Combined Heat And Biochar: An alternate economic option for renewable biomass

Breakout Session III on "Advanced Biomass Thermal Technologies / Carbon Negative Options"

presented April 15, 2011 at the 3rd Annual Conference of

Heating the Northeast with Renewable Biomass

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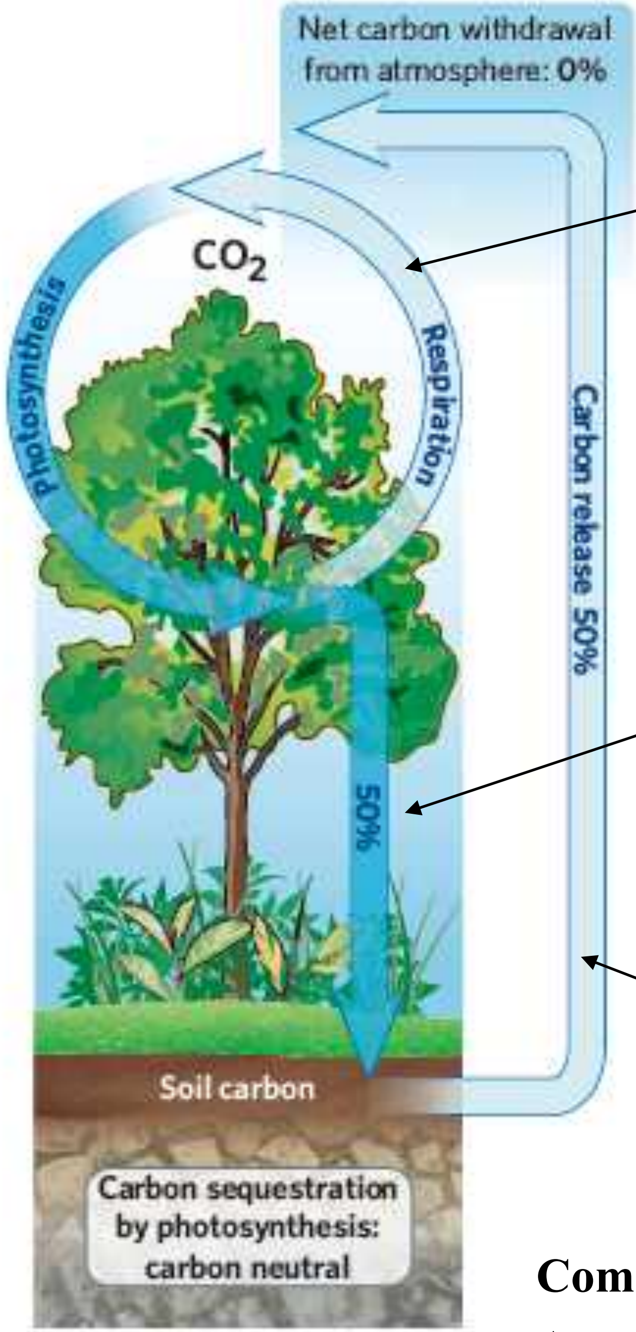


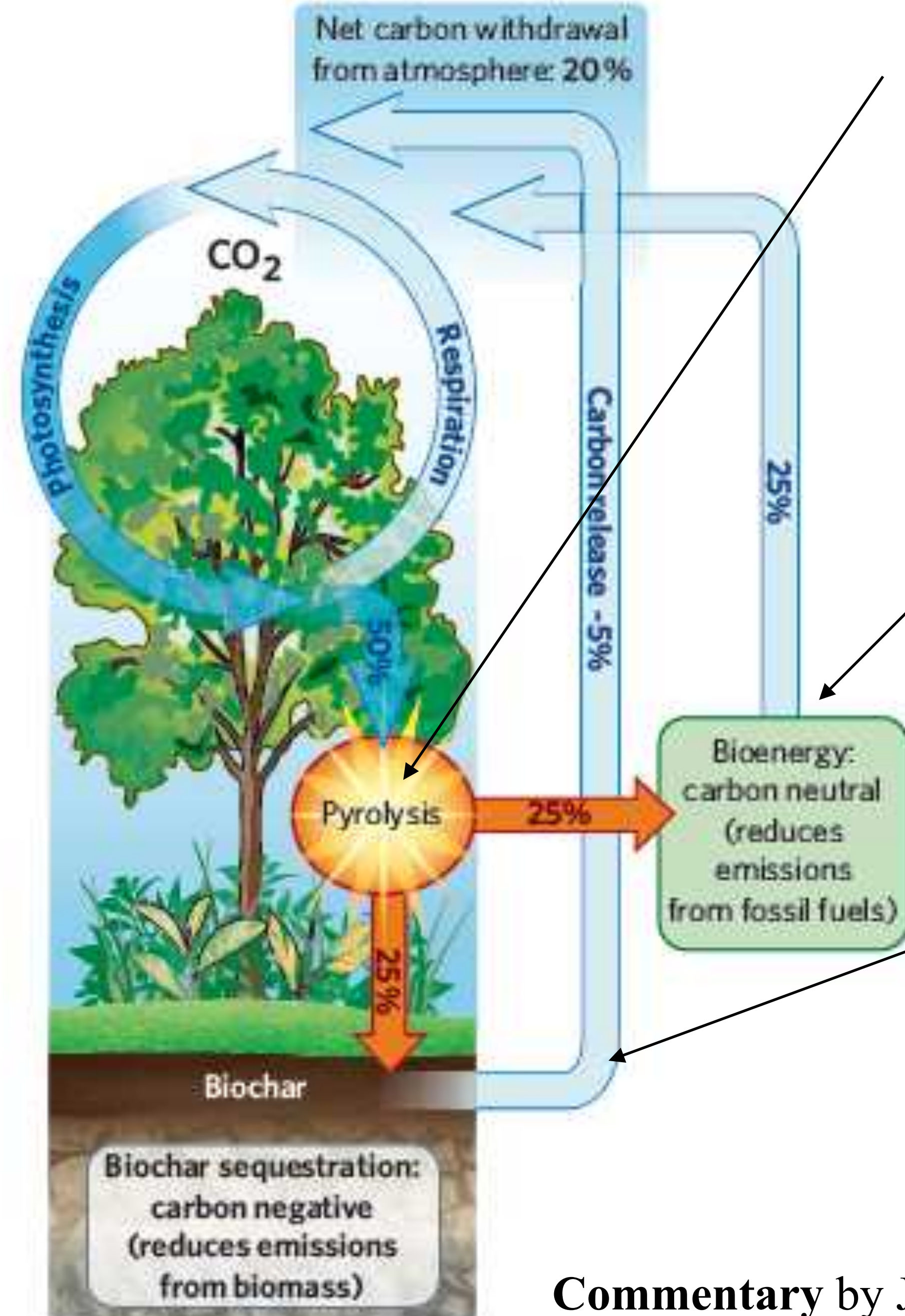
This is the tree as it grows. About one half of the carbon dioxide uptake results in additional carbon atoms in biomass

This is when biomass dies and becomes **detritus**: such as leaves and tree death

This is due to microbial breakdown of dead biomass – 95% in one to twenty years

Commentary by Johannes Lehmann

Appearing in Nature, Vol 44**,** 10 May 2007



Pyrolysis and Carbonization convert biomass into biochar: one half of the carbon atoms are released as volatiles and one half converted to biochar

The volatiles contain carbon atoms that the tree removed from the atmosphere as it grew = carbon neutral

A minority of biochar is slowly oxidized by soil microbes; the majority is stable for hundreds to thousands of years

Commentary by Johannes Lehmann
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U.S.-FOCUSED BIOCHAR REPORT

BIOCHAR AND ENERGY LINKAGES IN:
BIOCHAR AND ENERGY CO-PRODUCTS

USBI

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as found in Antal & Gronli, The Art, Science and Technology of Charcoal Production, *Ind. Eng. Chem. Res.* 2003, *42*, 1619-1640, on page 1621, Klason and co-workers (1908, 1925) report:

For the carbonization of "wood", at 400 Celsius:

$$2C_{42}H_{60}O_{28}$$

Wood (mixture of hemicellulose, cellulose, and lignin)

$$\downarrow$$

$$3C_{16}H_{10}O_2 + 28H_2O + 5CO_2 + 3CO + C_{28}H_{34}O_9$$

Biocarbon — water — carbon dioxide — carbon monoxide — pyrolysis tars

(35 wt %) (40 wt %) (25 wt %)

57% of carbon 0% + 6% + 4% of carbon 33% of carbon

How much energy in a ton of wood?

