# Potential Use of Biochar to Drawdown Atmospheric Carbon: A Preliminary Assessment for Washington State

J.E. Amonette*[1], M. Garcia-Perez[2], D. Sjoding[3] and M. Fuchs[4]

[1]Pacific Northwest National Laboratory, Richland, WA
[2]Washington State University, Pullman, WA
[3]Washington State Energy Program Office, Olympia, WA
[4]Washington Department of Ecology, Spokane, WA

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jim.amonette@pnnl.gov

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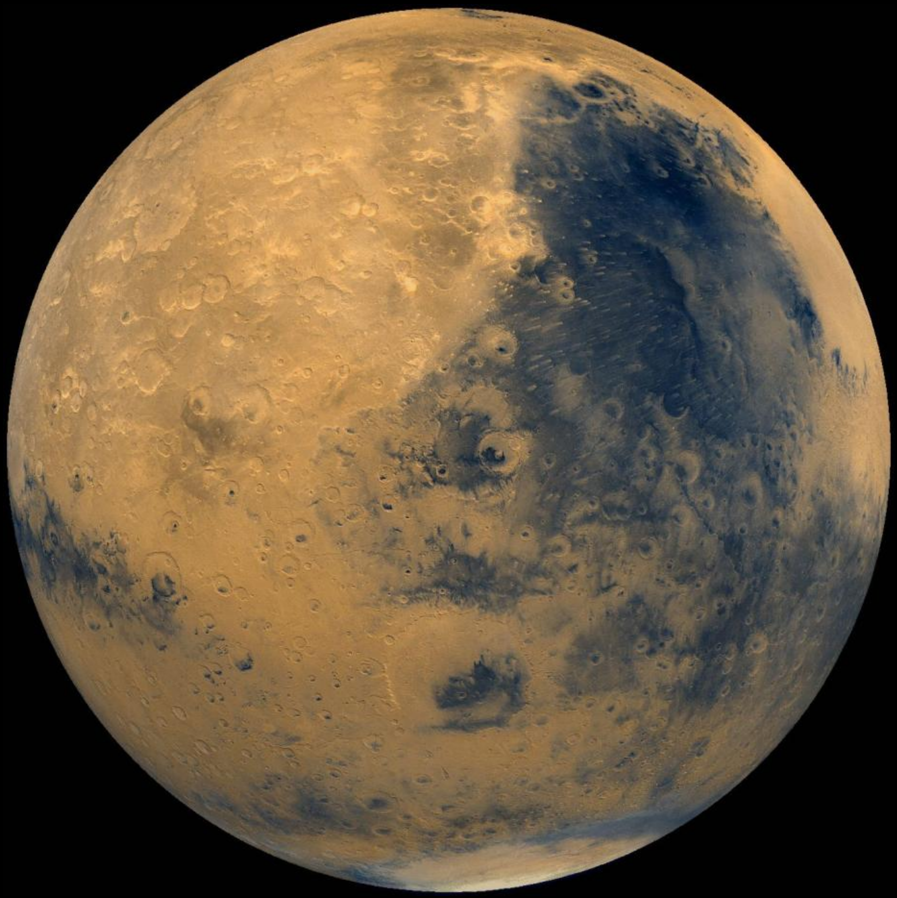
# Overview

- Considerations for Drawdown of Atmospheric $CO_2$
  - Carbon Cycle Mechanisms
  - Evidence of Past Drawdown
- A Modern Drawdown Approach Using Biochar
  - Waste Woody Biomass in WA State
  - Conversion of Existing Capital Stock
  - Efficiency Relative to Biomass Combustion
  - Expected Net Drawdown

