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Compare Costs of Different Fuels for Drying Lumber

PICMET ’11
International Conference

July 31-August 4, 2011
Portland, Oregon, USA

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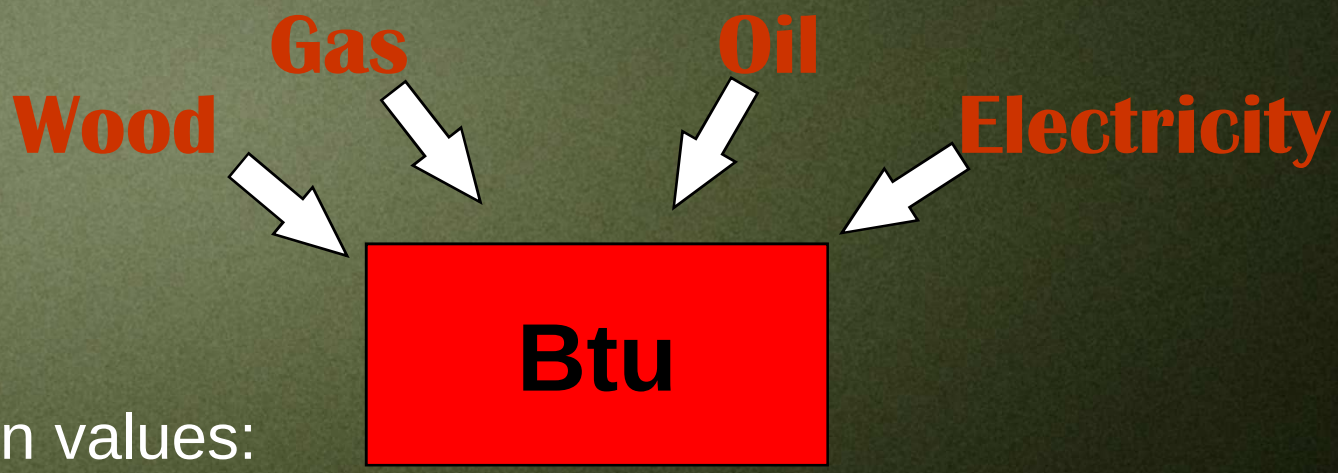
What the heck is a British Thermal Unit (Btu) and why do we care?

One Btu is the amount of energy needed to raise the temperature of one pound of water one degree Fahrenheit, and at sea level it takes 1,000 British thermal units of energy to evaporate 1 pound of water.

Different sources of energy, such as natural gas, electricity, propane and wood can be compared using their heat content. In the US, the most common measure of heat content is the British Thermal Unit (Btu).

Calculating Energy Use



Conversion values:

Unit of wood is 200 cu. ft.

= 1900 lbs. sawdust

= 2600 lbs. bark

(Dry lb. is ≅ 8,500 Btu's

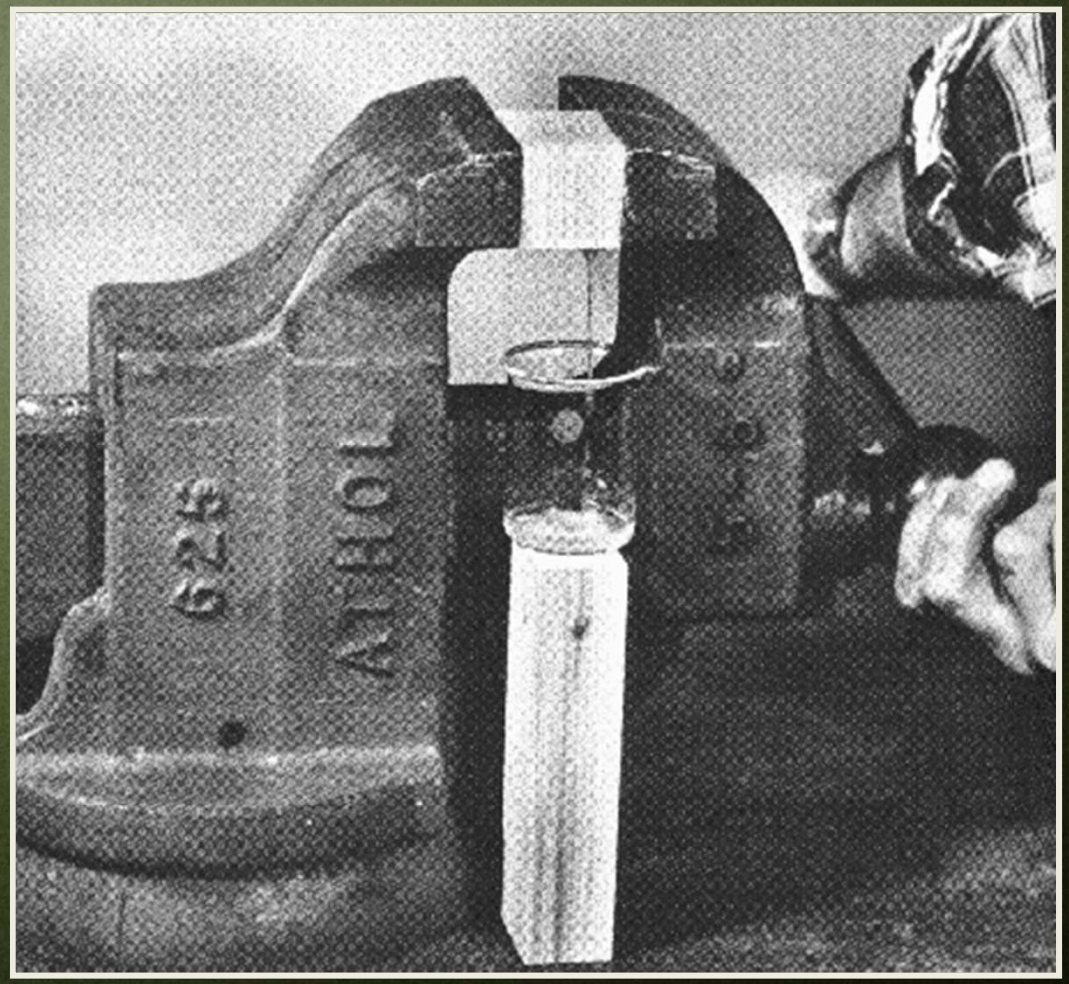
ranges from about 7,600-9,600 Btu's/lb)