- One ton = 2000 pounds
- **B**one **D**ry wood = 8,000 Btu/# (LHV)
- 1 ton of BD wood = 16 million Btu
- 1 truckload = 25 tons = 400 million Btu

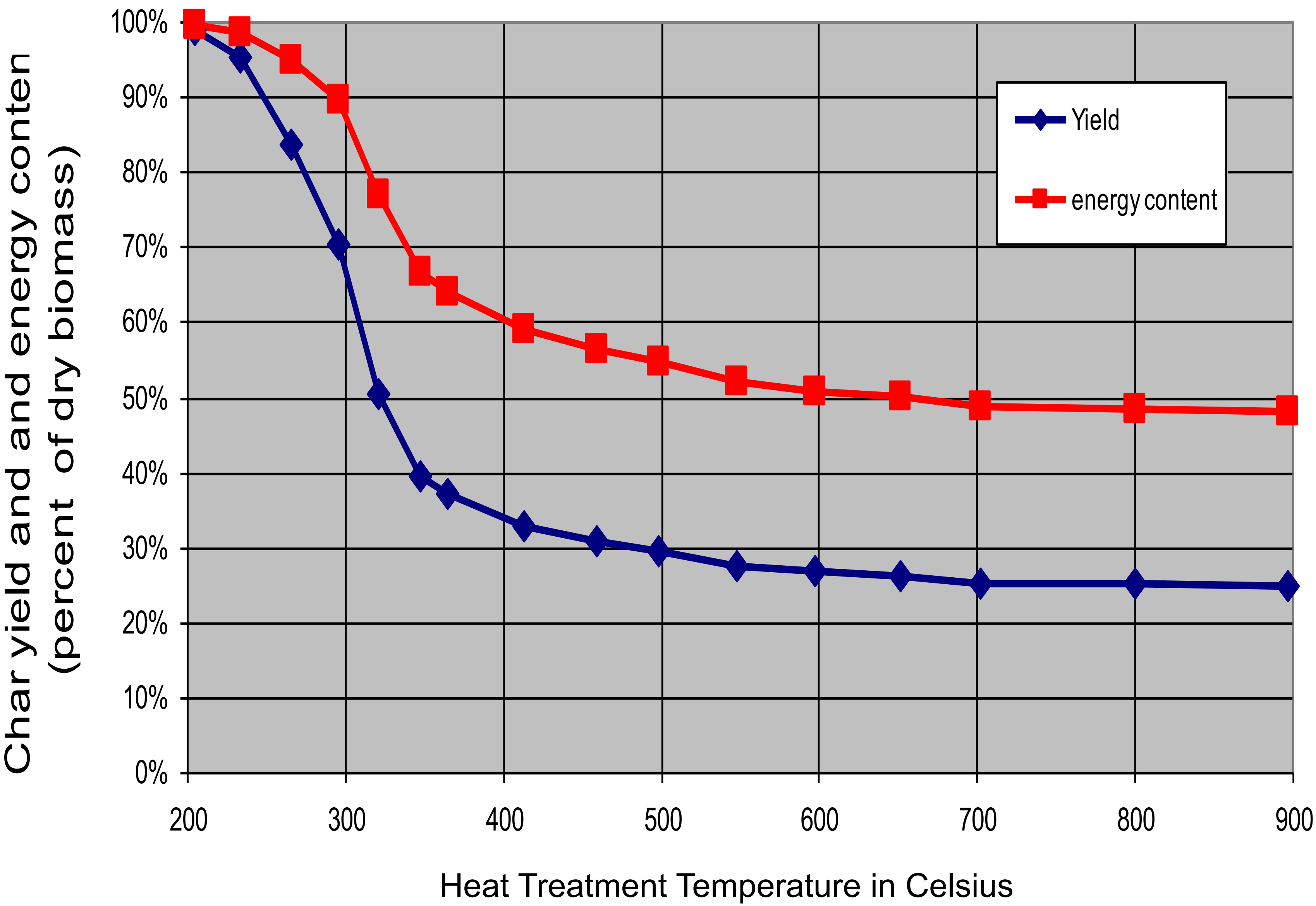
- Diesel fuel (#2) = 140,000 Btu/gallon
- Tankwagon = 5,000 to 8,000 gallons/load
- 8,000 gallons of Diesel = 1120 million Btu

How much do various Fuels cost?

- Natural gas: $5/million Btu (via pipeline)
- Coal: $2/million Btu, via train in quantity
- Gasoline/Diesel @ $2/gallon ($75/barrel)
  - > $15/million Btu (plus taxes)
- Electricity @ $0.10/kwh = $30/million Btu

- Wood pellets @ $200/ton = $12.50/MMBtu
- Hardwood @ $240/cord = $7.50/MMBtu
- Hog Fuel @ $25/ton = $1.56/MMBtu

Char Yield and Energy Content as wood becomes char



How much does it cost to make Biochar?

- Raw material cost = depends on co-products
- If CHAB (Combined Heat and Biochar), then the Raw Material cost = 1.5 x cost of wood fuel
  - Dry wood = 8,000 Btu/pound
  - Dry biochar = 12,000 Btu/pound
- If Biochar is the only product, then the Raw Material cost = Cost of Biomass/yield
- Yield of Good Biochar is 20%-30%

Additional Cost issues with CHAB

Material handling: Increased In and Out

- – Biochar takes energy content, need more biomass IN
- – Biochar is 1.5 x energy density of biomass by weight
- – Biochar = ½ the volume of biomass, but easily crushable

- **@ 12.5 wt % Biochar yield** = 18.75% of energy
  - Biomass requirement = 1/(1-.1875) = 123 percent
  - Weight of char out = 123% x 12.5% = 15.3 percent
  - Total weight handled *increases an additional 38 percent*
  - **Volume handled increases: 23% + (123%/2) = 84.5%**
- **@ 25 wt % Biochar yield** = 37.5% of energy
  - Biomass requirement = 1/(1-.375) = 160 percent
  - Weight of char out = 160% x 25% = 40 percent
  - Total weight handled *increases an additional 100 percent*
  - **Volume handled increases: 60% + (160%/2) = 140%**

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FROM BIOMASS TO BIOCARBON – TRENDS AND TRADEOFFS WHEN CO-FIRING

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http://www.actapress.com/Abstract.aspx?paperId=35017

FIGURE 2: Derived Fuel Metrics of Biofuels (dry wood = 100%)