Average Temperature -80 F

Average Temperature 57° F

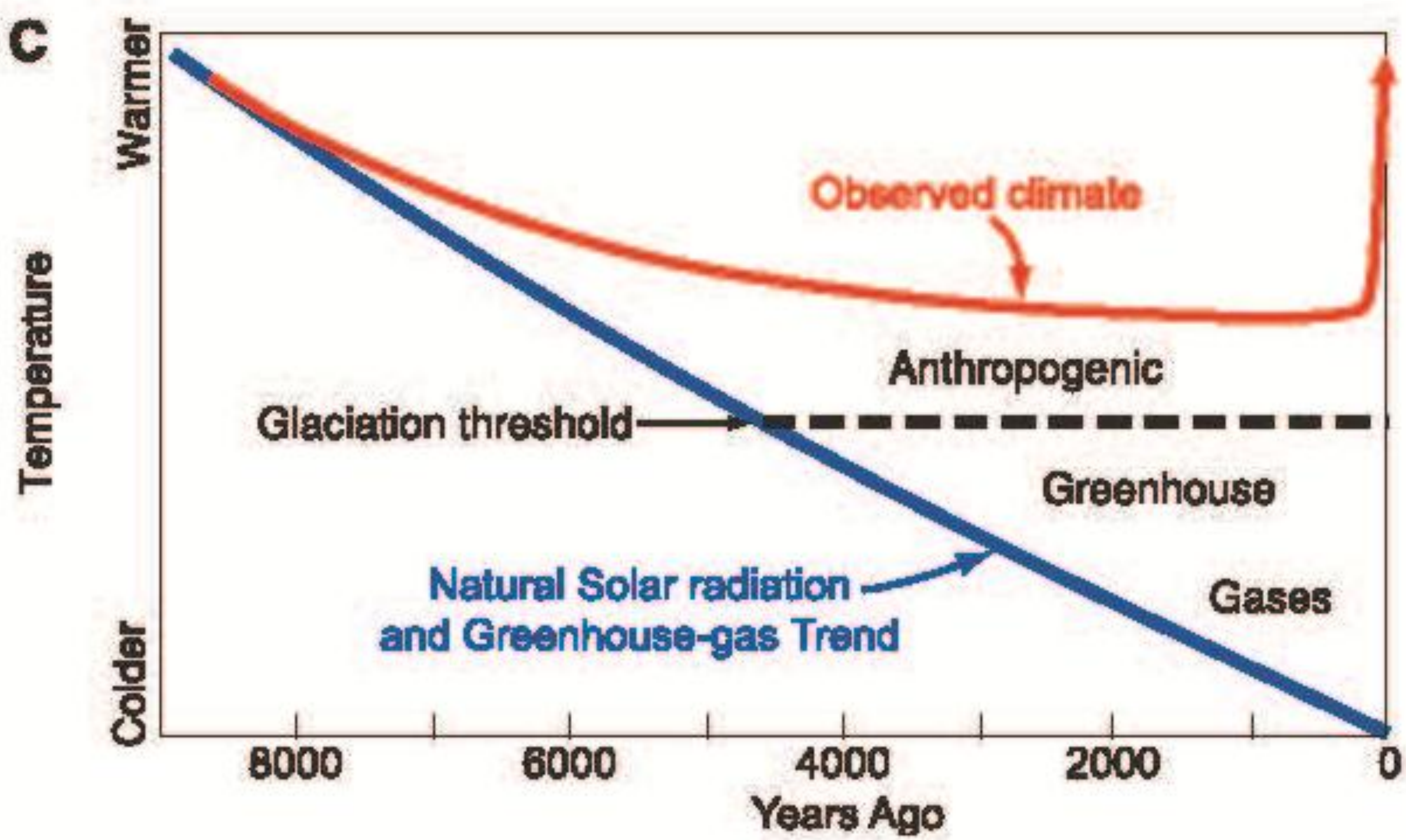


Mars

Earth

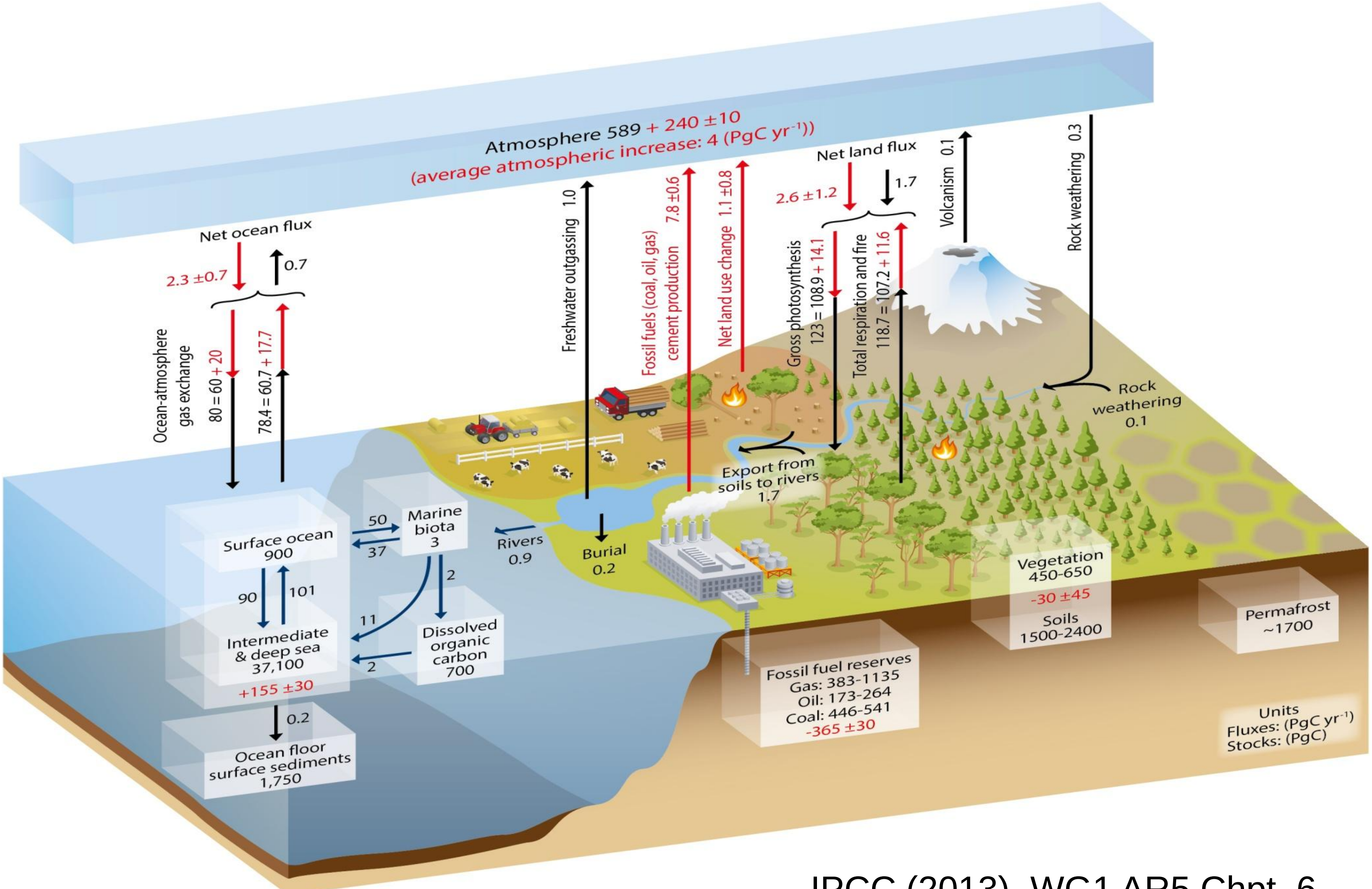
Source: NASA

# Anthropogenic Climate Change has not always been a bad thing . . .




Ruddiman et al., 2007

# Global Carbon Cycle




IPCC (2013), WG1 AR5 Chpt. 6

# The whale in the room . . .

| Reservoir | Carbon, Pg | Heat Capacity, ZJ |
|---|---|---|
| Atmosphere | 852 | 5.2 |
| | | |
| Terrestrial | | |
| Vegetation | 610 | 0.0 |