Therm of gas is ≅ 100,000 Btu

Gallon of heating oil is ≅ 140,000 Btu's

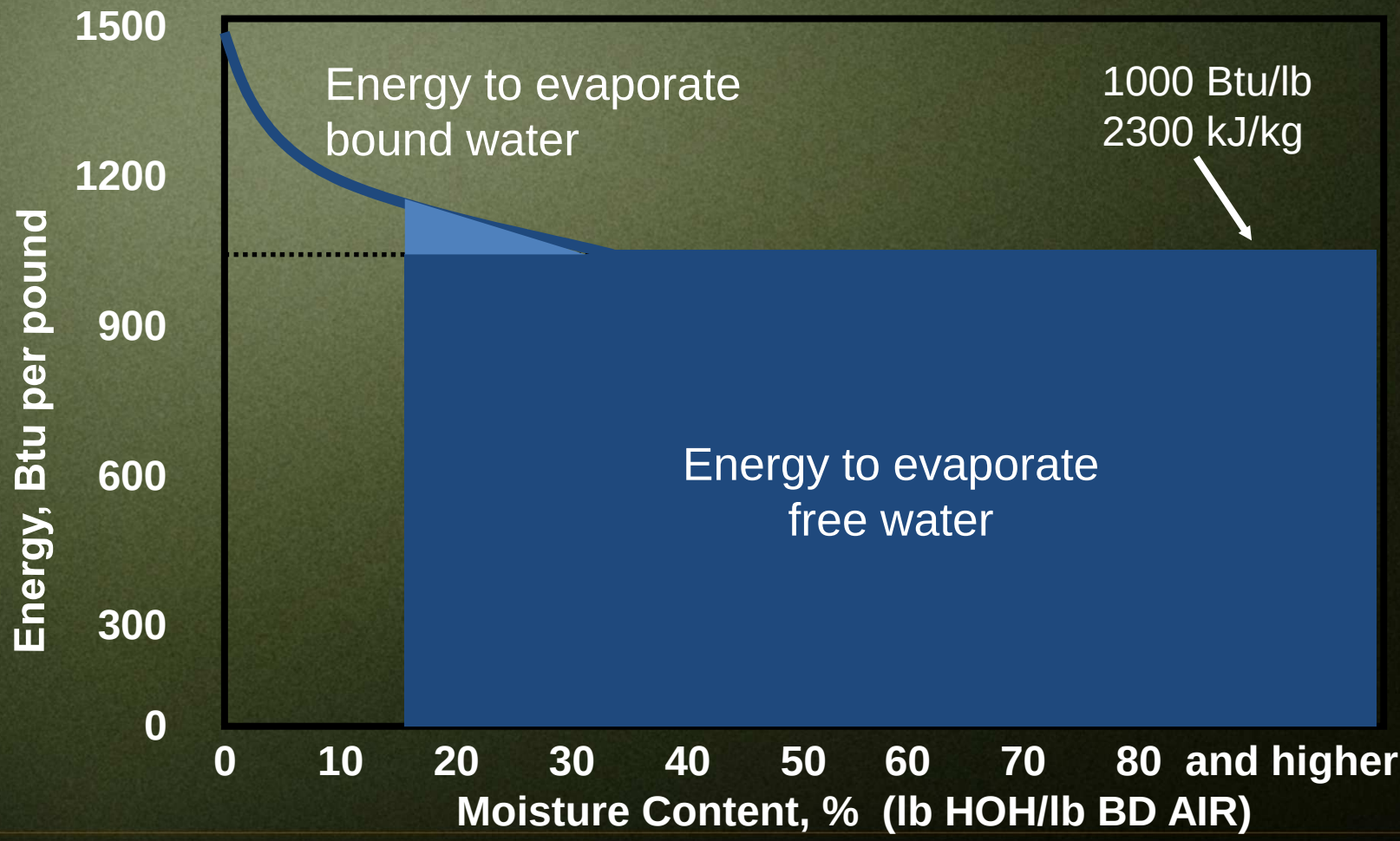
KWH of electricity is = 3,415 Btu's

Water and Wood



Source: Understanding Wood by Bruce Hoadley

RELATIVE ENERGY
80% to 15%



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IMPORTANT TO KNOW HOW TO CALCULATE ENERGY USE

- Must be able to determine the total energy use of all sources
- Must be able to determine how much water was removed from the wood

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FUEL VALUES FOR WOOD, GAS, OIL, AND ELECTRICITY FOR DRYING

	$/unit	$/MMBTU*
Wood	30	2.42
	40	3.22
	50	4.03
	$/therm	
Natural gas	0.5	6.43
	0.6	7.71
	1.05	13.50
	$/barrel	
No. 6 Heavy oil	75.00	14.43
	100.00	19.24
	$/KWH	
Electricity	.05	14.64
	.06	17.57
	.07	20.50

*The assumed combustion efficiencies of the three fuels are 61.2%, 77.8%, 82.5% and 100%, respectively. The wood fuel is at 45% MC (wet basis).

