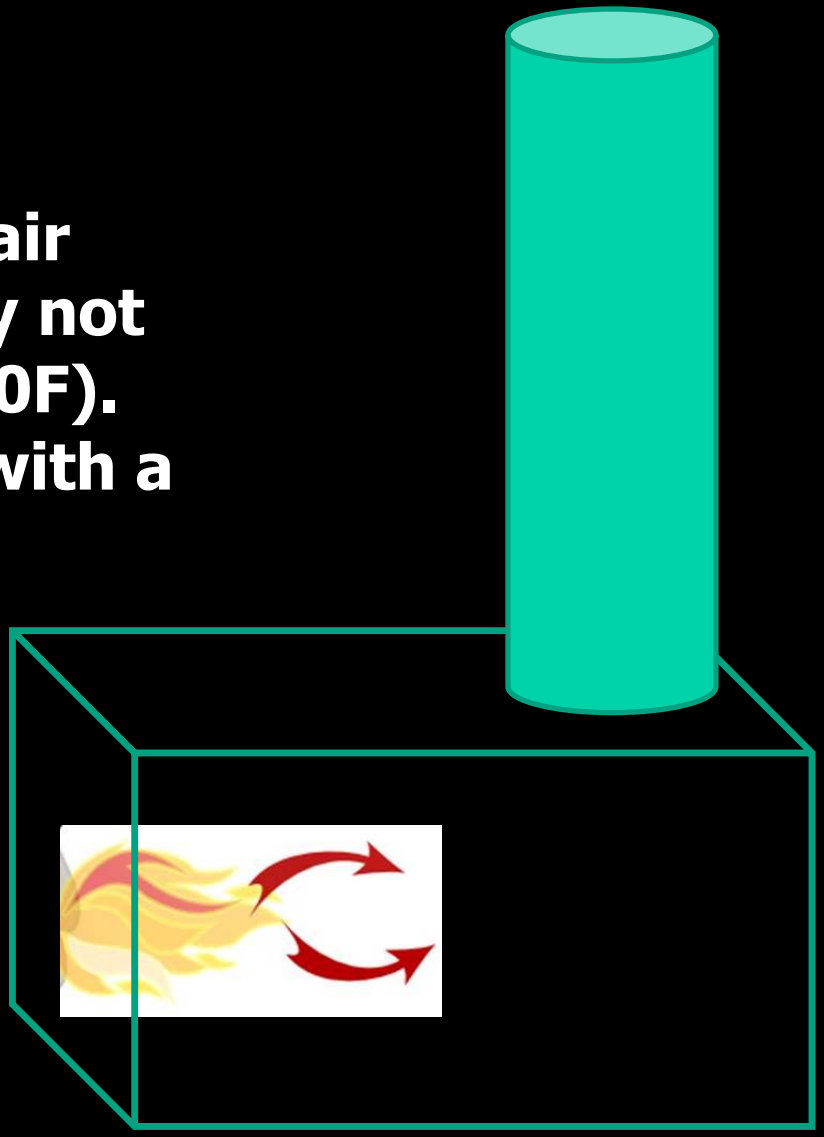
Small Heating Systems

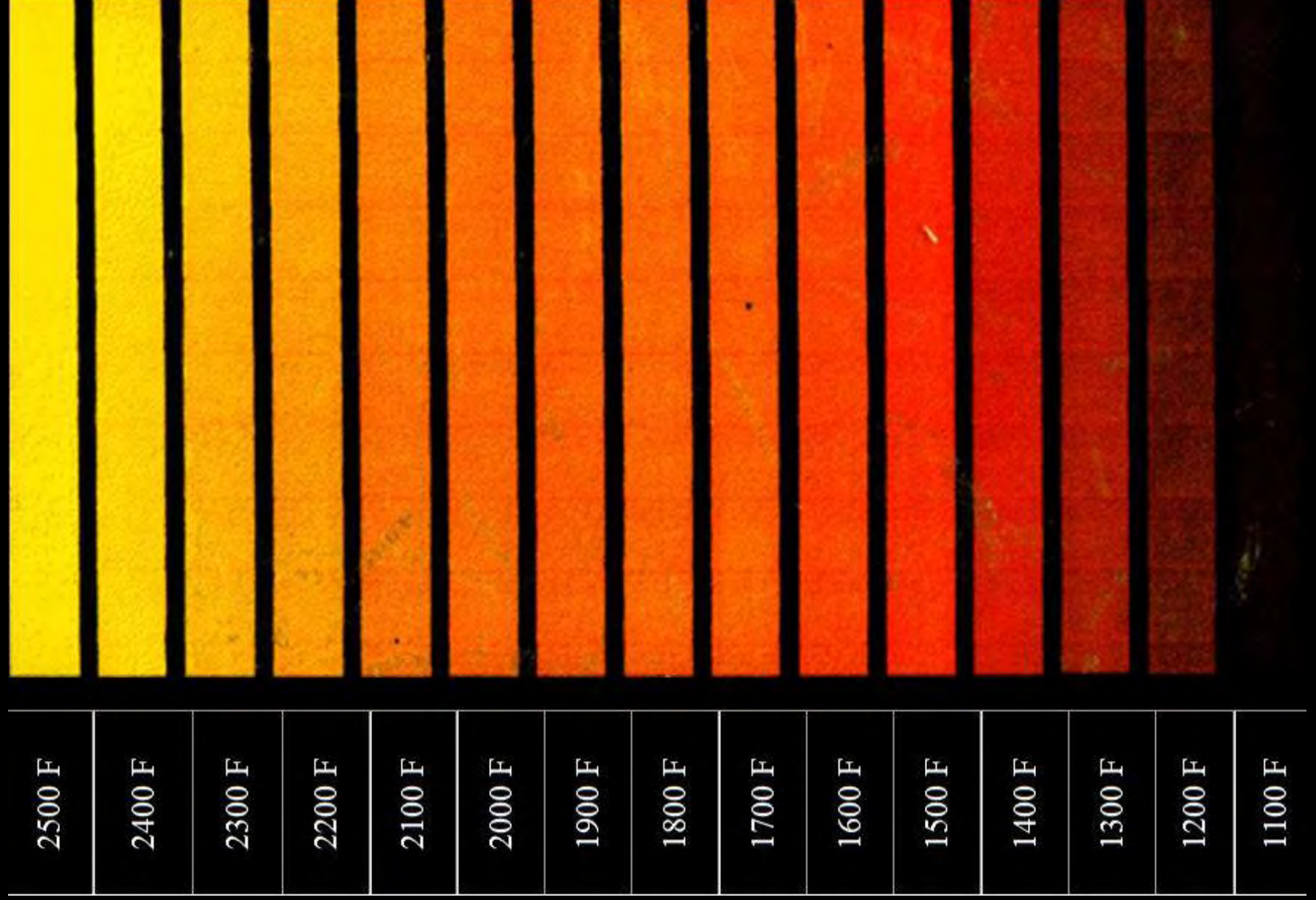
What it takes to burn well

1) The most common problem is getting more fuel started than you have air and heat to finish.

2) Even if you have enough air (no smoke) you are probably not hot enough to burn CO (1500F). High heat is less necessary with a catalytic converter.

The goal is that at some point to be between 1500F and 2300F with sufficient oxygen.