| Soil (2 m) | 1580 | 0.5 |
| Land Ice | 1 | 10.2 |
| Ocean | | |
| Surface (200 m) | 1020 | 1107 |
| Deep | 38100 | 4420 |

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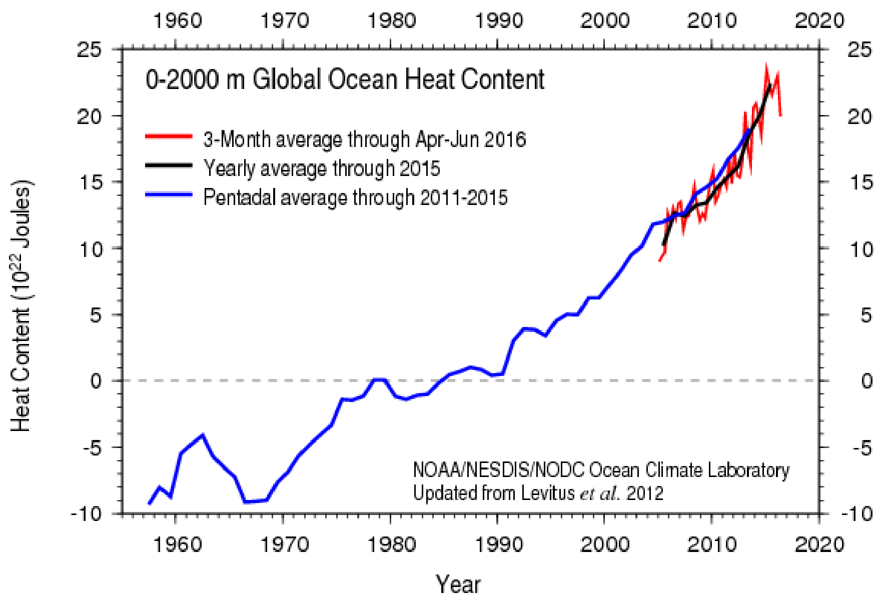
# Ocean Heat Content

- Oceans absorb 93% of global heat increase
- Annual increase is about 4.5 ZJ
  - 7x more than all the energy consumed by humans in a year!
- Since 1955
  - About 260 ZJ have been absorbed
  - Temperature in top 2000 m has risen by 0.1 °C