Energy for Drying Lumber

Natural Gas

- Easy to use
- Clean burning
- Lower capital cost
- Higher fuel cost
- >80% efficiency

Wood

- Must handle
- More emissions
- Higher initial cost
- Lower fuel cost
- 60-70% efficiency
- Availability

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Negative Effect of Moisture on Heating Value of Wood

Approximately, for every 1% increase in moisture content, starting at bone dry, there is a 1% decrease in heating value.

Example: if a piece of firewood has a heating value of 8,500 Btu's per pound at 0% moisture content (bone dry) then it will have an approximate heating value of only 1,700 Btu's per pound at 80% moisture content.

Species effect – high density woods have higher heating value than low density woods.

Dry wood cell wall material weighs ~95 lbs/cu ft

Dry wood weighs ~12 - 85 lbs/cu ft

Extremes:

Balsawood (Ochroma pyramidale) sp gravity 0.19 ≅ 12 lbs/cu ft

Lignum vitae (Guaiacum sanctum) sp gravity 1.37 ≅ 85 lbs/cu ft

Energy From Burning Wood

Wood Moisture Content (%)	HHV[1] (Btu's/lb)
0	8750
20	7000
50	4375
80	1750

[1]High heating value – approximate values, for example at oven-dry, HHV ranges from about 7600-9600 Btu's/lb

Energy Use for Drying Lumber

	MC (%)		Energy Use	
	Initial	Final	Btu's/lb of Water[1] Evaporated	MMBtu's/MBF
Doug-fir	45	15	2,000-3,000	1.2-1.8
S. pine	100	12	1,600-2,200	3.0-4.0
Red oak	80	6	3,000+	6.4+

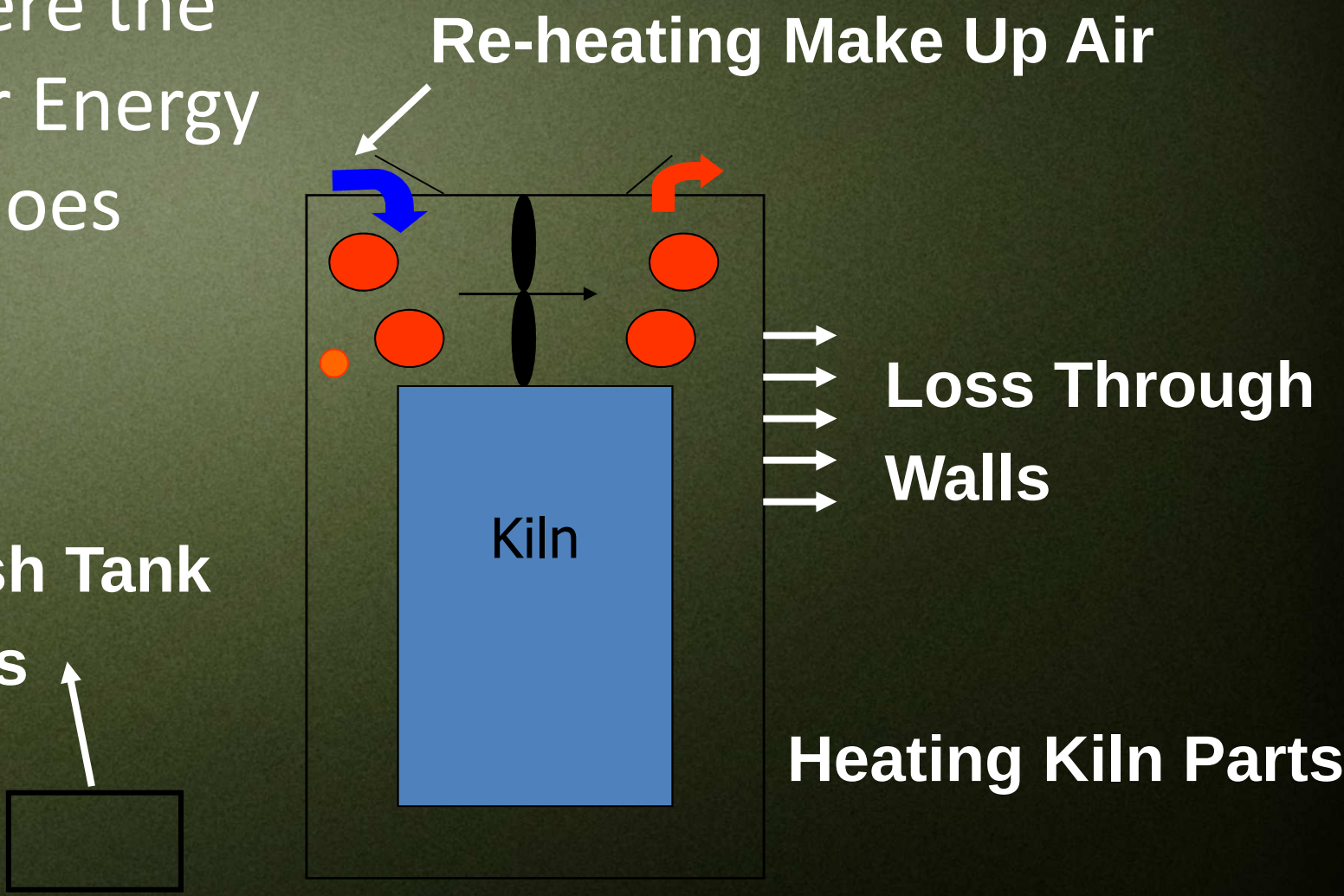
[1]Note: 1,000 Btu's is theoretical value of energy to evaporate 1 lb HOH.