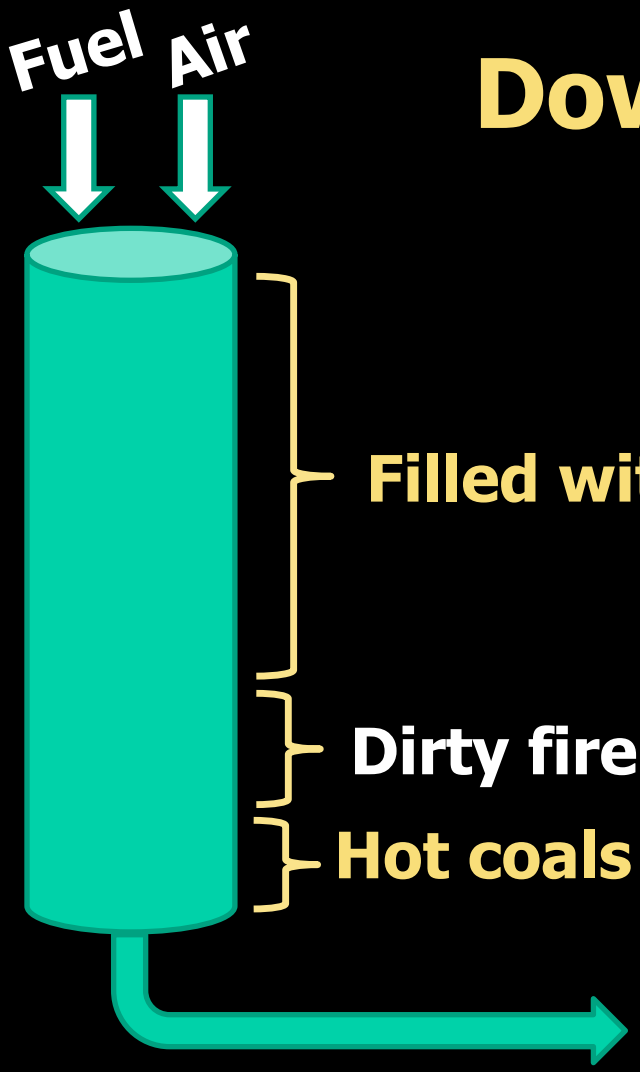




http://www.blksmth.com/heat_colors.htm

Down draft gasifier

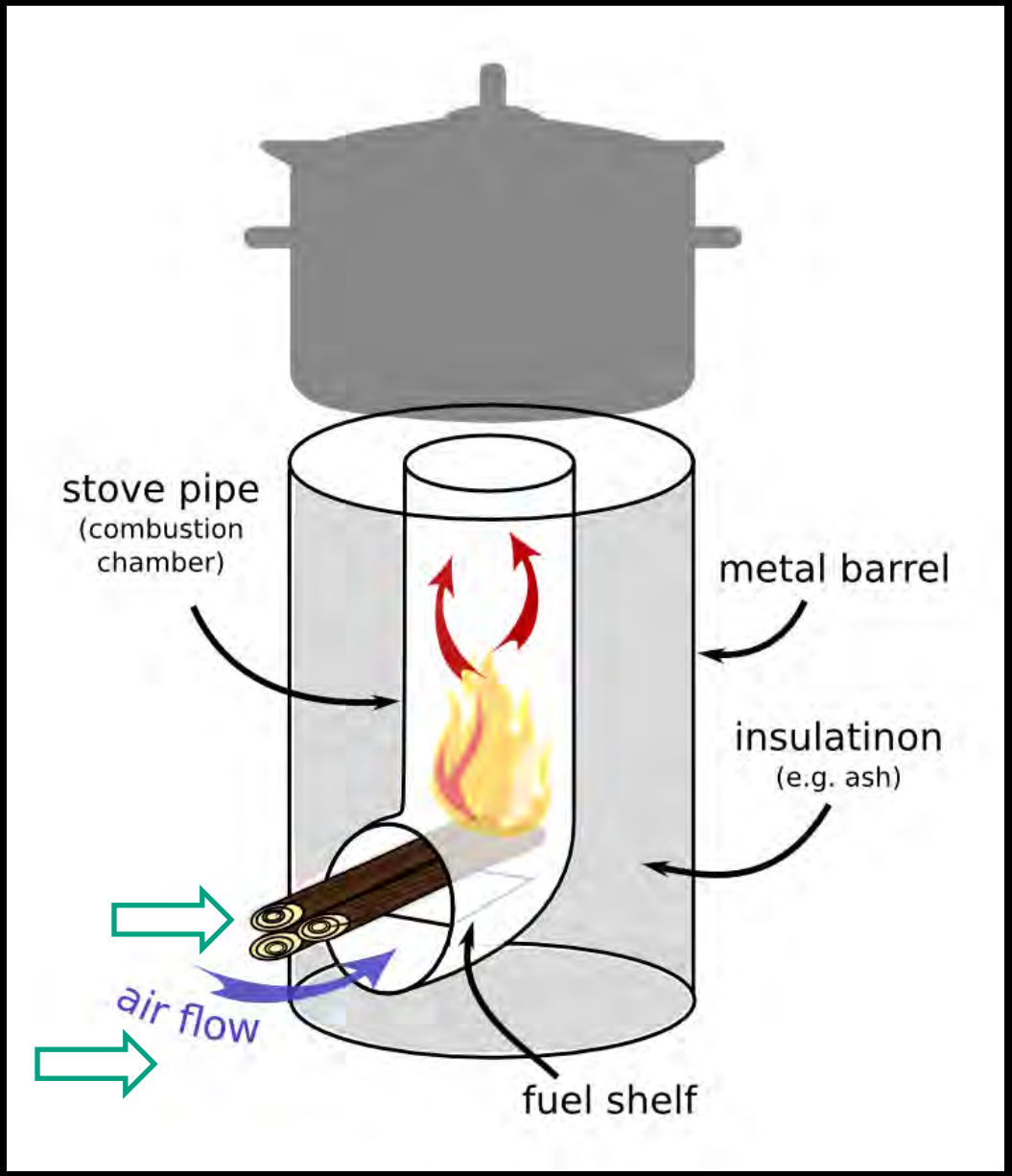
(Co-current)



Burn gas in IC engine, furnace or boiler (need 1500F)