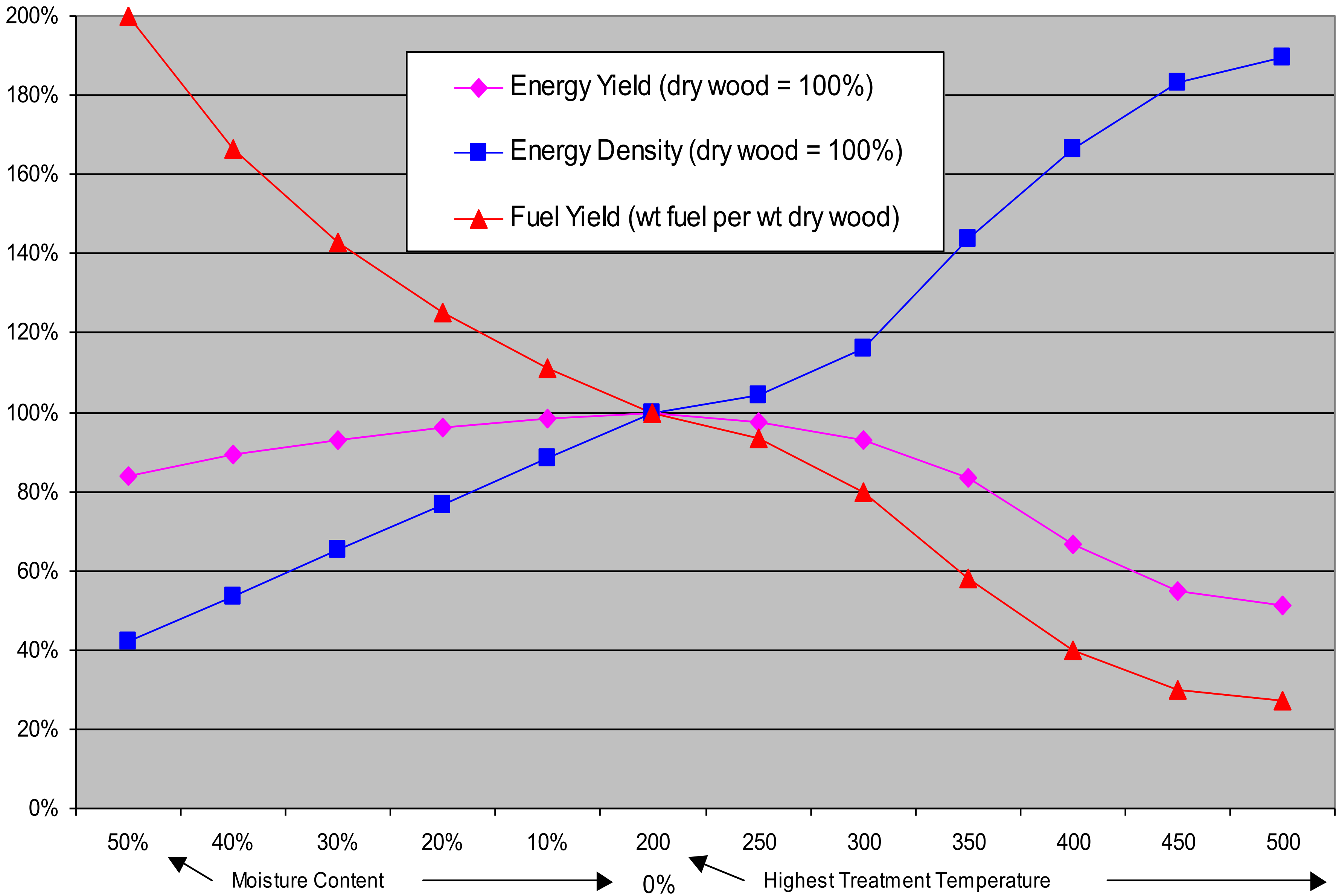
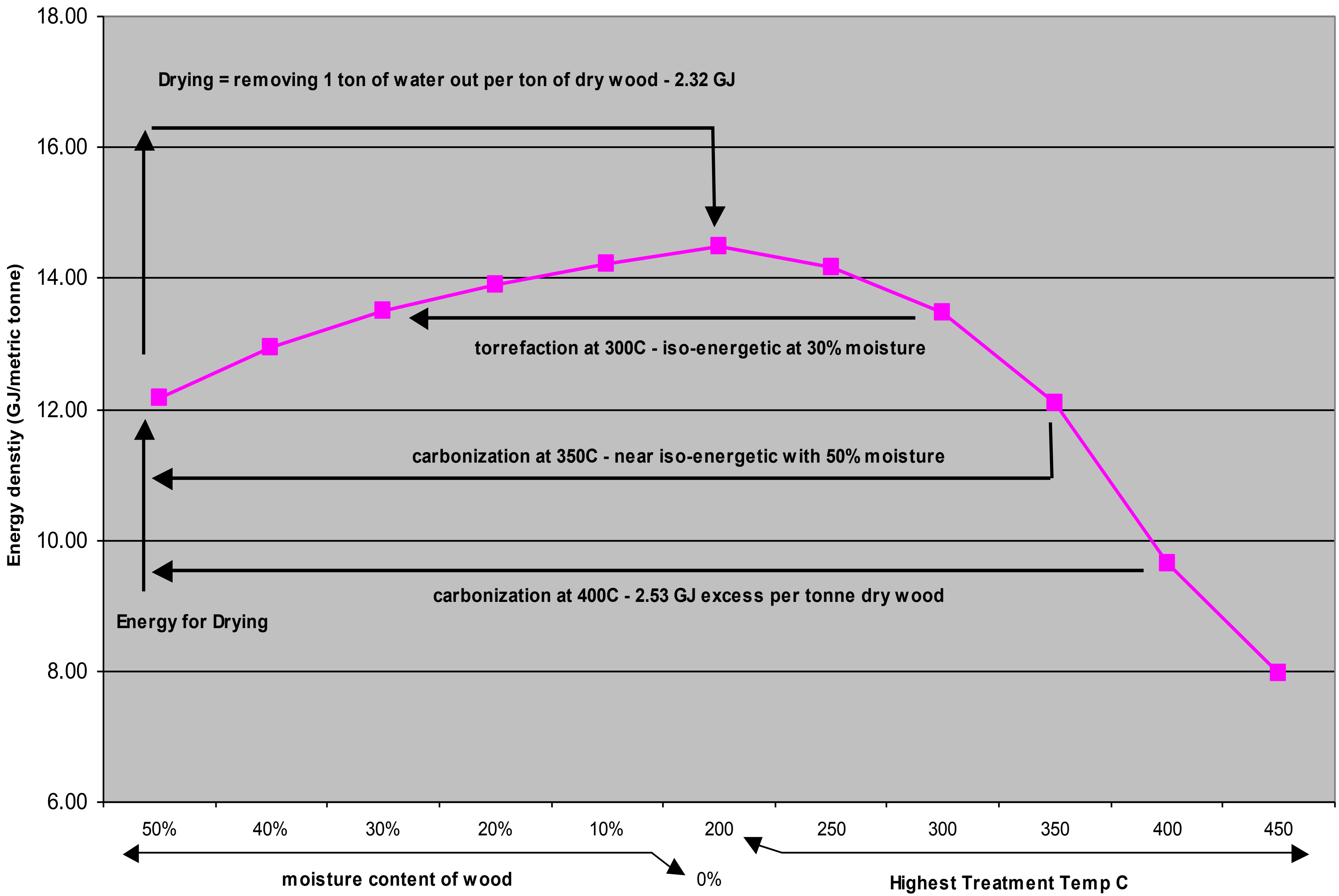
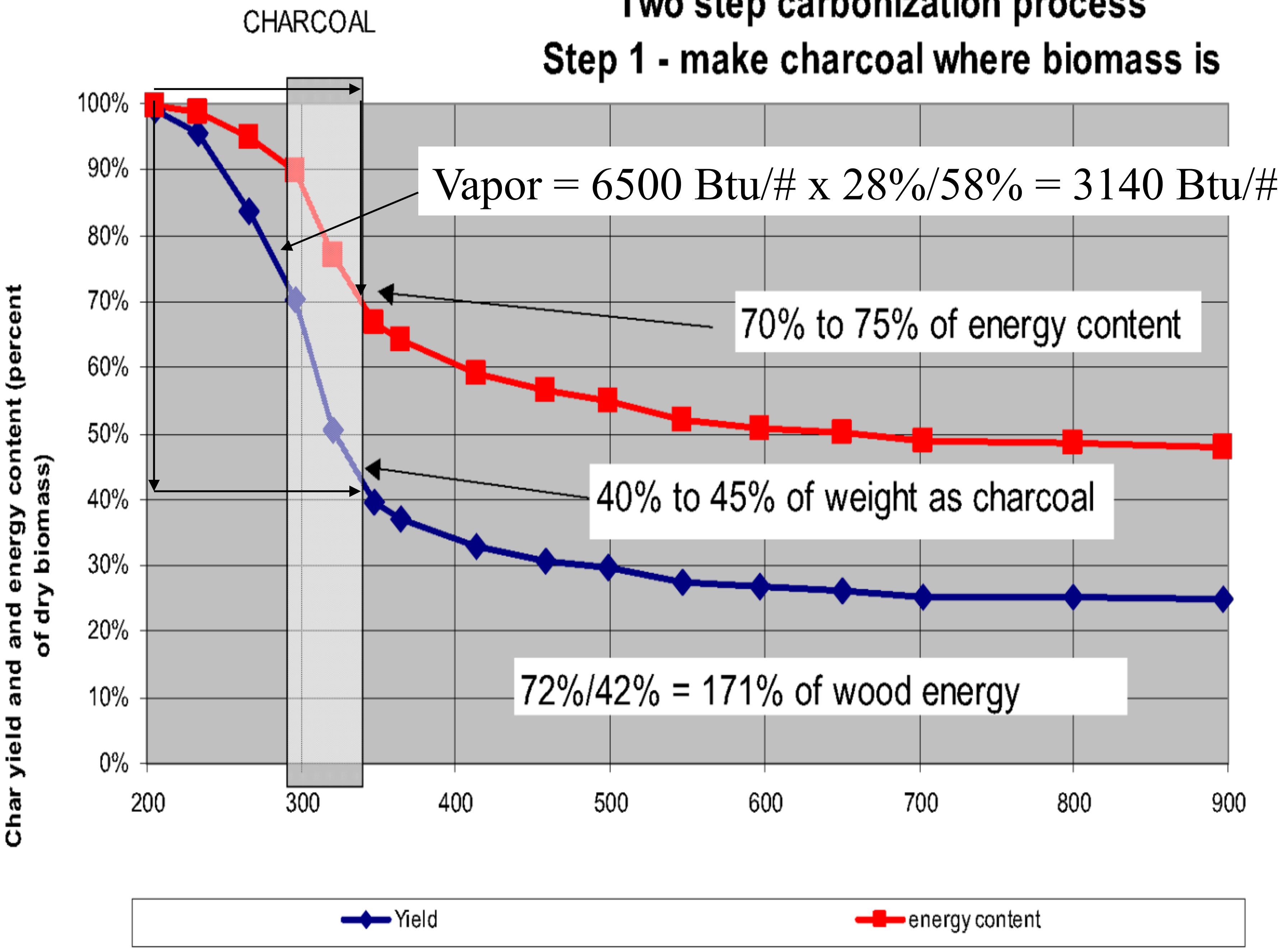