Wood-Related Energy Use

- Heat Wood
- Heat Water in Wood
- Heat of Wetting (energy to break chemical bounds)
- Evaporate Water from Wood Surface

- Maybe 50% or a bit more is used to actually dry the wood! What is the rest of the energy doing?

Where the Other Energy Goes



Use About 50% For Efficiency Because 50% Was Used for Drying and 50% for Other

Energy = Water Evaporated (lb's) X 2000 Btu's/lb = # of Btu's

Typical

- Softwoods – 1800 to 2500 Btu's/lb
- Hardwoods – 4000 Btu's/lb +

Minimize Energy Use

- Air dry before kiln dry
- Keep rain and snow off the lumber
- Reduce fan speed
- Dry to higher MC
- Higher temperature
- Vent less
- Avoid steam spray
- Maintain traps
- Fix steam leaks
- Insulate pipes
- Minimize time between charges

Steps to Approximate Cost of Drying Lumber

- Calculate the amount of water evaporated
- Use estimate of 2,000 Btu's/lb. water evaporated for most NW conifers
- Calculate or use attached table to determine the cost of energy using $/MMBtu for fuel source used

Drying cost = (lb. water evaporated) x
(2,000 Btu's/lb.) x (energy cost $/MMBtu)

Energy Drying Costs - Example

100,000 bf of western red cedar Avg SG_{grn} = 0.31

MC1 = 80% MC2 = 15% m1 = 0.80 lbs HOH/lb BDair
m2 = 0.15 lbs HOH/lb BDair

Estimate: 1 ft^3 = 14 bf

Drying Cost = lb HOH evaporated X 2,000 Btu/lb HOH evaporated X Energy Cost $/MM Btu

Weight of HOH evaporated (lbs) = SG X $\frac{62.4 \text{ lbs}}{ft^3}$ X $\frac{1 \ ft^3}{14 \text{ bf}}$ X (0.80 – 0.15) X 100,000 bf =

= 89,811 lbs of HOH evaporated

Btu needed = 89,811 lbs HOH X 2,000 Btu/lb HOH X $\frac{\text{Energy Cost \$}}{1{,}000{,}000{,}000 \text{ Btu}}$ = 179.62 MM Btu's

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Energy Drying Costs (continued)

Dry a 100 mbf of western red cedar from 80% to 15% MC

Drying costs = 89,811 lbs HOH X $\frac{2{,}000\ \text{BTU}}{\text{lb HOH}}$ X $\frac{\text{Energy Cost \$}}{\text{MM BTU}}$ =

= 179.62 MM BTU X $/MM BTU

If dry 100,000,000 bf per year, what would the annual cost be?

Cost to dry 100 mmbf

	$/MM BTU		MM Btu		Annual Cost
Wood	4.03	X	179.62	= ~$ 724	$ 724,000
Natural gas	13.50	X	179.62	= ~$2,425	$2,425,000
Oil	19.24	X	179.62	= ~$3,456	$3,455,000
Electricity	20.50	X	179.62	= ~$3,682	$3,682,000

Other considerations:
Initial cost of wood boiler is greater
Wood has to be handled and stored on site – operating costs are greater
Wood is usually available so might actually be “free” or low cost (have to ignore opportunity costs if you think its free!)

Depreciation, upkeep, etc. are costs not accounted for in this example – upkeep is greater for a wood-fired boiler.

SUMMARY: REDUCING THE COST OF DRYING LUMBER

- Need to realize importance of knowing the true drying cost for lumber
- Need to examine means of reducing drying costs
- Need to reduce energy consumption—electricity, natural gas, oil, and hogged fuel