CO_2 H_2O

Rocket Stove



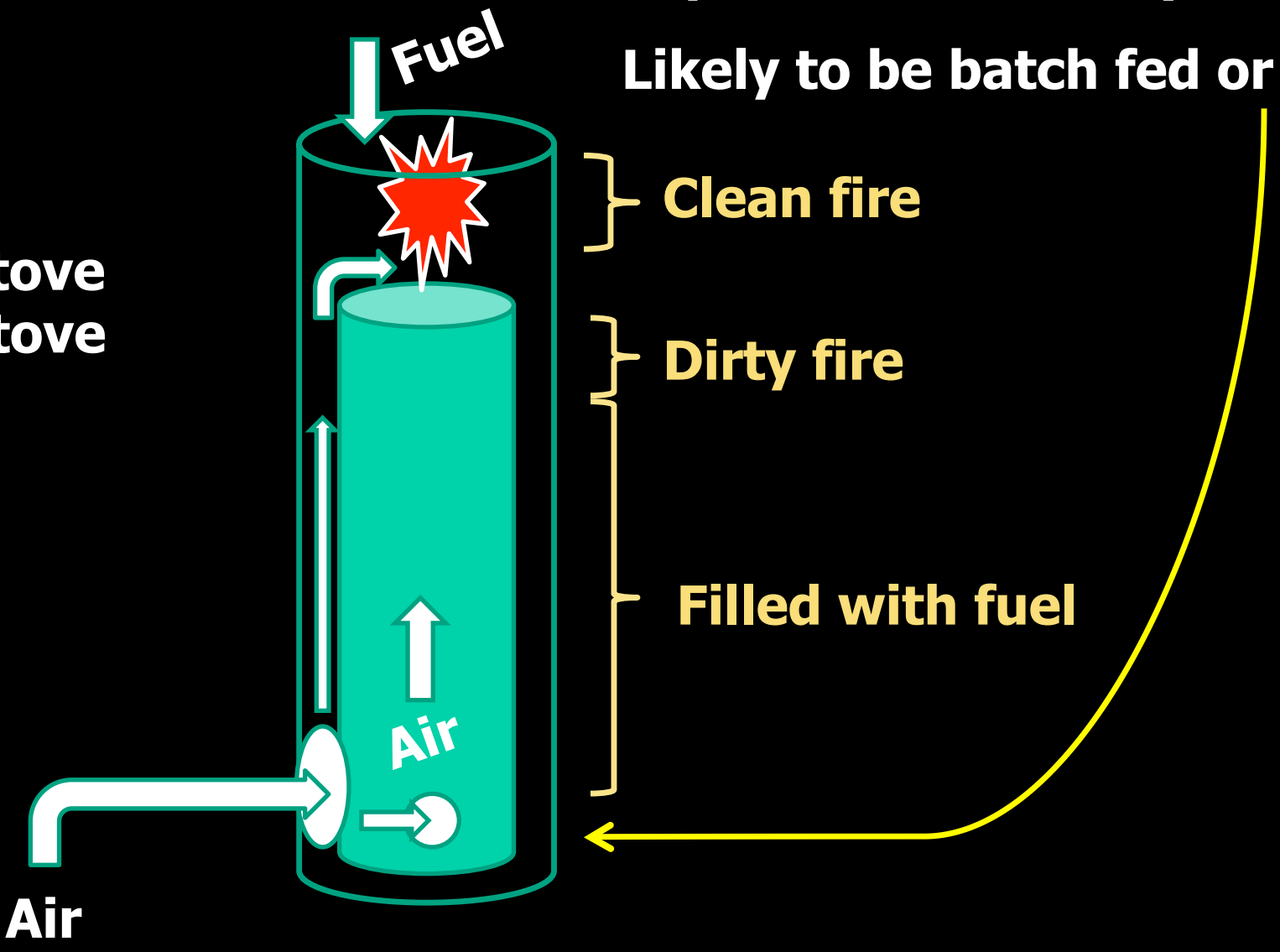
Similar to a down draft gasifier

Fuel and air from same end.

(Co-current)

Up draft gasifier

