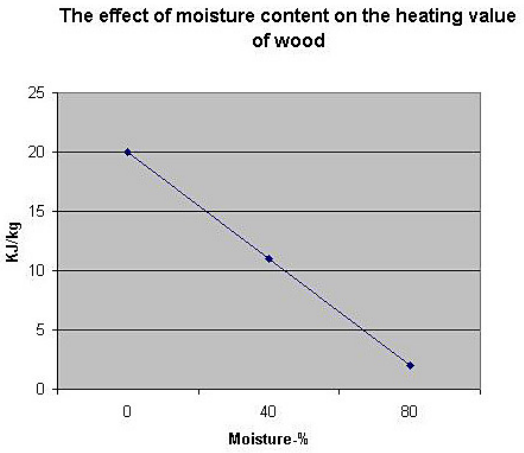
- Softwoods “often produce a little more creosote than do hardwoods, but not under all circumstances”
- “In our experiments, we've found that depending on the air setting on the test stove and the fuel moisture content, pine (a softwood) resulted in anywhere from the same amount of creosote as oak to about four times as much.” – Mother Earth News
- “We observed up to 48 times more creosote with a smoldering fire than with a hot flaming fire using the same fuel.” – Mother Earth News

Safety

- Be Prepared for Chimney Fire!
  - No wood burning system is 100 percent safe and fireproof.
- Chimney fires are most likely to occur during a very hot fire, as when cardboard or Christmas tree branches are burned or even when a stove burns normal wood but at a higher than normal rate
- Make certain everyone in the house is familiar with the warning signs of a chimney fire – sucking sounds, aloud roar, and shaking pipes. Instruct everyone on what to do in case of fire. Practice fire drills and instruct all adults on how and when to use a fire extinguisher.
- Put the fire department phone number in an obvious place near the phone.

What moisture content should wood be and how should wood be stored?

- Firewood should be between 15 and 20 % MC
- Problems with higher MC?
  - Hard to light
  - Lots of smoke
  - Less heat (drying the water)
    - Each pound of water vaporized uses about 1,200 Btu.
  - More creosote
  - Any moisture in the wood reduces the recoverable heat by carrying heat up the chimney during vaporization.



Moisture Content

$$\%MC = \frac{\text{Wet Weight - Oven Dry Weight}}{\text{Oven Dry Weight}} X100$$

$$\%MC = \left(\frac{\text{Wet Weight}}{\text{Oven Dry Weight}} - 1 \right) X100$$

Moisture Content (oven dry basis)

$$\%MC = \frac{\text{Wet Weight - Oven Dry Weight}}{\text{Oven Dry Weight}} X100$$

$$\%MC = \frac{0.90\,\text{kg} - 0.60\,\text{kg}}{0.60\,\text{kg}} X100 =$$ 50%MC

Green Moisture Content

Species	Heartwood	Sapwood
Douglas-fir	30	112
Shortleaf pine	32	122
Eastern hemlock	97	119
Red oak	80	70
Yellow poplar	83	106
Hickory	70	50
White oak	64	78

- When first cut, the wood is at its highest moisture content
- The "green" or fresh cut moisture content of wood is typically higher than 60% for most hardwoods and for some species, over 100%.

Wood Ash

- Results from burning wood
- Consists mainly of minerals that the trees have absorbed over their lifetime
- Wood without bark contains very little ash
- Wood with bark contains more ash
- Fuel made of whole trees with needles or leaves, than the ash level will be at its highest

Ash Content

Table 1: Typical ash content of wood fuels.