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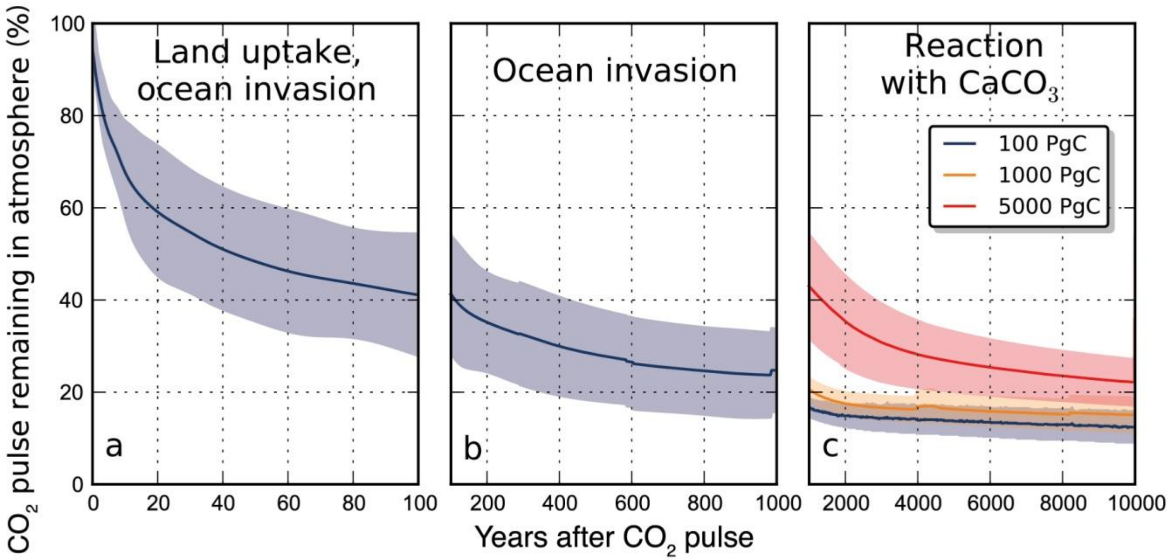
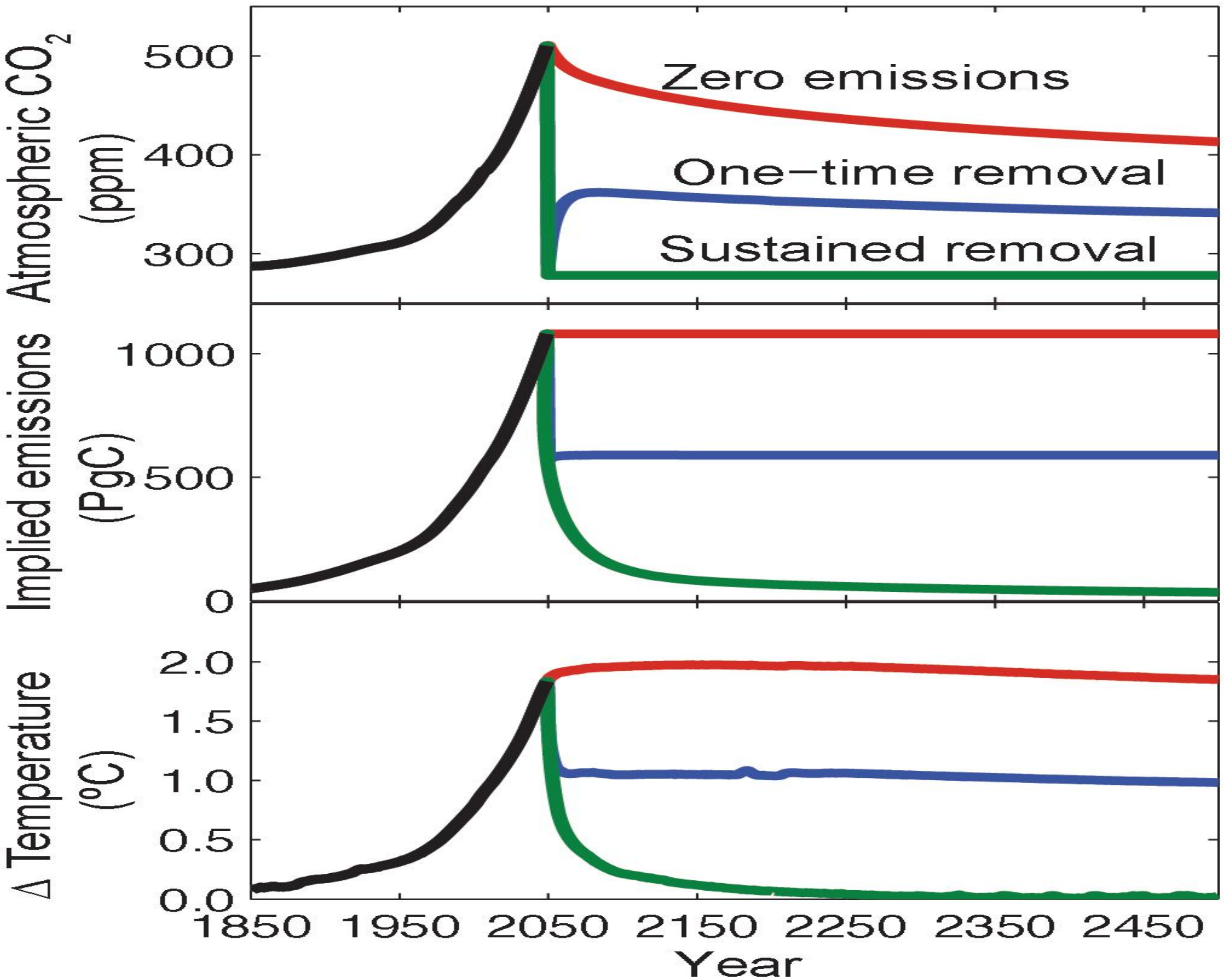
# Ocean Carbon Chemistry