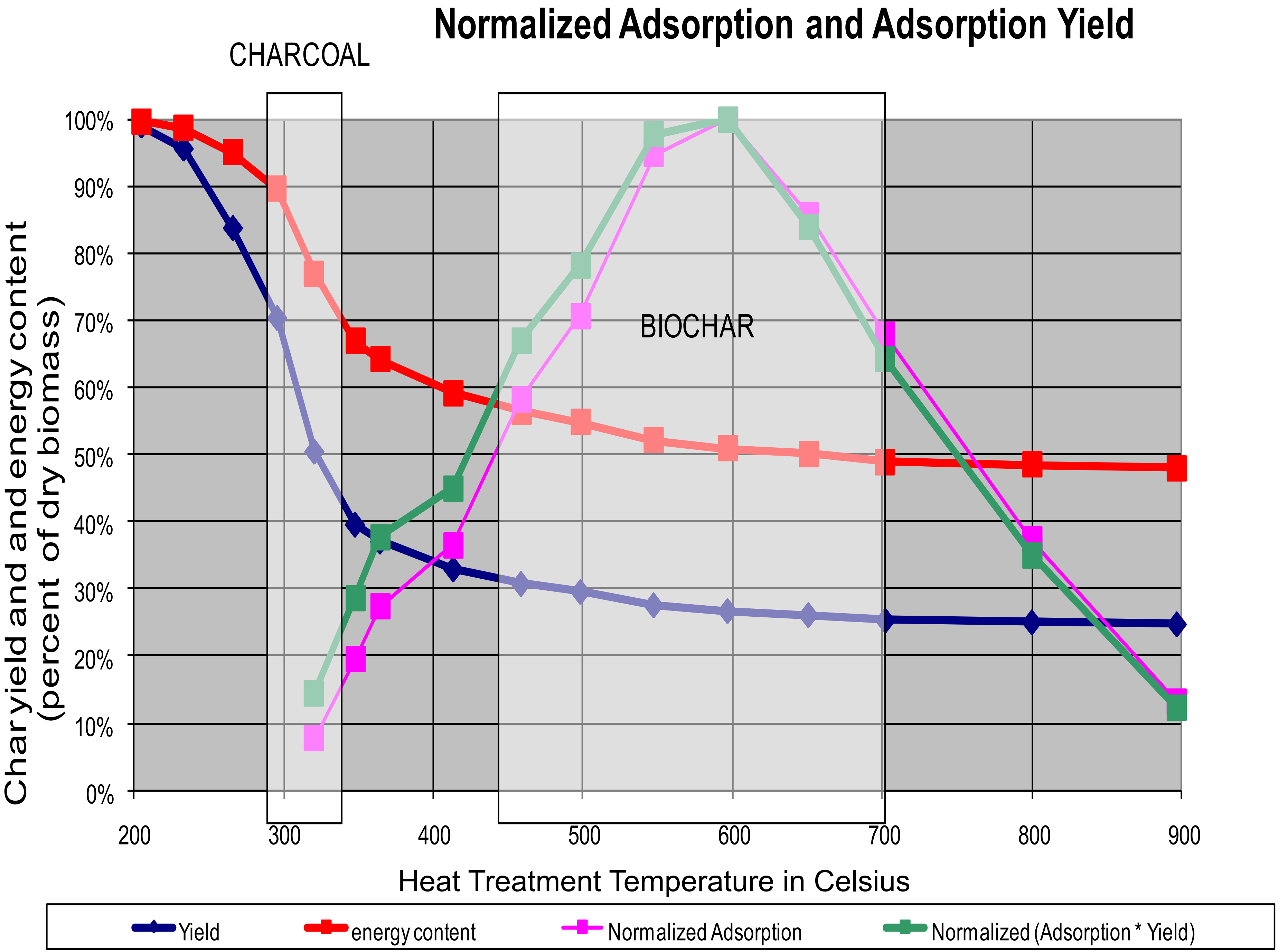
FIGURE 4: Energy Balance - supplying the energy for Drying from the Pyrolysis Process