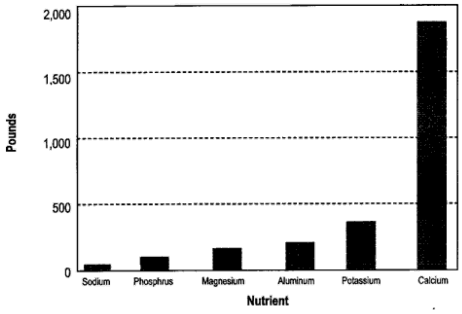
Fuel type	Ash content hardwood	Ash content softwood
	% dry weight	
Wood pellets (pure wood only)	0.7	0.5
Firewood (wood with bark)	1.2	1.0
Wood chips (roundwood with bark)	1.2	1.0
Wood chips (whole tree)	1.5	1.2
Hogfuel[1] from stumps	6-8	6-8
Hogfuel from garden waste	6-10	6-10

Wood Ash

- A good wood ash is light grey
- Ash that is black
  - the fuel has not completely combusted
  - valuable fuel is being thrown out with the ash
- Wood ash is highly basic with a pH around 12
  - it is corrosive

Wood Ash

- Contains most of the minerals that a tree will take up during its lifetime.
- These comprise three main categories:
  - Macronutrients
  - Micronutrients
  - Heavy metals
- Macro nutrients include:
  - Phosphorus
  - Potassium
  - Calcium
  - Magnesium
- Micronutrients include:
  - Iron
  - Sodium
  - Manganese
  - Copper
- Heavy metals include:
  - Zinc
  - Lead
  - Cobalt
  - Cadmium



Macro and micronutrients, and heavy metals in wood ash

Fuel type	P	K	Ca	Mg	Fe	Na	Mn	Cu	Zn	Pb	Co	Cd
	%						ppm					
SWTC	1.40	4.63	12.9	1.70	1.27	0.76	1.32	135	817	107	15	8
HWTC	1.78	5.18	23.2	1.83	1.12	0.92	0.25	142	242	158	17	4
B	0.70	1.84	9.10	0.96	1.12	0.44	0.44	134	325	50	12	3
F	0.79	6.78	18.9	1.16	2.07	0.63	1.28	200	900	130	27	8

- (SWTC) softwood whole tree chips
- (HWTC), hardwood whole tree chips
- (B) bark
- (F) hardwood firewood

Pieter D. Kofman, 2016

Wood Ash

- Wood ash as a liming agent
  - Wood ash is commonly used as a liming agent because of its high calcium content
  - Used to raise soil pH
- Potassium and Phosphorus
- Some concerns about using in gardens and for plants for food consumption
  - Heavy metals

What insects attack firewood and how to prevent them?

Insects

- Alarm when:
  - Sawdust is pushed out of the firewood
  - Faint rustling or gnawing noises are heard
  - insects emerge to crawl or fly within the house.
- For the most part:
  - Firewood insects are a nuisance by their presence
  - Will cause no harm to the home, household furnishings or humans

Roundheaded Borers

- (1/3 to 3 inches long)
- Adults, also known as long horned beetles
- Attracted to dying, freshly cut or recently-killed trees
- Eggs are laid in the bark crevices of the green (unseasoned) wood
  - larvae tunneling throughout the wood for a year or longer
  - The amount of feeding depends on:
  - Moisture content and temperature
  - After larvae pupate, adults emerge with large amounts of sawdust exuded from the circular exit holes
    - diameter of a pencil or larger

Elm Borer

Red Headed Ash Borer

Painted Hickory Borer

Flatheaded Borers

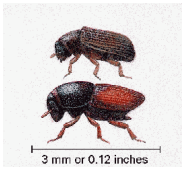
- 1/4 to 1-1/3 inches long
- Attack living, dying and weakened trees
- Eggs are laid in the bark crevices with larvae tunneling under the bark surface
- After larvae pupate, adults emerge out of oval D-shaped exit holes.
- None of the flatheaded borers will infest structural or interior woodwork

Shothole Borer

Figure 1. Bronze birch borer adult and two D-shaped exit holes.