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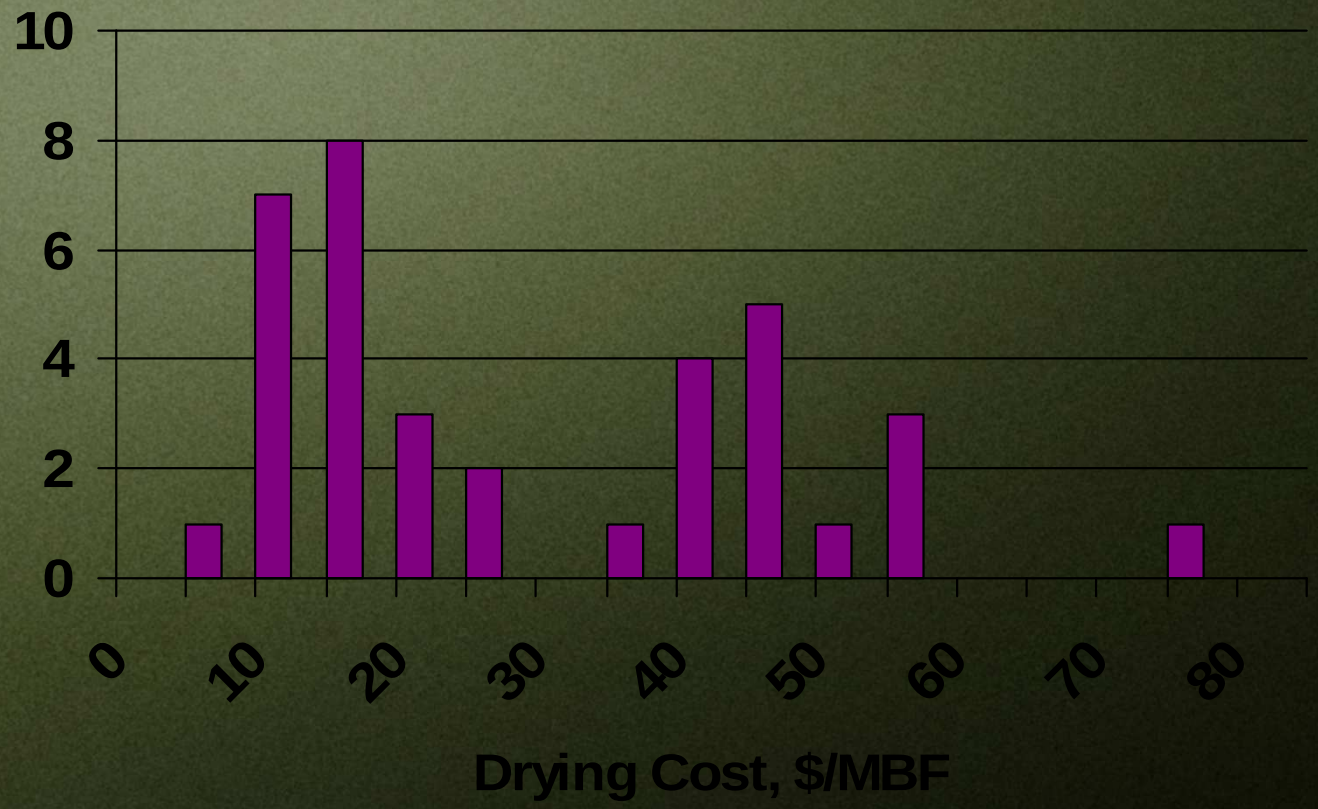
DRYING COST FOR SOFTWOOD LUMBER

Survey of Lumber Drying Participants

(11 participants didn't know their drying cost)



Dr. Jim Wilson, Oregon State University, CORRIM

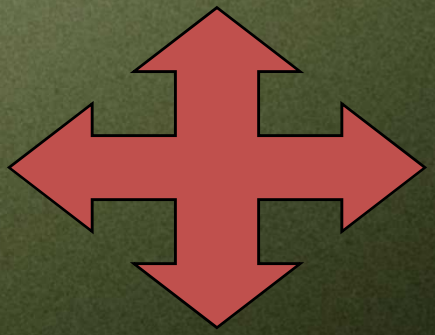
DRYING COSTS INCLUDE

- Energy Use
- Capital
- Maintenance and Repair
- Insurance
- Labor
- Permits
- Environmental
- Overhead
- Lumber Degrade

FACTORS AFFECTING THE COST OF DRYING

Operator

Kiln Schedule



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DETERMINING DRYING COST

Example: Drying cost of 2x4 hem-fir with new equipment

Operating Conditions

Kiln capacity (MBF)	**180**
Operating days per year (days)	**340**
Kiln residence time (days)	**2.5**
Annual kiln throughput (MBF)	**24,480**

Capital cost	**$572,000**

DRYING COST OF 2X4 HEM-FIR WITH NEW EQUIPMENT

Annual Cost and Expenses

Annual cost and expenses	
Electrical power	69,693
Steam (from wood-fired boiler)	455,000
Depreciation (straight-line)	57,200
Interest	25,370
Sticker replacement	21,630
Maintenance, supplies, office o/h	3l,930
Labor (includes all payroll expenses)	86,560
Total annual operating cost	$747,383

DRYING COST OF 2X4 HEM-FIR WITH NEW EQUIPMENT

$$\$ \text{ per MBF} = \frac{\text{Total annual operating cost (\$)}}{\text{Annual kiln throughput (MBF)}}$$