Two step carbonization process

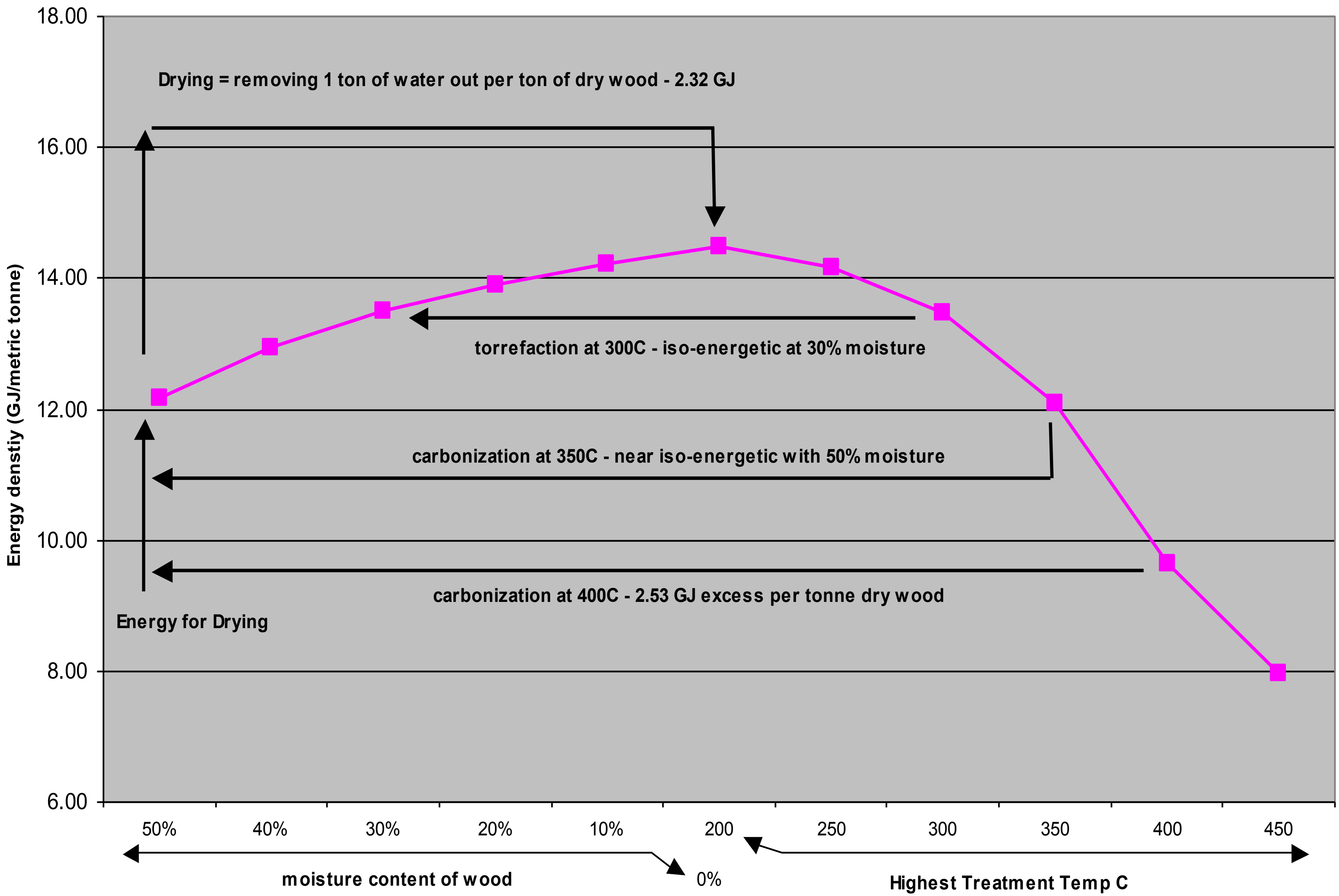
Step 1 - make charcoal where biomass is



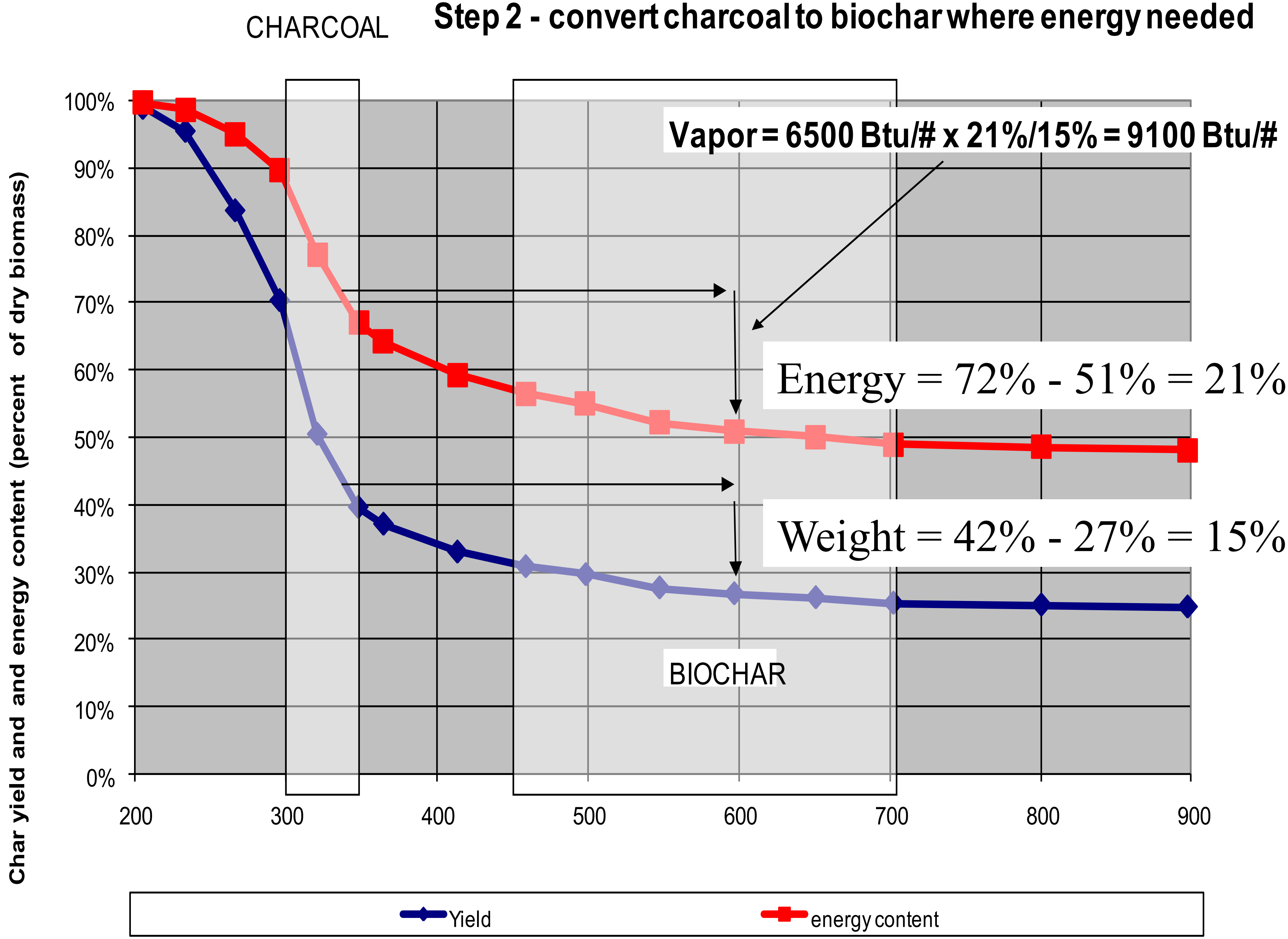


Normalized Adsorption and Adsorption Yield
CHARCOAL
BIOCHAR
Char yield and and energy content
(percent of dry biomass)
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
200
300
400
500
600
700
800
900
Heat Treatment Temperature in Celsius
Yield
energy content
Normalized Adsorption
Normalized (Adsorption * Yield)

FIGURE 4: Energy Balance - supplying the energy for Drying from the Pyrolysis Process



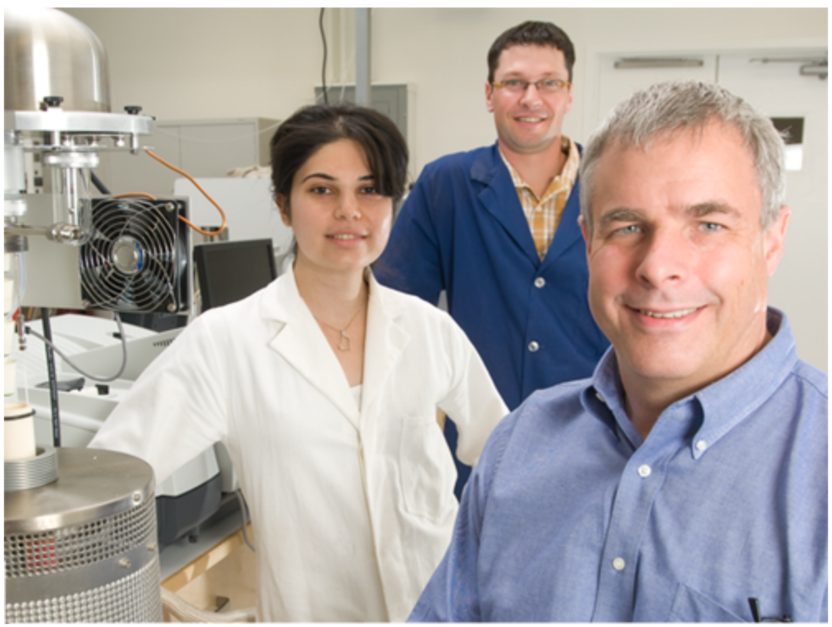
Two step carbonization process
Step 2 - convert charcoal to biochar where energy needed



When it comes to bio-oil, my opinion mirrors this statement:

"Pyrolysis bio-oil from whole biomass is a disaster"

- quote attributed to Dr. Murray Gray, Dept of Chemical and Materials Engineering, U of Alberta, Canada



Dr. Murray Gray is the scientific director for The Centre for Oil Sands Innovation and holds the NSERC-Imperial Oil Industrial Research Chair in Oil Sands Upgrading and the Canada Research Chair in Oil Sands Upgrading.