Bark Beetle and Ambrosia Beetles

- Bark Beetles (1/16 to 1/4 inch long)
- Primarily attack dead and dying trees
- Adults bore through the bark, forming galleries, grooving the surfaces of both the wood and the inner side of the bark
- Eggs hatch into larvae which feed in the cambium region
- After larvae pupate, adults emerge through numerous small holes
  - about the diameter of small lead shot

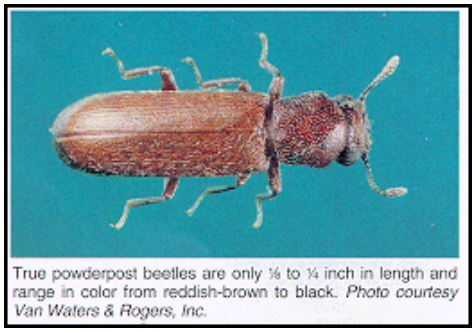


European Elm Bark Beetle

Ambrosia Beetle

Powderpost Beetles

- 3/32 to 1/3 inch long
- Adults can be found in dead wood as well as dried and seasoned lumber.
- Adults can emerge from firewood in the home and infest structural wood or furniture
- Exit holes are about 1/32 to 1/16 inch in diameter.
  - Flour or talc-like frass falls out of the exit holes and cracks.
- Anobiid powderpost beetles attack both hardwoods and softwoods
- Most wood-infesting beetles will not re-infest wood that is painted, varnished, waxed or shellacked



True powderpost beetles are only ⅛ to ¼ inch in length and range in color from reddish-brown to black. *Photo courtesy Van Waters & Rogers, Inc.*

Carpenter Ants and Termites

- Infest undisturbed piles of damp, unsound, wet firewood stacked on the ground outside
- Not noticed until the stacked wood is moved
- Usually will not result in infestations starting in the house
- Both are social insects and the colony becomes so disturbed when the wood is moved, dried, cut or split that establishment indoors is very unlikely

Carpenter Bees (3/4 to 1 inch long)

- Adults resemble bumble bees
- Bore round holes into outside wooden furniture, railings, fence posts, dead tree limbs and other weathered wood
- Lay eggs in wood galleries
- Do not use wood as a food sources

Insects and their relatives seeking shelter

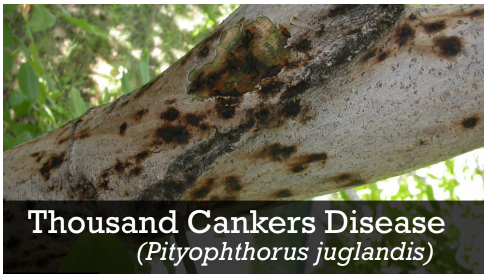
- Darkling Beetles
  - 1 inch long
- Pennsylvania Woods Roaches
  - 1/2 to 2 inches long
- Occasional Pests
- Spiders, woolyworm caterpillars and both mice and rats, snakes, etc.

Control and Prevention

- Remove logs from the forest or woods
- Split and dry rapidly
- Don’t use dead trees
- Never stack wood against buildings
- Store firewood outdoors in an open area
- Stack firewood off the ground
- Burn older wood first
- Try not to carry over large quantities of firewood from season to season
- Bring indoors as needed

Insecticides

- It is best not to treat firewood with any pesticide!
  - Burning any insecticide-treated firewood indoors could cause a potential health hazard due to the toxic chemical fumes released into the living space by the burning wood
- Spray treatments applied to the firewood will not kill woodborers within



Drying Firewood

- How Do I:
  - Get More BTU's per pound
  - Reduce creosote build up
  - Reduce insect infestations

http://nhfirewood.com

Drying Wood Also…..

- Reduce the total volume of firewood you will need
- Reduce the total amount of time you will spend collecting, hauling, and preparing will also be reduced

Impact of MC on BTU

- Freshly cut hardwoods often have a 75% MC
- For every pound of wood
  - 0.57 pounds of dry wood
  - 0.43 pounds of water
    - 0.57 pounds x 8,600 BTU/pound = 4,90BTU
    - Assuming a 50% efficiency that is 2,450 BTU per pound
- Air dry at 20% MC
  - 0.83 pounds of dry wood
  - 0.17 pounds of water
    - heat value is 7,200 BTU or 3,600 BTU at 50% eff.