$$= \frac{\$747{,}383}{24{,}480 \text{ MBF}} = \$30.53/\text{MBF}$$

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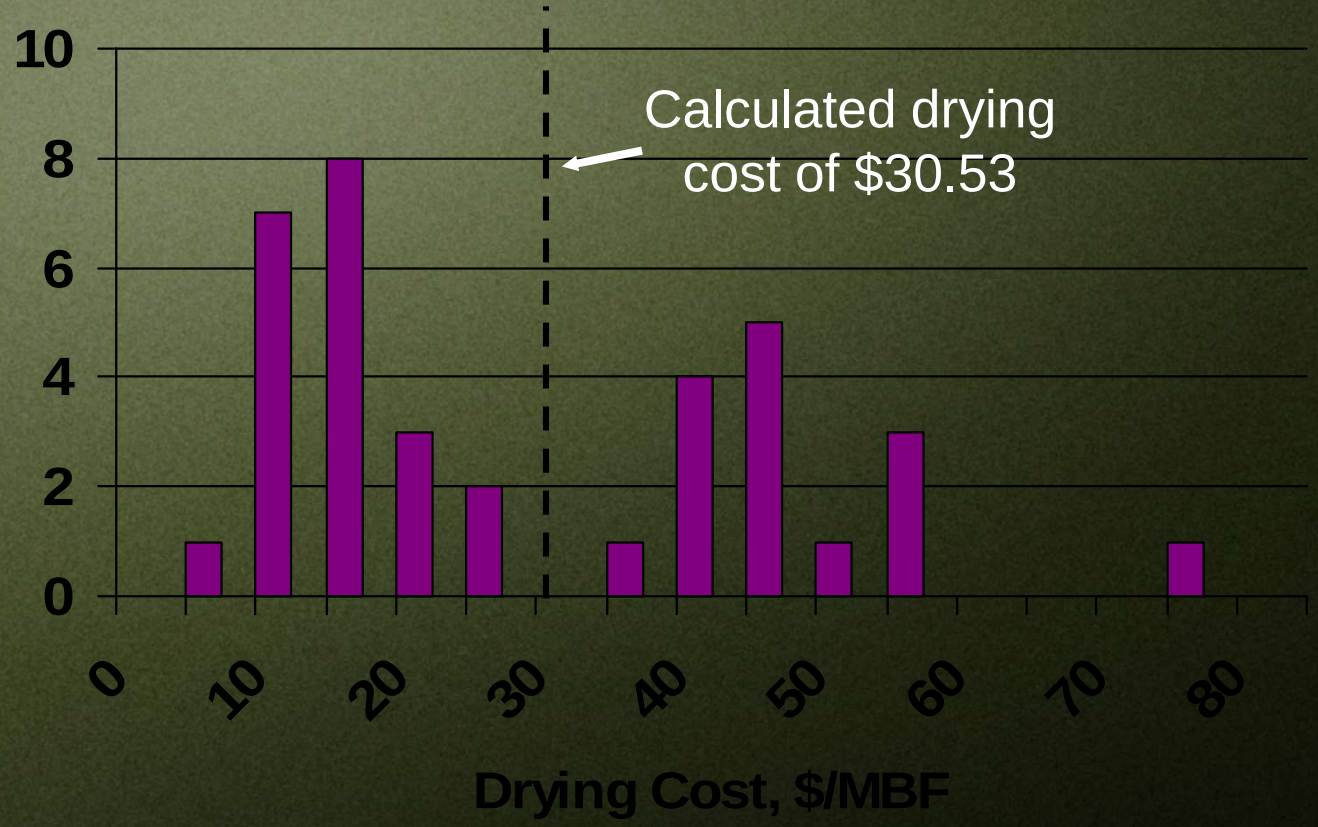
DRYING COST FOR SOFTWOOD LUMBER

Survey of Lumber Drying Participants

(11 participants didn't know their drying cost)



NOTES ON DRYING CALCULATIONS

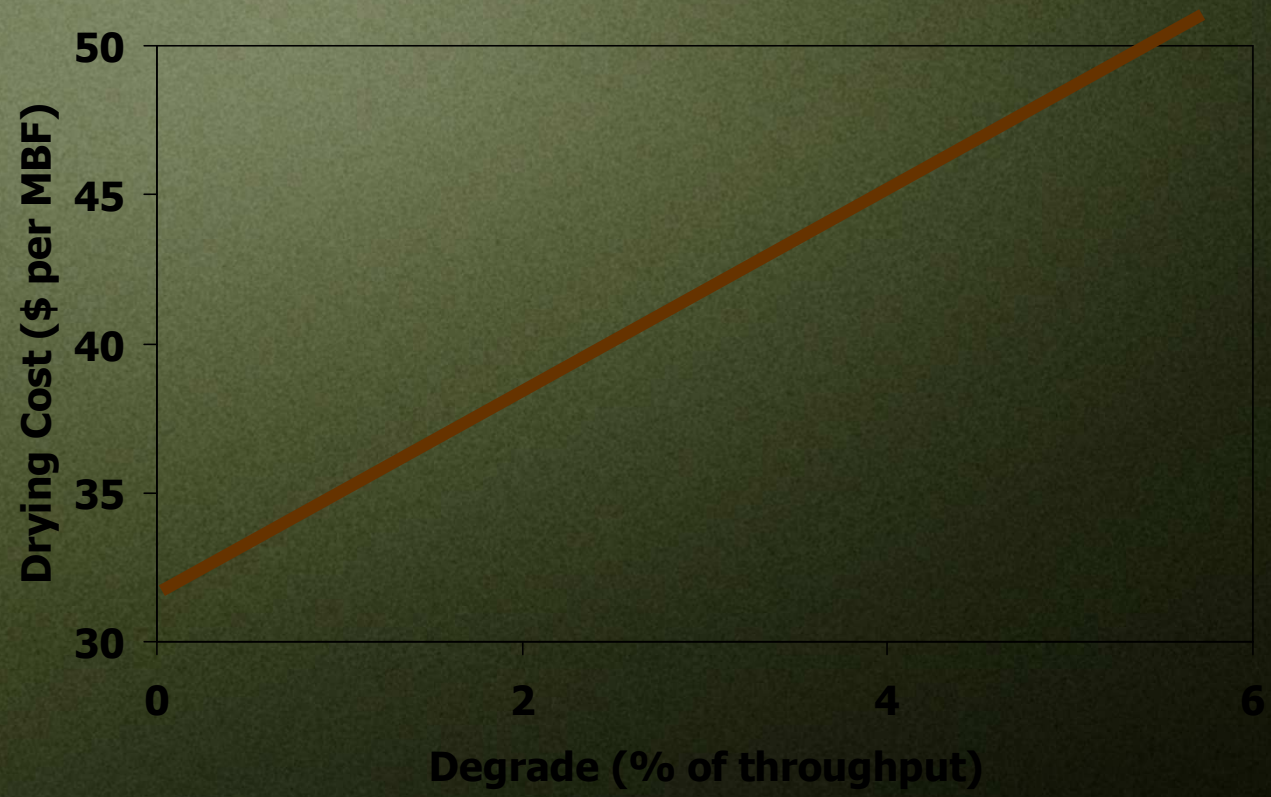
- The steam cost was determined based on a cost of $13 per 1,000 pounds, which reflects the true cost for operating a new boiler. If fully depreciated, older boiler is used to supply steam and the cost would be $5 to $10 per 1,000 pounds of steam.