QUESTIONS about this presentation?
- as time and Jock Gill allow

Combined Heat And Biochar: An alternate economic option for renewable biomass

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Does Biochar sequester Carbon Dioxide?

Let's agree that biomass gets it's carbon atoms by removing carbon dioxide from the atmosphere via photosynthesis …

Consider a plot of marginal land, unimproved and asymptotic in biota, with a total of 20 units of organic carbon, above ground and in the soil.

At year 0, 100 units of marked carbon in biochar is added, bringing the total organic carbon to 120 units.

Returning at 10 years and measuring total organic carbon at the site?

Now the site has some growing vegetation above ground and microbial activity in the soil.

The total organic carbon is 160 units, consisting of plants, microbes in the soil and SOM.

The SOM includes 60 units of the original 100 units of marked biochar added at Year 0.

Returning at 20 years and measuring total organic carbon at the site?

Now the site has mature trees and diverse vegetation above ground and pronounced microbial activity in the soil.

The total organic carbon is 200 units, consisting of plants, microbes in the soil and SOM.

The SOM includes 40 units of the original 100 units of marked biochar added at Year 0.

So, did the biochar sequester any carbon dioxide and, if so, how much?

Year 0: 20 units + 100 units of biochar = 120 total

Year 10: 160 total units with 60 units of biochar

Year 20: 200 total units with 40 units of biochar

Year 21: Fire, removing 80 units of above ground organic carbon, leaving 120 total units with 38 units of biochar, but rapid revegetation due to good soil

After 20 years, most growing systems reach asymptotic organic carbon content – similar to how humans reach approximate final height, and sometimes even weight?

Undisturbed ecosystems cycle much of the annual growth back to the soil. Example: leaves, detritus

Periodic episodes (forest fires, disease, wind) convert growing biomass into CO2 or decaying biomass.

Examples of Carbon Positive Forests:

- **Most of the Northeast United States**,
  due to an ice storm in December of 2008
- **The Province of British Columbia**,
  due to pine beetle infestation (no hard frosts)

Managed woodlots sequester more CO2 if excess biomass is converted to biochar

Year 0: 2 marginal lots with 20 units + 100 units of biochar = 120 units of total organic carbon.

Year 20: both woodlots have 200 total units, with 80 units of above ground.

Lot B: Harvest 80 units of above ground biomass, convert to 40 units of biochar. After biochar recycling, Lot B has 160 carbon units total.

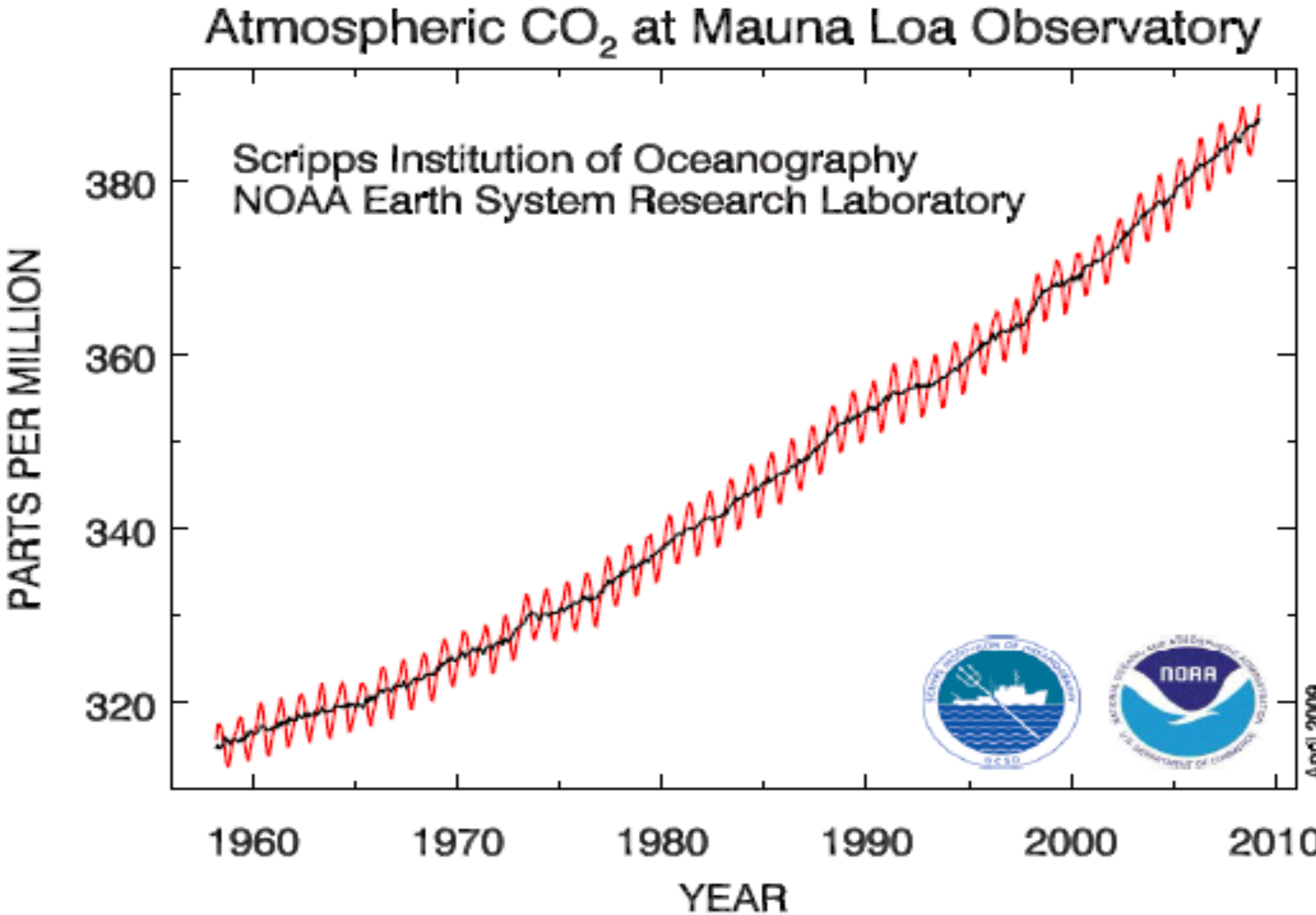
Year 20 to 100: Lot A left asymptotic at 200 units.

Lot B at Year 40, regrown to 240 units total, harvest 80 units of biomass → 40 units of biochar. After biochar recycling, Lot B has 200 carbon units.