- $CO_2 + H_2O + CO_3^{2-} \leftrightarrow 2\ HCO_3^-$
- Oceans absorb about half of anthropogenic $CO_2$ emissions
- Absorption is REVERSIBLE (over course of decades to centuries)




IPCC (2013), WG1 AR5 Chpt. 6

# IPCC Drawdown Models




IPCC (2013), WG1 AR5 Chpt. 6

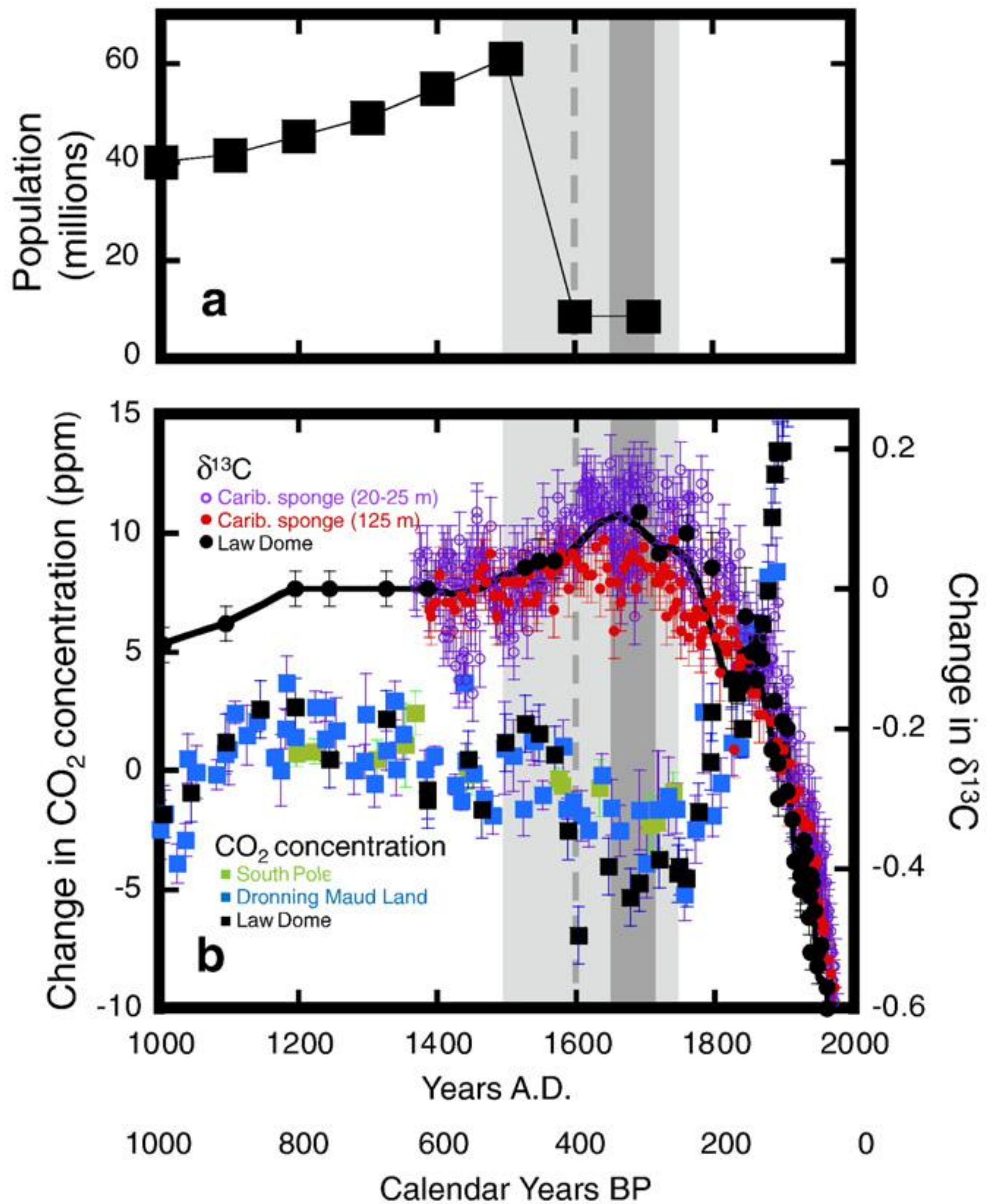
# The Little Ice Age

Hendrick Avercamp (ca.1608) Winter landscape with ice skaters

# Evidence for a drawdown in the Americas 1500-1600 AD

Factors contributing to Little Ice Age:

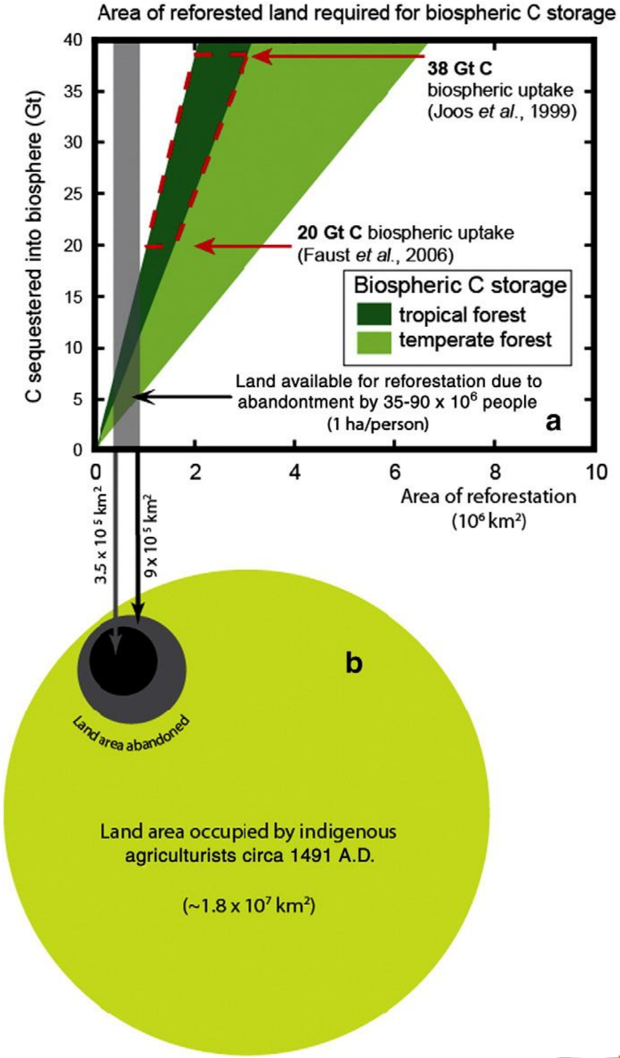
1) Pandemic followed by reforestation in the Americas (1500-1600)
2) Eruption of Huaynaputina volcano in 1600
3) Lower Solar Radiation (Maunder Minimum, 1645-1715)




Nevle and Bird, 2008

# Estimates of Drawdown Size (Pg C)

| C Reservoir | Joos et al. (1999) | Faust et al. (2006) | Nevle and Bird (2008) |
|---|---|---|---|
| Terrestrial | 37 | 17 | 5-10 |
| Ocean | -29 | -- | -- |
| Atmosphere | -8 | -8 | -8 |
| Efficiency % | 22 | 47 | 80 |



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# The Lowdown on Drawdowns

"It is thus virtually certain that the removal of $CO_2$ by carbon dioxide removal methods (CDR) will be partially offset by outgassing of $CO_2$ from the ocean and land ecosystems. Therefore, returning to pre-industrial $CO_2$ levels would require permanently sequestering an amount of carbon equal to total anthropogenic $CO_2$ emissions that have been released before the time of CDR, **roughly twice as much** the excess of atmospheric $CO_2$ above pre-industrial level . . ."

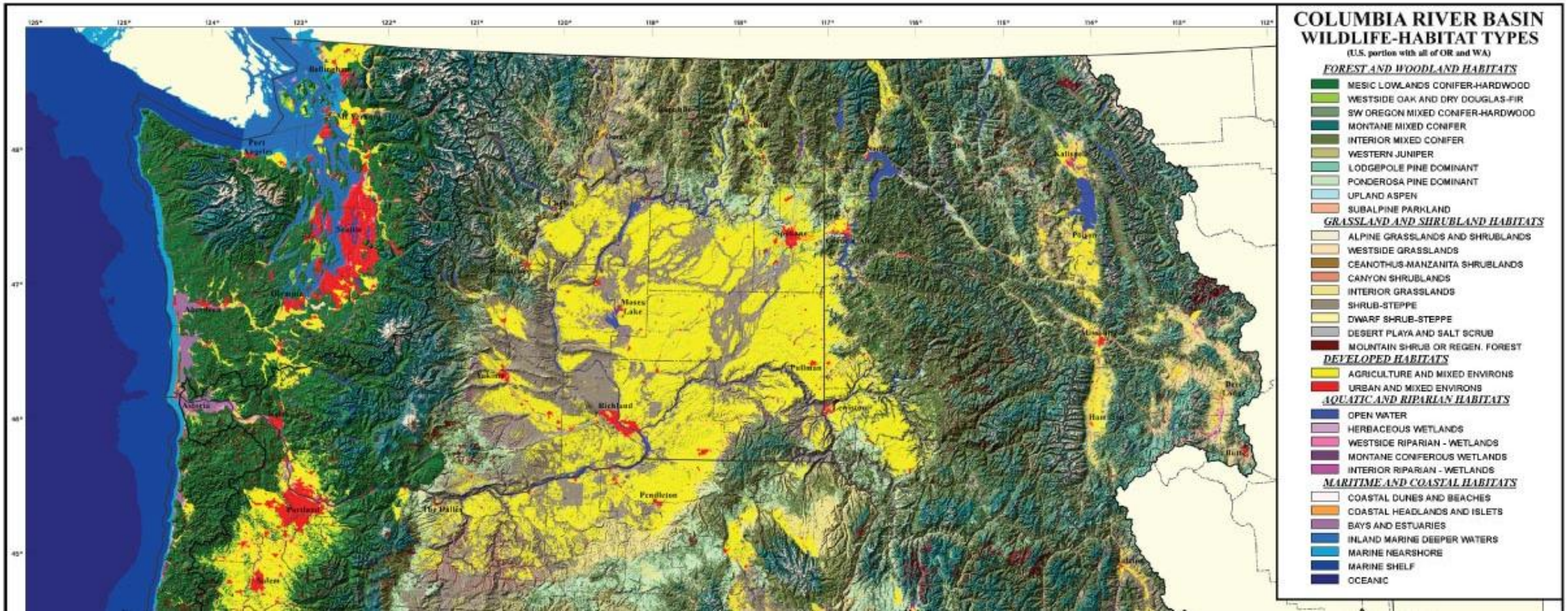
IPCC (2013), WG1 AR5, Chapter 6, p. 546-547.