- Calculated by assuming project financed with borrowed funds at the rate of 8.5%.

- Cost ignores degrade value and tax shield which would be equal to the product of tax rate (45%) and the sum of the annual depreciation and interest charges.

THE AMOUNT OF DEGRADE WILL AFFECT THE DRYING COST

Based on a 2x4 hem-fir price of $326/MBF



SUMMARY:
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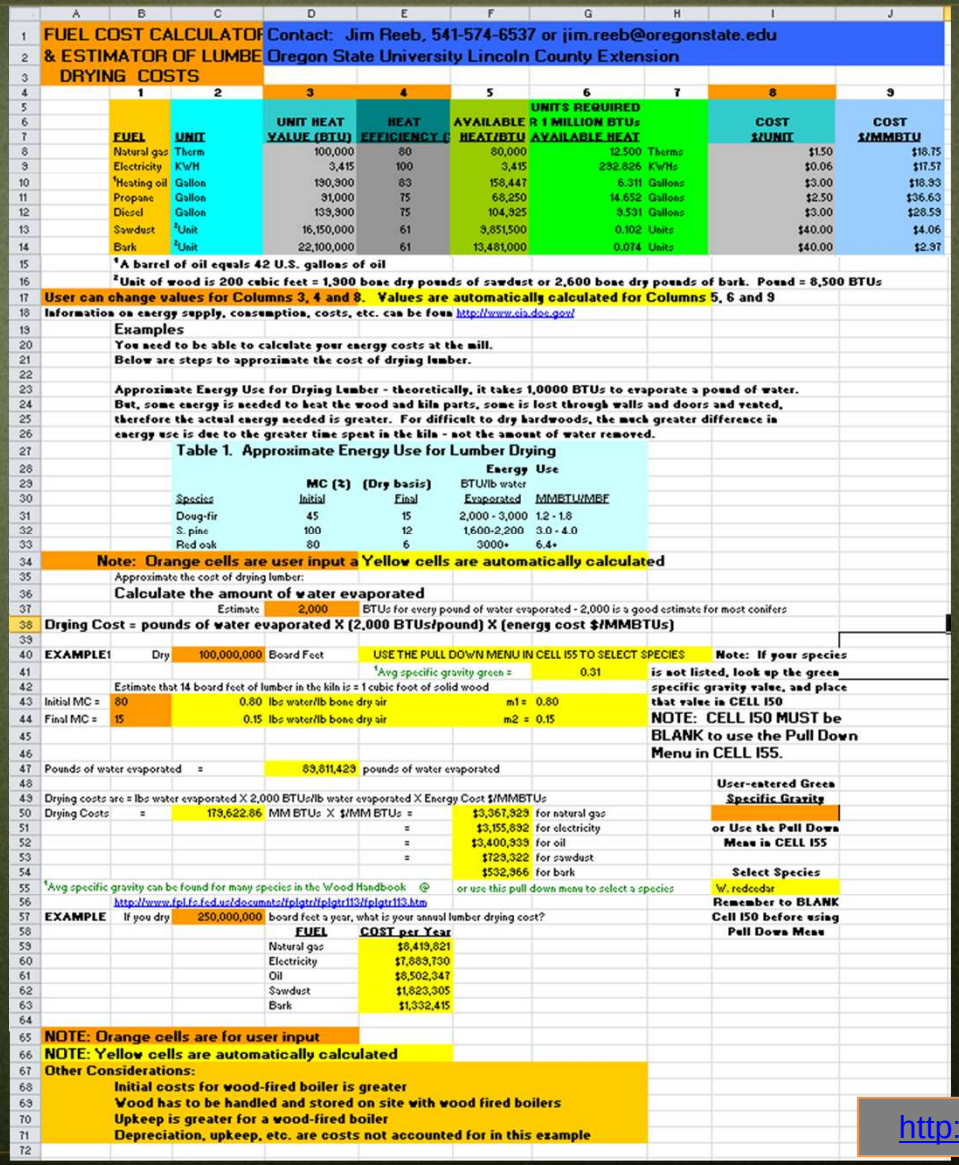