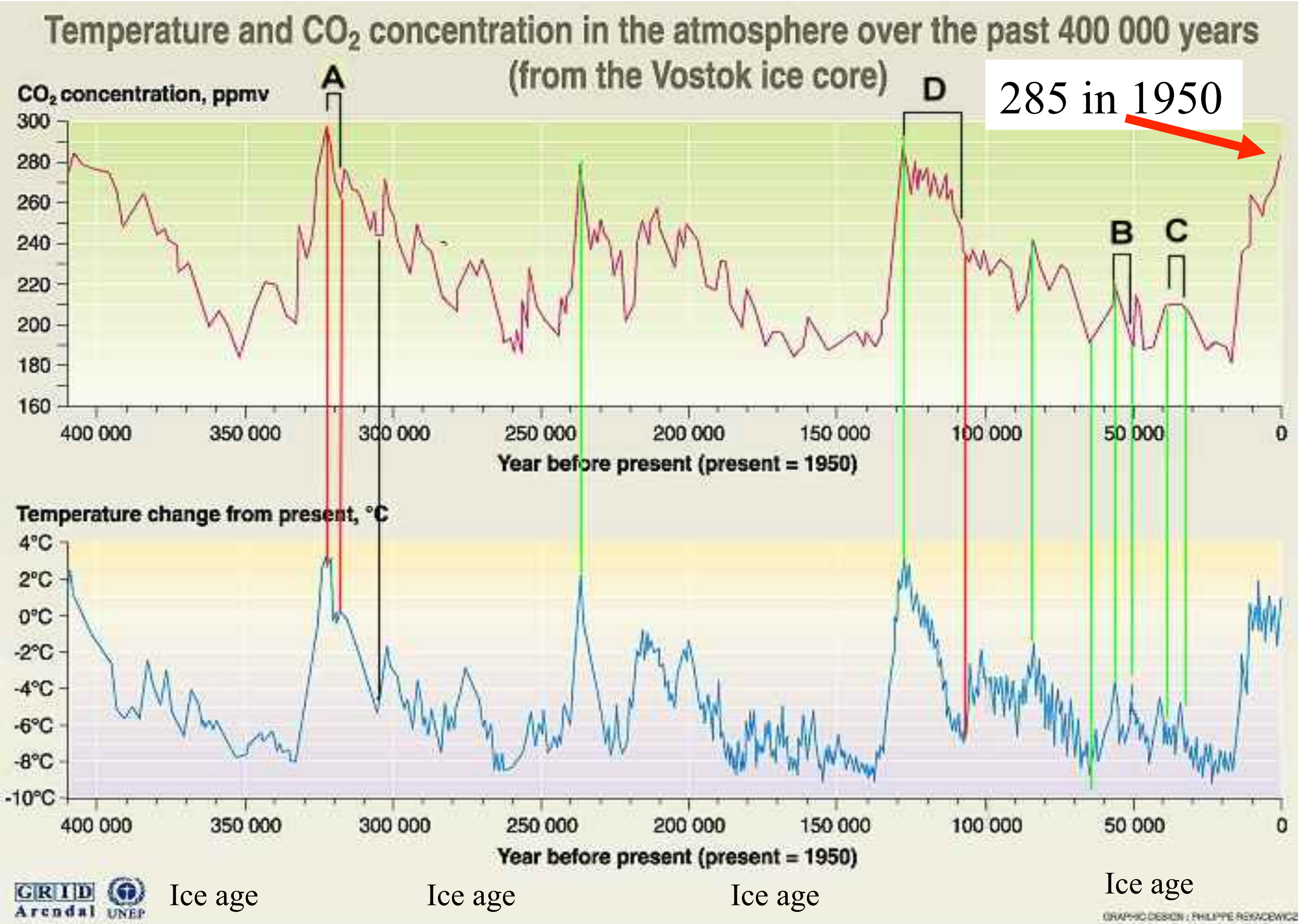
Lot B at Year 60, regrown to 280 units total, harvest 80 units of biomass → 40 units of biochar.
After biochar recycling, Lot B has 240 carbon units.

Lot B at Year 80, regrown to 320 units total, harvest 80 units of biomass → 40 units of biochar.
After biochar recycling, Lot B has 280 carbon units.

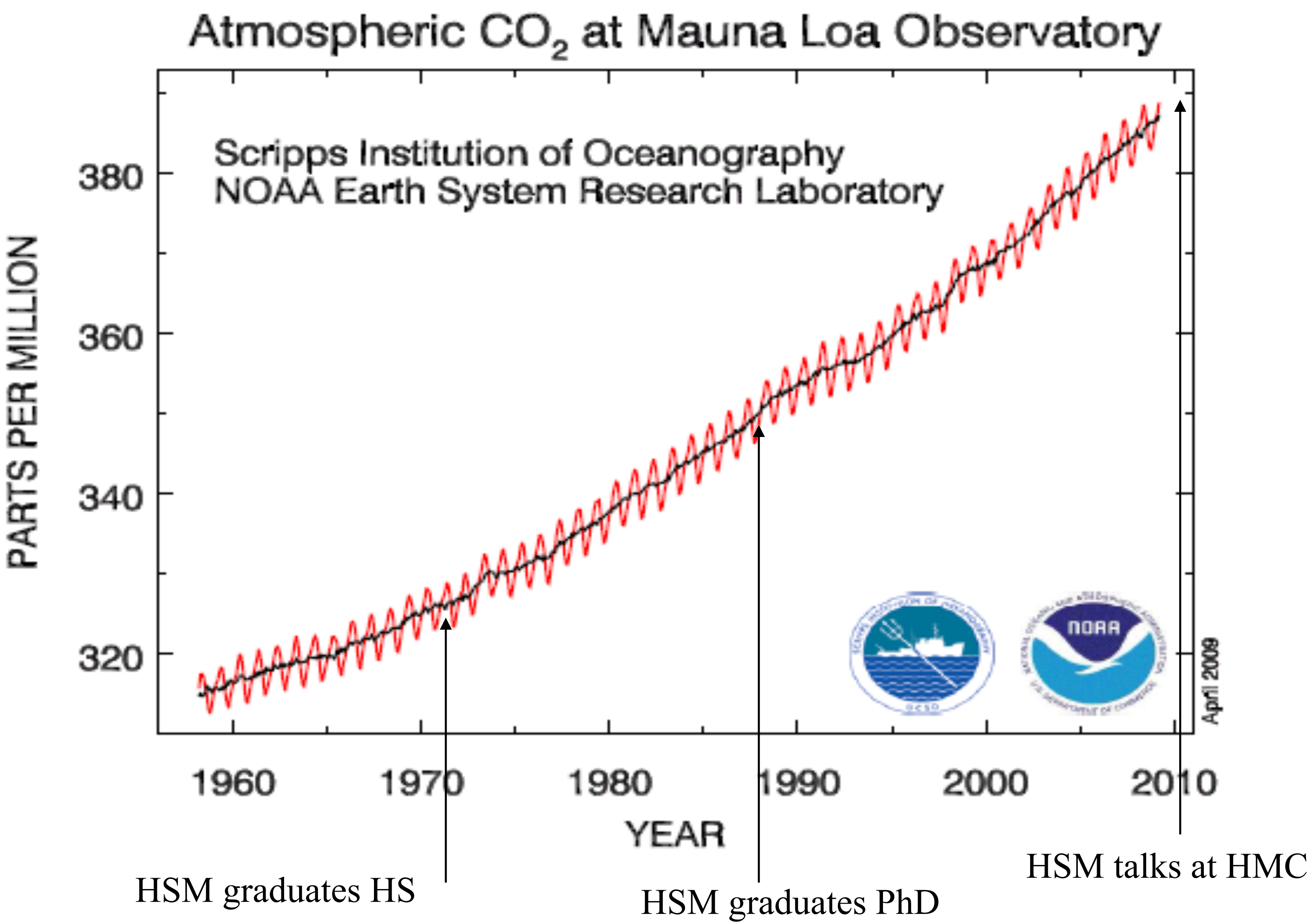
Lot B at Year 100, regrown to 360 units total, bsp.
After biochar recycling, Lot B has 320 carbon units.



Atmospheric CO_2 at Mauna Loa Observatory
Scripps Institution of Oceanography
NOAA Earth System Research Laboratory
PARTS PER MILLION
380
360
340
320
1960
1970
1980
1990
2000
2010
YEAR
April 2009
NOAA



Source: J.R. Petit, J. Jouzel, et al. Climate and atmospheric history of the past 420 000 years from the Vostok ice core in Antarctica, Nature 399 (3June), pp 429-436, 1999.