# Biochar: A Better Way to Draw Down $CO_2$

- No pandemic required!
- Multiple benefits
  - Rural Economic Development
  - Enhanced Agricultural Production
  - Water Use Efficiency
  - Forest Health
  - Filtration of Contaminants
  - Climate Change Mitigation

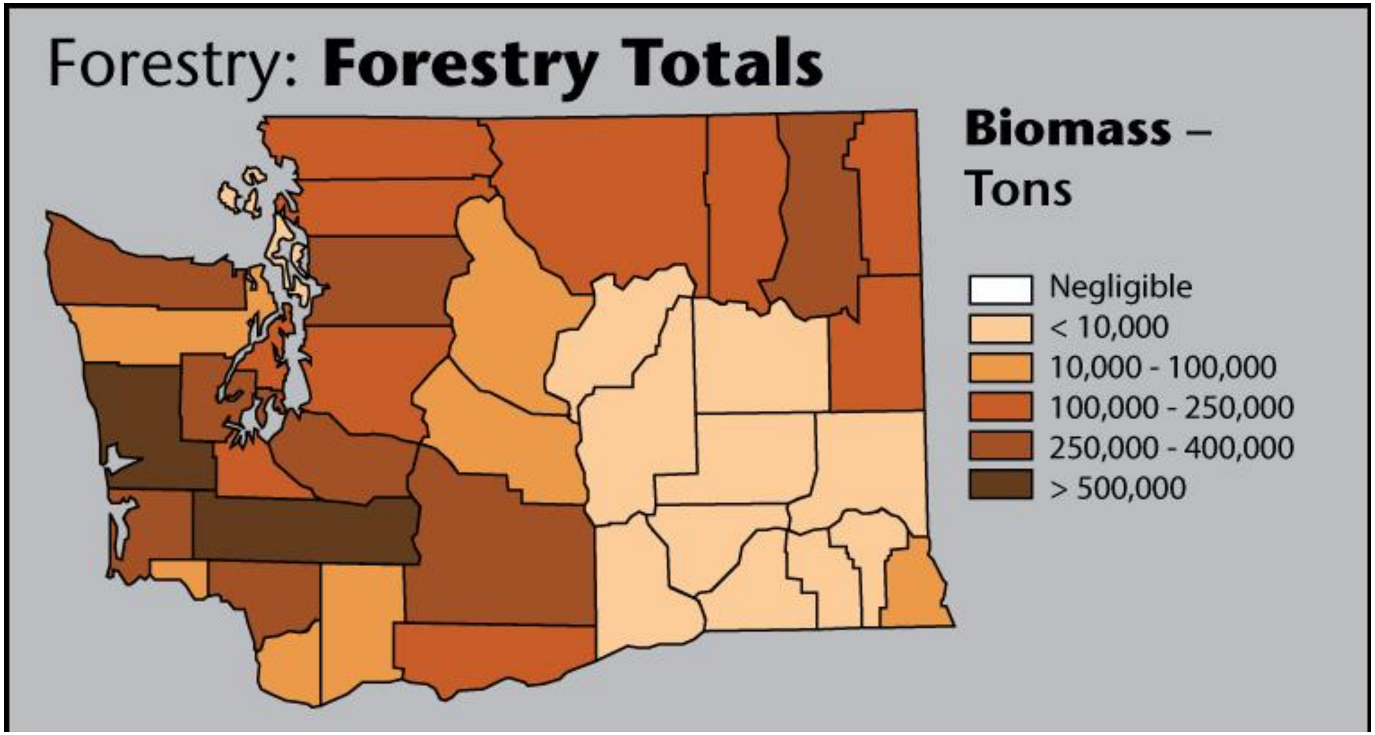
# A State Level Approach: Washington State