FUEL COST CALCULATOR & ESTIMATOR OF LUMBER DRYING COSTS

Contact: Jim Reeb, 541-574-6537 or jim.reeb@oregonstate.edu
Oregon State University Lincoln County Extension

	1	2	3	4	5	6	7	8	9
	FUEL	UNIT	UNIT HEAT VALUE (BTU)	HEAT EFFICIENCY (	AVAILABLE HEAT/BTU	UNITS REQUIRED FOR 1 MILLION BTUs AVAILABLE HEAT		COST $/UNIT	COST $/MMBTU
	Natural gas	Therm	100,000	80	80,000	12.500	Therms	$1.50	$18.75
	Electricity	KWH	3,415	100	3,415	292.826	KWHs	$0.06	$17.57
	[1]Heating oil	Gallon	130,300	83	158,447	6.311	Gallons	$3.00	$18.93
	Propane	Gallon	91,000	75	68,250	14.652	Gallons	$2.50	$36.63
	Diesel	Gallon	133,900	75	104,925	9.531	Gallons	$3.00	$28.59
	Sawdust	[2]Unit	16,150,000	61	9,851,500	0.102	Units	$40.00	$4.06
	Bark	[2]Unit	22,100,000	61	13,481,000	0.074	Units	$40.00	$2.97

[1]A barrel of oil equals 42 U.S. gallons of oil

[2]Unit of wood is 200 cubic feet = 1,300 bone dry pounds of sawdust or 2,600 bone dry pounds of bark. Pound = 8,500 BTUs

User can change values for Columns 3, 4 and 8. Values are automatically calculated for Columns 5, 6 and 9

Information on energy supply, consumption, costs, etc. can be foun http://www.eia.doe.gov/

Examples

You need to be able to calculate your energy costs at the mill.
Below are steps to approximate the cost of drying lumber.

Approximate Energy Use for Drying Lumber - theoretically, it takes 1,0000 BTUs to evaporate a pound of water. But, some energy is needed to heat the wood and kiln parts, some is lost through walls and doors and vented, therefore the actual energy needed is greater. For difficult to dry hardwoods, the much greater difference in energy use is due to the greater time spent in the kiln - not the amount of water removed.

Table 1. Approximate Energy Use for Lumber Drying

Species	MC (%) (Dry basis) Initial	Final	Energy Use BTU/lb water Evaporated	MMBTU/MBF
Doug-fir	45	15	2,000 - 3,000	1.2 - 1.8
S. pine	100	12	1,600-2,200	3.0 - 4.0
Red oak	80	6	3000+	6.4+

Note: Orange cells are user input a Yellow cells are automatically calculated

Approximate the cost of drying lumber:

Calculate the amount of water evaporated

Estimate 2,000 BTUs for every pound of water evaporated - 2,000 is a good estimate for most conifers

Drying Cost = pounds of water evaporated X (2,000 BTUs/pound) X (energy cost $/MMBTUs)

EXAMPLE1 Dry 100,000,000 Board Feet — USE THE PULL DOWN MENU IN CELL I55 TO SELECT SPECIES — Note: If your species is not listed, look up the green specific gravity value, and place that value in CELL I50

[1]Avg specific gravity green = 0.31

Estimate that 14 board feet of lumber in the kiln is = 1 cubic foot of solid wood

Initial MC = 80 0.80 lbs water/lb bone dry air m1 = 0.80

Final MC = 15 0.15 lbs water/lb bone dry air m2 = 0.15

NOTE: CELL I50 MUST be BLANK to use the Pull Down Menu in CELL I55.

Pounds of water evaporated = 89,811,429 pounds of water evaporated

Drying costs are = lbs water evaporated X 2,000 BTUs/lb water evaporated X Energy Cost $/MMBTUs

Drying Costs =	179,622.86	MM BTUs X $/MM BTUs =	$3,367,929	for natural gas
		=	$3,155,892	for electricity
		=	$3,400,933	for oil
		=	$729,322	for sawdust
		=	$532,366	for bark

User-entered Green Specific Gravity

or Use the Pull Down Menu in CELL I55

Select Species

W. redcedar

Remember to BLANK Cell I50 before using Pull Down Menu

[1]Avg specific gravity can be found for many species in the Wood Handbook @ http://www.fpl.fs.fed.us/documnts/fplgtr/fplgtr113/fplgtr113.htm or use this pull down menu to select a species

EXAMPLE If you dry 250,000,000 board feet a year, what is your annual lumber drying cost?

FUEL	COST per Year
Natural gas	$8,419,821
Electricity	$7,889,730
Oil	$8,502,347
Sawdust	$1,823,305
Bark	$1,332,415

NOTE: Orange cells are for user input

NOTE: Yellow cells are automatically calculated

Other Considerations:

Initial costs for wood-fired boiler is greater
Wood has to be handled and stored on site with wood fired boilers
Upkeep is greater for a wood-fired boiler
Depreciation, upkeep, etc. are costs not accounted for in this example

Fuel Cost Calculator & Estimator of Lumber Drying Costs

http://extension.oregonstate.edu/lincoln/forestry/wood-industry

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References:

Dry Kiln Operator's Manual
http://www.treesearch.fs.fed.us/pubs/7164

U.S. Energy Information Administration
http://www.eia.doe.gov/

Wood Handbook: Wood As An Engineering Material
http://www.treesearch.fs.fed.us/pubs/5734