(Counter-current; fuel from top air from bottom)



Easier to make harder to burn clean

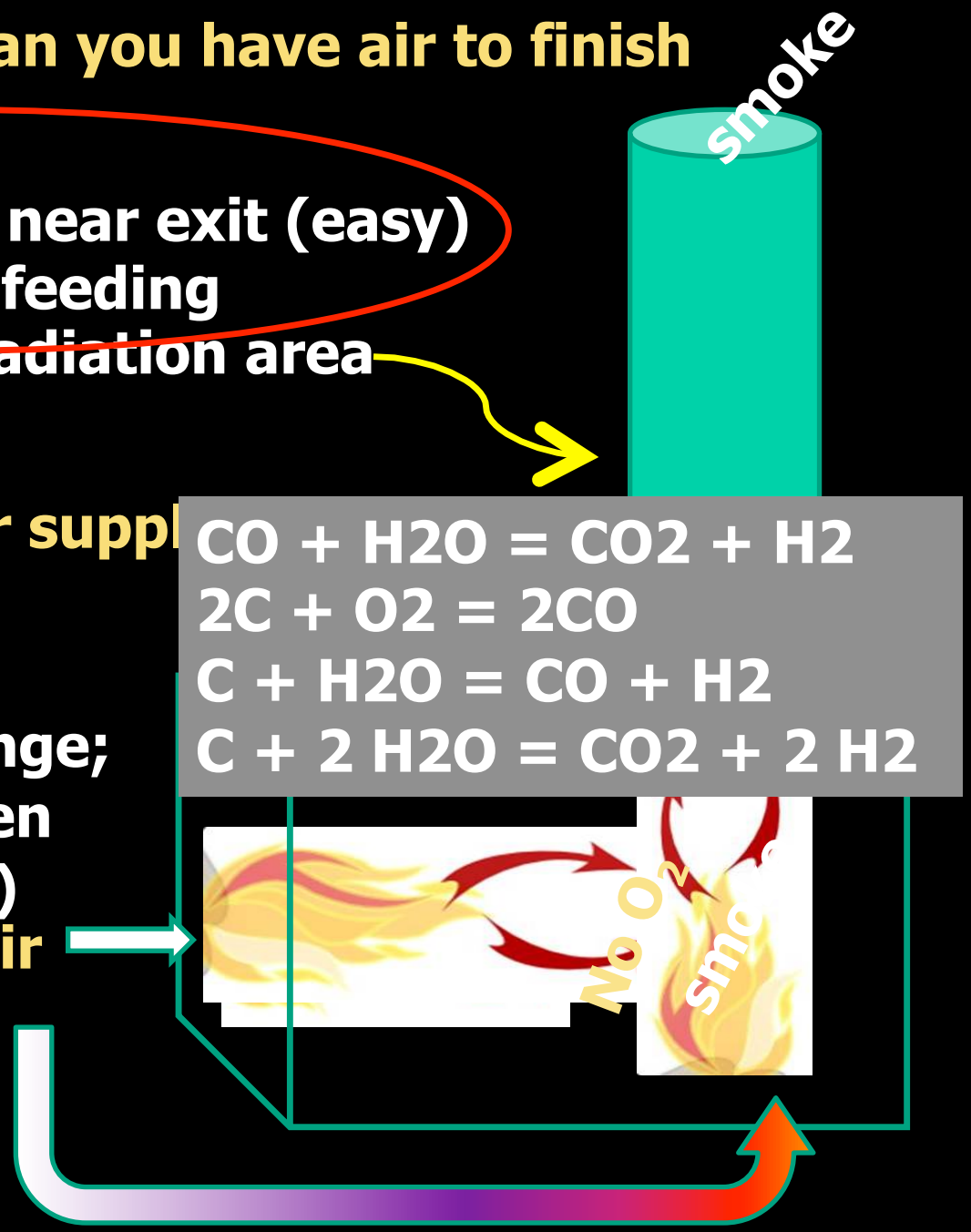
Q) more fuel started than you have air to finish