Table 3. Moisture content and green and air-dried weight per cubic foot for some common Indiana woods.

Species	Moisture content	Weight per cubic foot of solid wood	
		Green	Air-dried[1]
	(%)	(lb.)	(lb.)
White Ash	45	49.8	36.2
Basswood	107	41.3	20.6
Beech	64	57.3	36.8
Cherry	58	46.3	30.6
Cottonwood	153	50.5	20.6
A. Elm	94	55.7	30.0
Hackberry	63	49.8	31.8
Hickory	61	64.3	42.4
Black Locust	40	57.6	43.7
Soft Maple	78	48.9	28.7
Sugar Maple	69	59.0	36.8
Red Oak	75	59.0	35.6
White Oak	71	64.0	39.3
Sweetgum	108	59.7	30.0
Sycamore	122	63.7	30.0
Walnut	82	57.9	33.7
Yellow Poplar	95	48.7	26.2

[1] 20% moisture content on an oven-dry basis

Drying Firewood

- Air drying is most common
  - Drying times will depend on:
    - your location
    - how you pile it
    - protection from rain and snow
    - How its split
      - Splitting wood will increase drying since there will be more exposed wood surface to the air
- For most locations it takes approximately 9-12 months to dry firewood from green to 20% moisture content

Hearth.com

How you stack it matters!

Reddit.com

Seasoning: Stacking Firewood

- A firewood stack:
  - located too far from the house will draw angered comments inversely proportional to the outside temperature!”
  - located too close to the house wil
    - cut down on circulation and increase mess and insect problems
    - present a fire hazard
    - Stacked firewood should be raised off the ground slightly to increase air circulation.
  - Under a shelter will reduce drying time by keeping outside moisture off the stack
    - Plastic sheeting shelters however need to have proper ventilation so that moisture can escape

Kiln Drying

- Steam, direct fired or indirect fired kilns
- Green firewood can be kiln dried from 52% to 20% in 30 hours using temperatures of 220F.
- Temperatures of 140 and 180 F require drying times of 260 and 90 hours respectively.

Seasoning: Stacking techniques

Get the wood off the ground

Expose it to sun and wind

Many different opinions on what the stack should look like

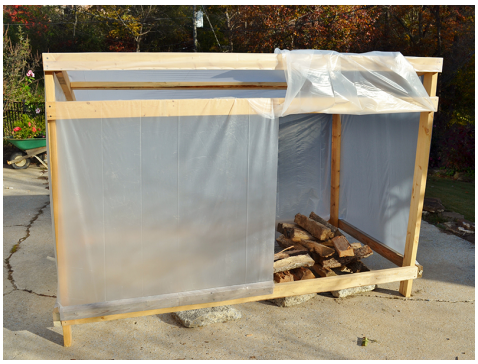
Seasoning: Cover the stack?

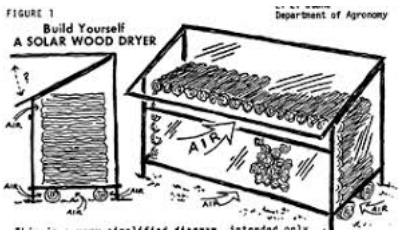
- Some people say that there is no need to cover, and they believe covers will inhibit drying of the top layer of wood
- Others say that the effect of rain on the stack is significant, so a cover is warranted
- If you are going to cover your stack, ensure that the cover does not hang over the side which can trap moisture and slow drying

Drying Firewood

- 120-day drying period in Alaska

Drying method	Initial moisture	Ending moisture
	Percent	
Polyethylene covered piles:		
Conventional stack	86	34
Tiers in alternate directions	89	33
Control pile	92	33
Whole trees	72	49