Atmospheric CO_2 at Mauna Loa Observatory
Scripps Institution of Oceanography
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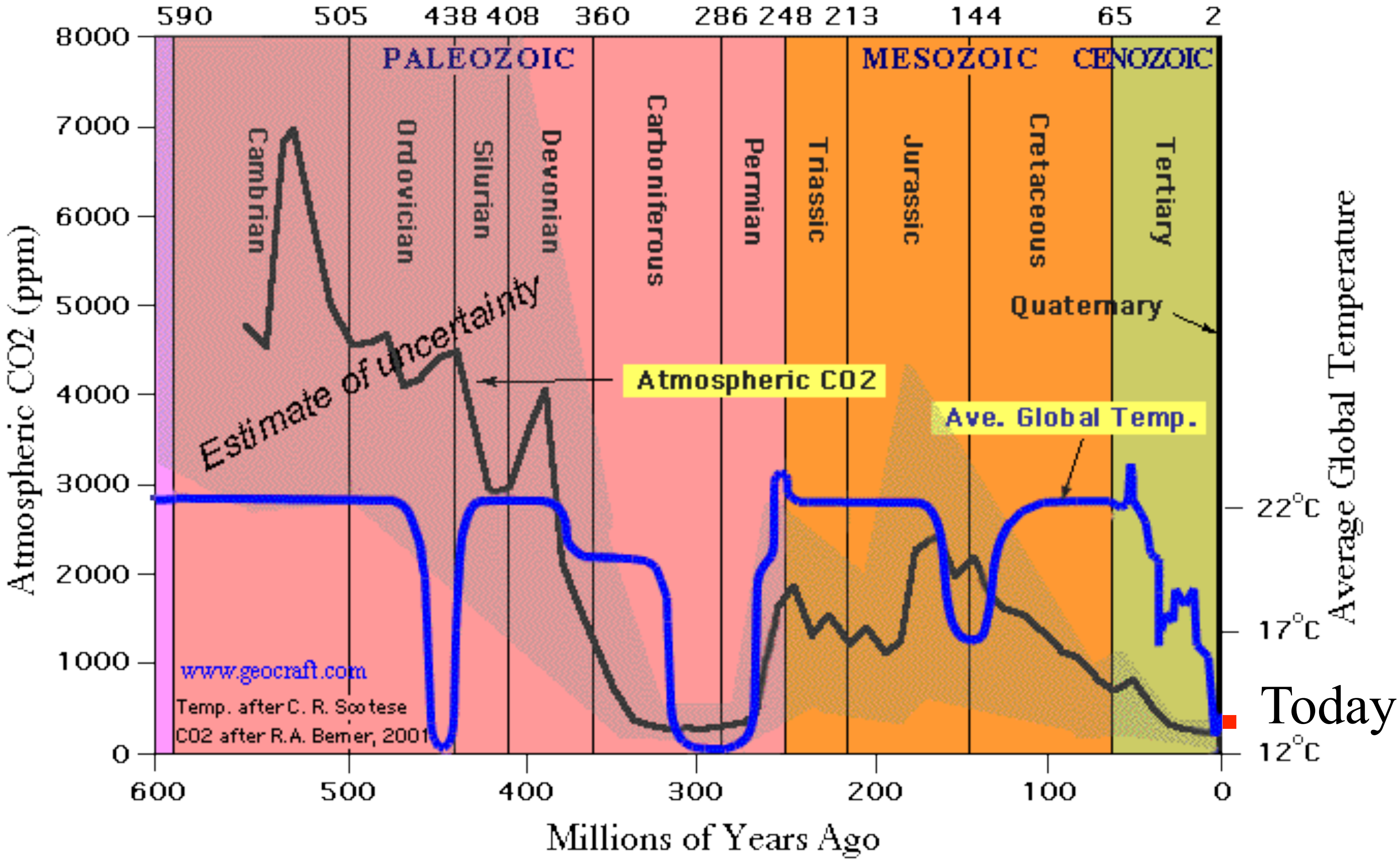
PARTS PER MILLION
380
360
340
320
1960
1970
1980
1990
2000
2010
YEAR
April 2009
NOAA
HSM graduates HS
HSM graduates PhD
HSM talks at HMC

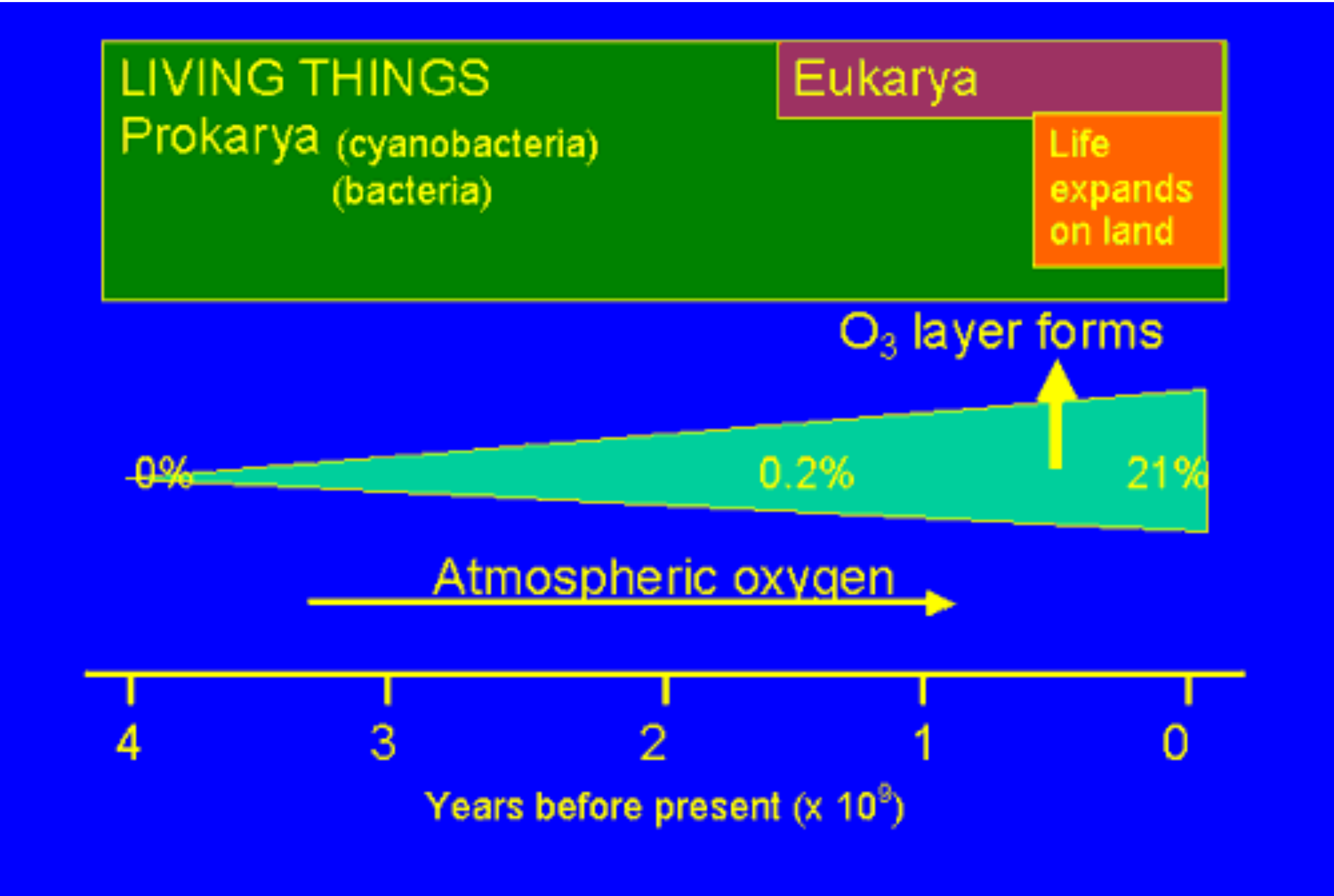
Global Temperature and Atmospheric CO2 over Geologic Time



Late Carboniferous to **Early Permian** time (315 mya -- 270 mya) is the only time period in the last 600 million years when **both** atmospheric **CO2** and **temperatures** were as low as they are today **(Quaternary Period).** *Temperature after C.R. Scotese http://www.scotese.com/climate.htm* *CO2 after R.A. Berner, 2001 (GEOCARB III)*

Source: http://www.geocraft.com/WVFossils/Carboniferous_climate.html

Why focus on the last 600 million years:



Conclusions

- Global warming can be debated, but the increase in atmospheric CO_2 levels is clearly measured.
- The Earth is very capable of existing with much higher CO_2 levels, but our desired human society probably could not.
- The only current reasonable method for human action to remove significant amounts of atmospheric CO_2 is through biochar for carbon sequestration in soils (and improving the soils).

More QUESTIONS about this presentation?
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