A) Light on top and/or near exit (easy)
Push when feeding
Might have to add radiation area

OR

A) Add secondary air supp

Difficult to control as burning conditions change; original design fine when flames done (just coals)

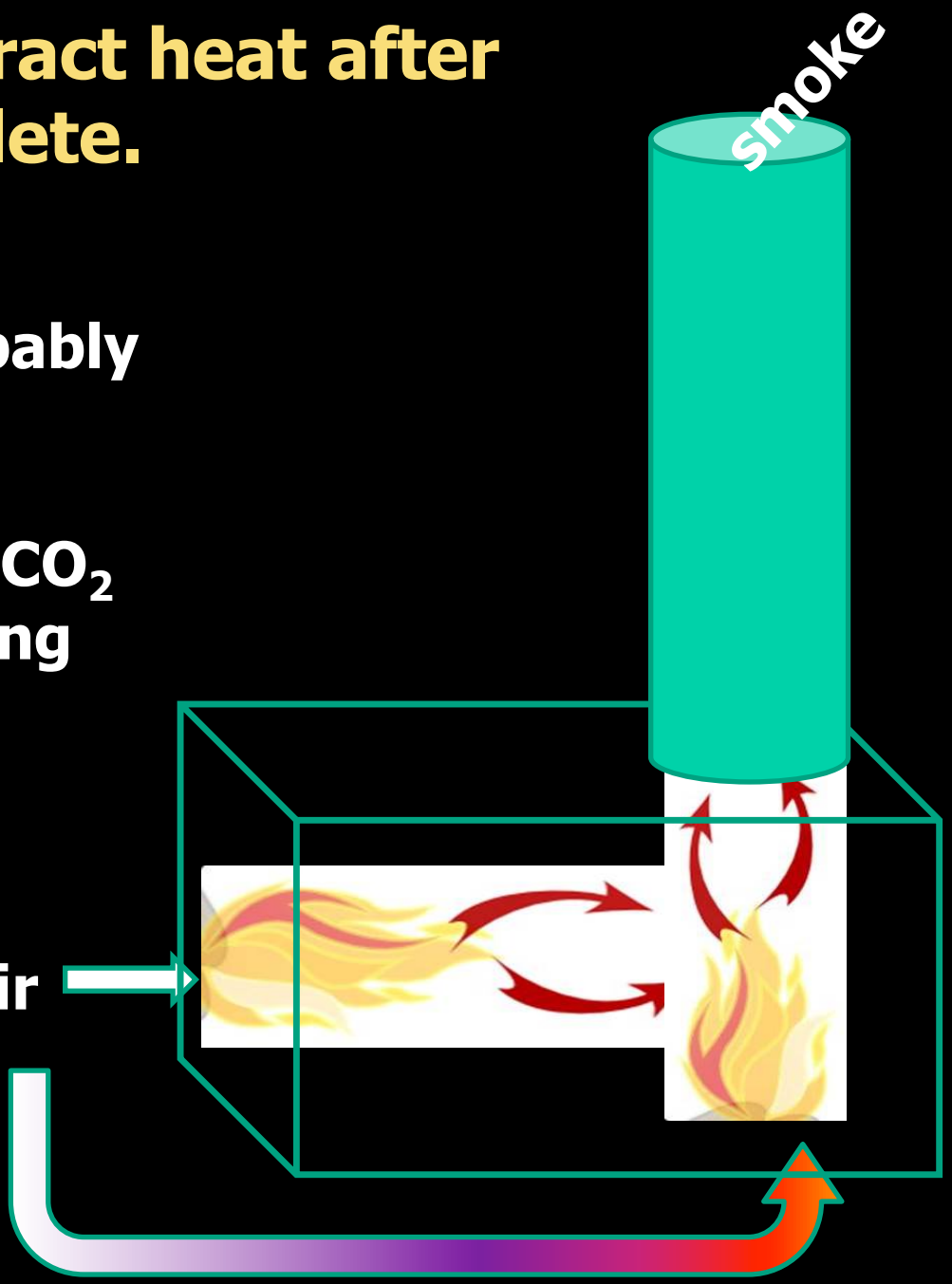


In all cases only extract heat after combustion is complete.