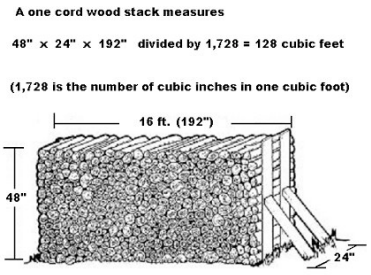


Firewood Measurements

- A truckload of firewood……

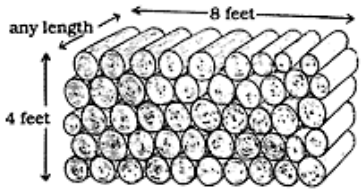
Firewood Measures

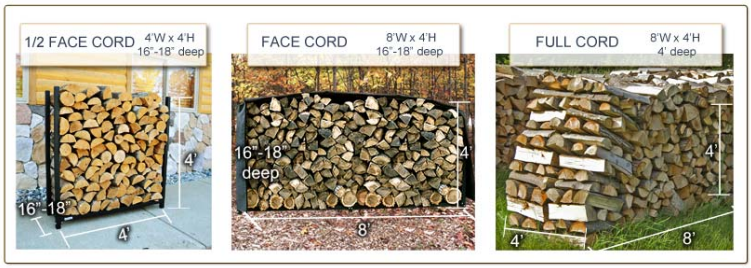
- Cord
- A standard cord of wood
  - The volume of stacked wood including air space occupying 128 cubic feet
  - Often defined as the volume of a stack of wood 4 feet high by 4 feet wide by 8 feet long



Face Cord of Short Cord

- A face cord is a stack of wood four feet high, eight feet long, and as deep as the pieces are long
- Pieces are commonly 12 to 18 inches long, so a face cord may contain 32 to 48 cubic feet of wood and air.





Variation?

- Cord
  - The actual solid content of wood in a cord may range from:
    - 60 to 110 cubic feet
    - 58 to 94 cubic feet
- Solid content of 80 cubic feet of solid wood per cord is often assumed for hardwoods three to eight inches in diameter
- Actual volume of wood can vary greatly depending on:
  - how tightly the wood is packed
  - the diameter of the pieces
  - the straightness of the piece

Weight per air dry cord and total heat content of different hardwoods

Species of wood	Weight per cord[1]	Total heat per cord (million Btu's)
Osage-orange	4,800	33.5
Black locust	4,200	29.3
Shagbark hickory	4,100	28.6
Ironwood	4,100	28.6
White or bur oak	3,800	26.5
Honey locust	3,800	26.5
Red or black oak	3,500	24.4
White ash	3,500	24.4
Mulberry	3,500	24.4
Hard maple	3,400	23.7
Green ash	3,300	23.0
Black walnut	3,200	22.3
Larch	3,200	22.3
Red elm	3,000	20.9
Sycamore	2,900	20.2
American elm	2,900	20.2
Black cherry	2,900	20.2
Silver maple	2,800	19.5
Boxelder	2,600	18.1
Alder	2,500	17.5
Cottonwood	2,300	16.1
Willow	2,300	16.1
Basswood	2,000	14.0

[1]Assumes a cord of wood contains 80 cu. ft of solid wood

Truck Load of Firewood

- Obviously, trucks vary in size and corresponding volume capacities
  - A "truck-load" is a vague term and depends upon the dealer's truck
  - Was the dealer's truck a standard sized long bed, a standard sized short bed, a small truck or a dump truck?
- Was the wood stacked or randomly loaded into the truck?
  - Another variable specification that will affect the volume capacity of a "truck-load" is the height to which that wood is stacked within the pickup bed.