In fact insulation is probably necessary!

If the only products are CO_2 and H_2O, then condensing water is possible

A jet of air makes it look like a good fire, but blows ash particulates up chimney.



Startup

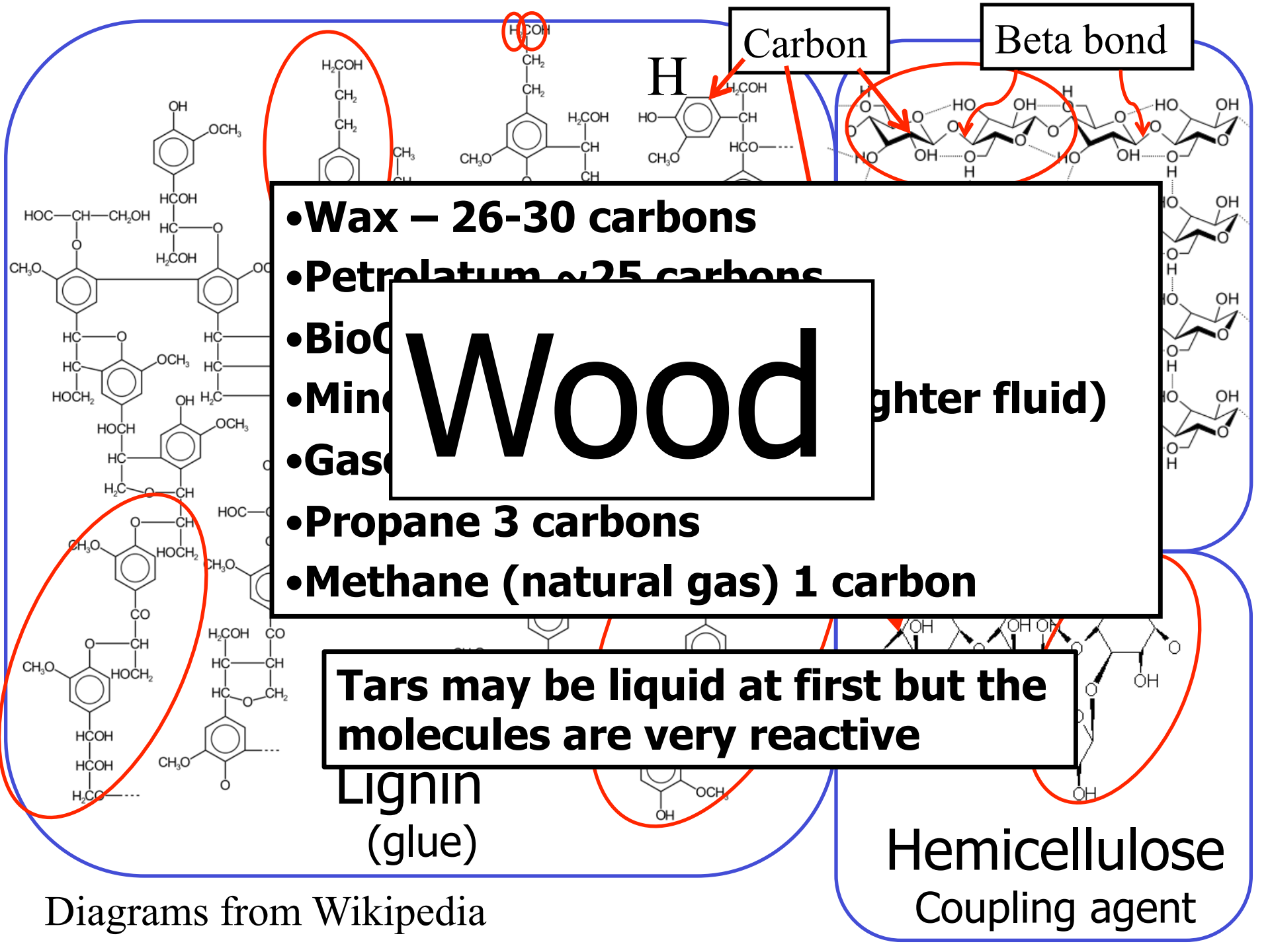
Burning wood will create smoke until critical zone reaches the proper temperature.
PreHeat with other fuel?

This is a disadvantage to batch fed stoves,
less so if you feed while still hot.

If no catalytic converter then CO produced until 1500°F reached.

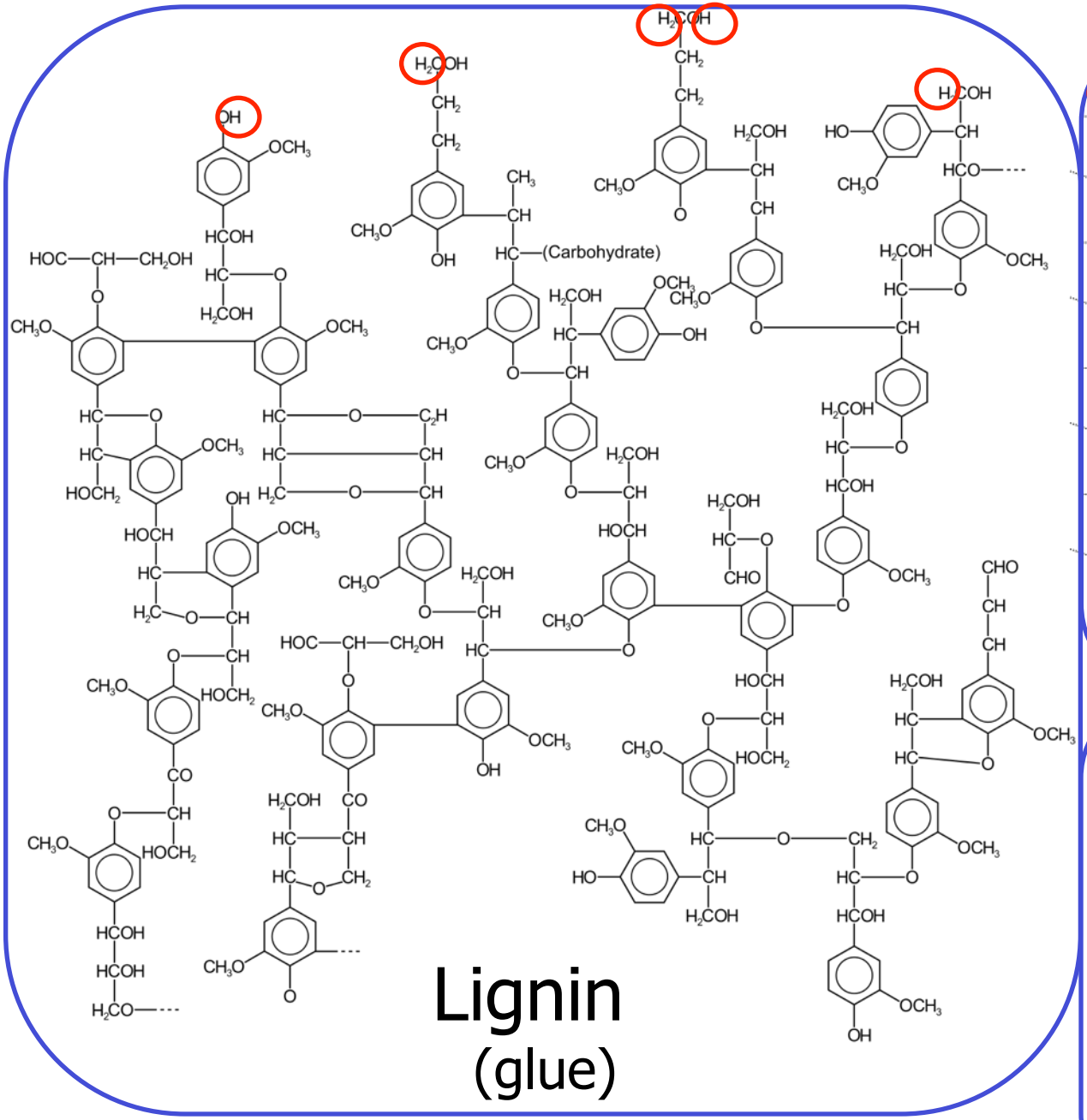
Pellet stoves have low mass in burn zone so it heats up relatively fast.
Commercial boilers burn continuously.

At all times, Stay below 2300°F to prevent oxidizing atmospheric nitrogen to NOx

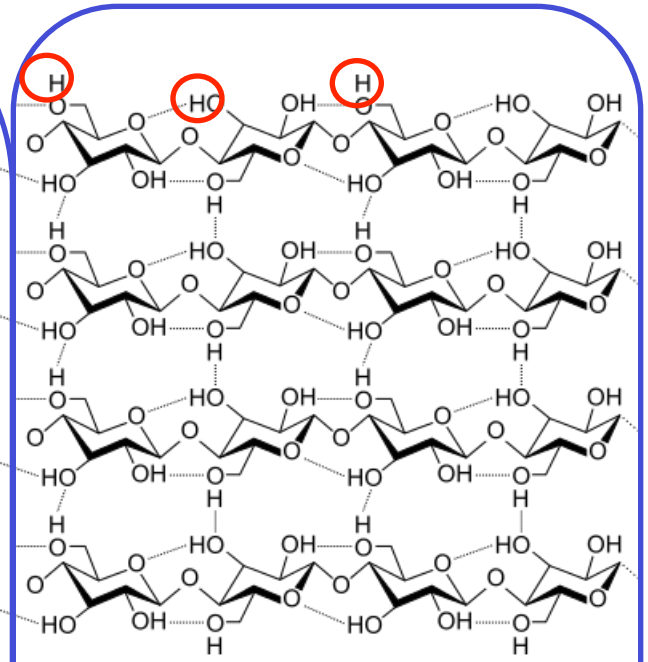


Diagrams from Wikipedia

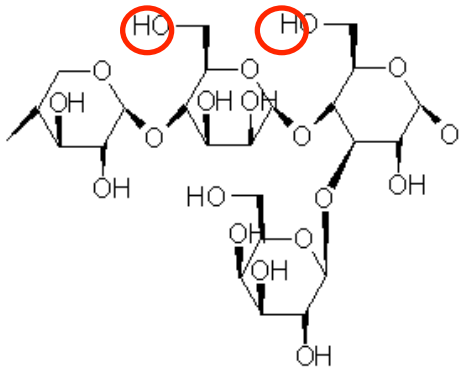
3) Then, what about water?