Firewood Measures

- Face cord, rick, pile, truckload, etc. are not standardized
  - "truck load" of firewood may vary form a 1/5 cord in a short bed light pickup to 4 cords as in a pulpwood truck
  - Firewood capacity of different sized trucks varied from less than 1/5 cord to slightly +1/2 cord
  - Capacities were noticeably affected by how they were loaded

Firewood Measures

- Using volume figures obtained from the dimension of the trucks will, in most cases, tends to overestimate the capacity of the trucks

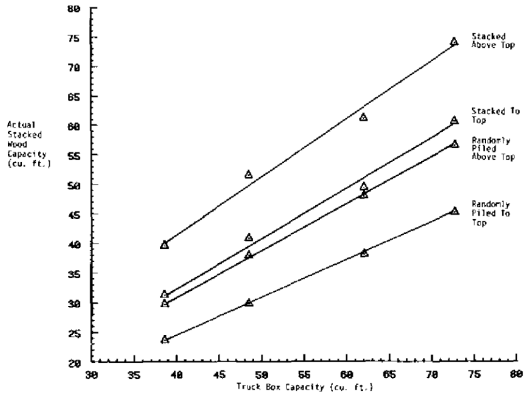
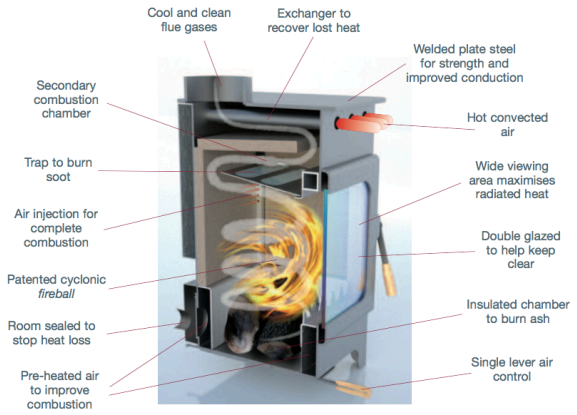


Figure 1. — Relationship between capacity of trucks and actual volume of wood.

Lets end with a little on efficiency



Fireplaces

- Least efficient
  - 10-15 %
  - Must draw in as much as 300 cubic feet per minute of heated room air for combustion but then send it straight up the chimney
- Limited ability to control a fire or to temperatures for combustion

Wood Stoves

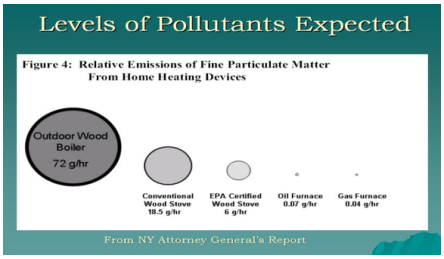
- **The modern wood stove**
- EPA is setting efficiency requirements
- 75 to 80 % efficient
- EPA's mandatory smoke emission limit for wood stoves
  - 7.5 grams of smoke per hour (g/h) for non-catalytic stoves
  - 4.1 g/h for catalytic stoves.
  - Some newer stoves have certified emissions in the 1 to 4 g/h range
- 30 to 40% more efficient than old stoves

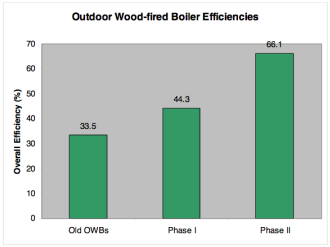
Indoor Boilers

- Outputs high enough to heat an entire house through forced air or radiator systems
  - Also provides household's hot water supply
- Highly efficient
- Meet EPA requirements
  - Reduced particulate and smoke

Outdoor Wood Boilers

- Located outdoors, heat water that is then circulated into the home through underground pipes.
- The heated water may be used directly or as a source of residential heating
- Employ very primitive combustion technology and are designed to burn wood at lower combustion temperatures and generally have shorter stacks
  - emit smoke closer to homes and neighborhoods





Masonry Stoves

- Masonry stoves have a small, powerful firebox and a large masonry mass
- 18 and 20 hours of radiant heat from a single fuel load.
- 80 to 95% efficient

Wood is the only fuel that heats twice ...
first when you cut and stack it, and again when you burn it!

www.CartoonStock.com