Lignin
(glue)



Cellulose



Hemicellulose
Coupling agent

Diagrams from Wikipedia

Empirical formula for wood

$C_6H_9O_4$

6.2% Hydrogen

by weight

Water (H_2O) is 18 times heavier than hydrogen
9 fold increase in weight

100 lbs. of dry wood has 6.2 lbs. of hydrogen which when burned becomes 56 lbs. of water

100 lbs. of Wood ~ 8,600 Btu/lb

water ~ 1,200 Btu/lb to boil away

1/deg F,	970 vaporize, (Btu/lb)	.485/degF	
MC also lbs. of water	0	20	50
lbs of wood	100	80	50
lbs. water created	56	44.8	28
Total lbs. of water	56	64.8	78
btu available	860,000	688,000	430,000
lost as steam	67,704	78,343	94,302
net Btu	792,296	609,656	335,698
	8%	**11%**	**22%**

Btu/ton/1000 with 350°F stack				
MC wet basis	Bomb BTU	BTU loss extra water	BTU loss created water	NET BTU
0	17,200	0	1,354	15,846
5	16,340	121	1,286	14,933
10	15,480	242	1,219	14,020
15	14,620	363	1,151	13,106
20	13,760	484	1,083	12,193
25	12,900	604	1,016	11,280
30	12,040	725	948	10,367
35	11,180	846	880	9,454
40	10,320	967	812	8,540
45	9,460	1,088	745	7,627
50	8,600	1,209	677	6,714
55	7,740	1,330	609	5,801
60	6,880	1,451	542	4,888
86.7615	2,277	2,098	179	0
35.8974	11,026	868	868	9,290

For your stove/boiler, Use dry wood!
Light farther down stream.
If it smokes for more than 5 minutes, there is room for improvement.

Turning down a flaming fire is difficult to do well.

Commercial stoves are getting better

Mark Knaebe
Forest Products Lab

Some Problems Now

Cold jacket & Low load = smolder

Incomplete Combustion
= Inefficient & Polluting

New designs = better

Two efficient wood boilers

Tarm

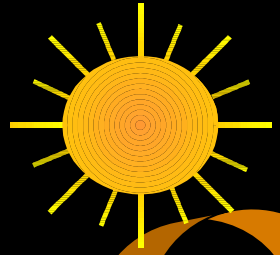
100,000-200,000 BTU/hr

Garn

350,000 - 950,000 BTU/hr

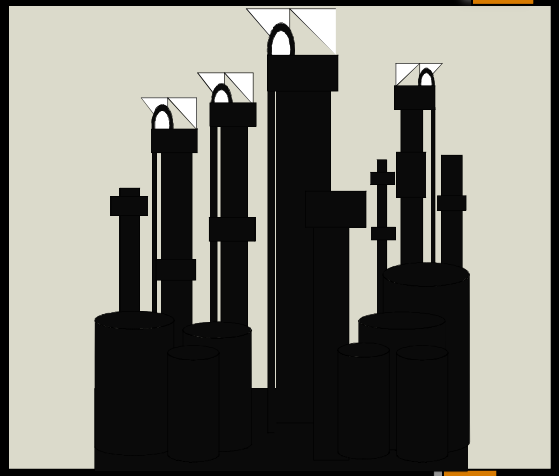
Called gasification units although the time as a gas is very short

Fire at optimal intensity and heat up to 2000 gallons of water & then burn out, never smolder.



66×10^6 MT CO_2

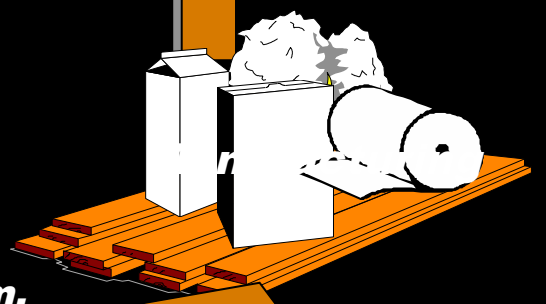
O_2



Syngas

Power Export
$3.8 Billion
or
Liquid Fuels/Chemicals
$5.5. Billion

Black Liquor
& Residuals



Steam, Power & Chemicals

➥Extract Hemicelluloses
➥New Products
Chemicals Polymers
$3.3 Billion

➥BL Gasifier
➥Wood Residual Gasifier
➥Combined Cycle System
➥Process to Manufacture
Liquid Fuels and Chemicals

➥Pulp
$5.5 Billion

The Forest Biorefinery

Net Revenue Assumptions:

Acetic Acid - $1.73/gallon	Purchased Electricity - $43.16/MWH
Ethanol - $1.15/gallon	Exported Electricity - $40.44/MWH
Pulp - $100/ton net profit	Renewable Fisher Tropsch Fuel - $57/bbl

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