- Large agricultural land area for incorporation
- Moderate soil fertility
- Adequate feedstock supply
- Need for more efficient irrigation methods
- Low carbon intensity of energy supply



# Available Feedstock

- 5.8 M tons dry woody waste potentially available in WA
  - Logging, thinnings, mill residue, land clearing, orchard debris
- 3.3 M tons accounted for in 2010 solid waste survey
  - 0.9 M tons sent to landfill or incinerator



# Possible Biochar Production Methods

- Pyrolysis (slow or fast pyrolyzers, absence of oxygen, 350-550°C, highest char yields and climate benefit, but technically complex and expensive)

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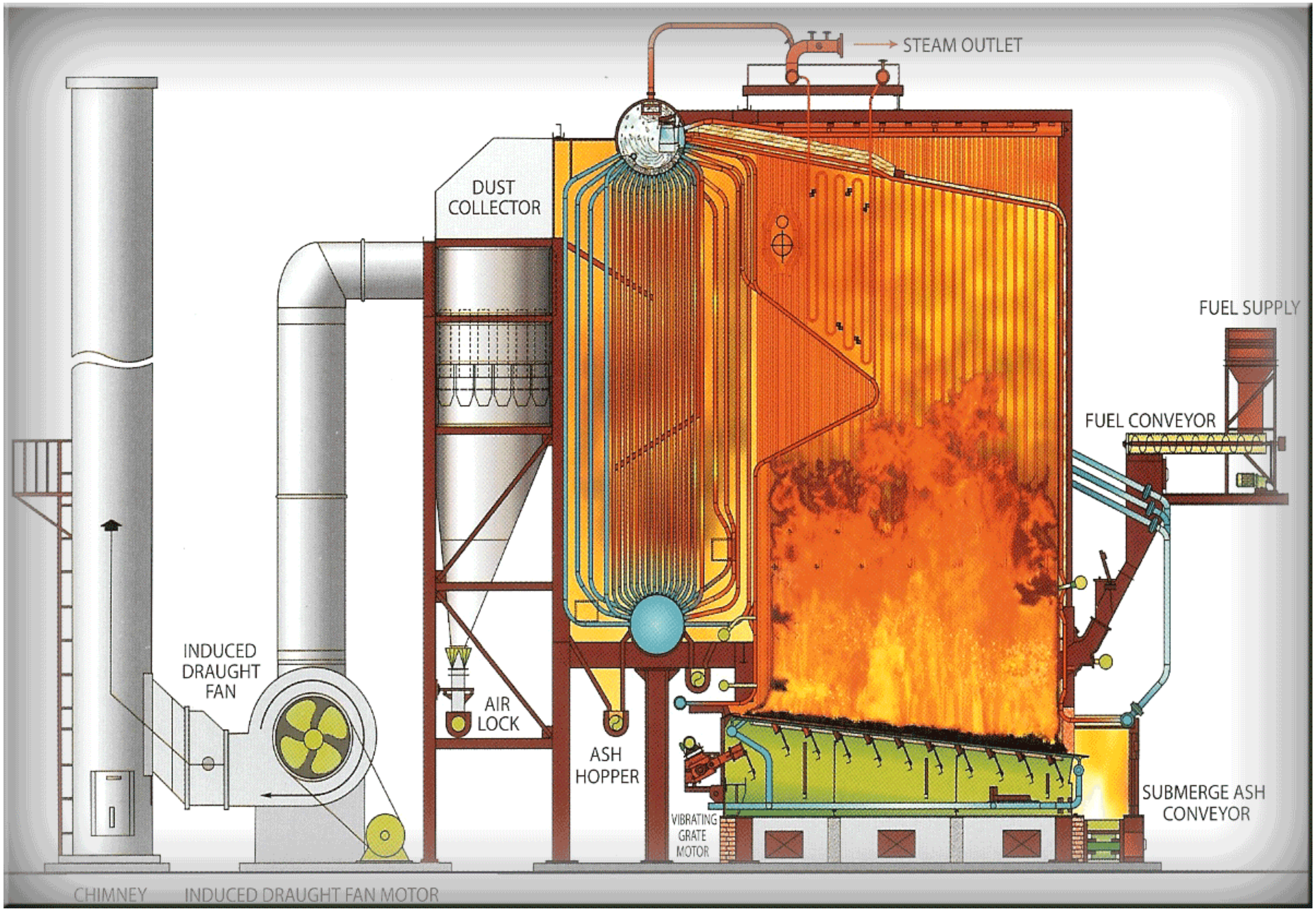
- Pyrolysis (slow or fast pyrolyzers, absence of oxygen, 350-550°C, highest char yields and climate benefit, but technically complex and expensive)
- Gasification (small units with substoichiometric levels of oxidants, 600-1000°C, lowest char yields)
- Boiler Conversion (alteration of existing wood combustion units to minimize char oxidation to ash. This can be achieved by reducing the residence time of the char inside the boiler)
  - Simpler and more economical than some of competing options
  - Alter feedstock moisture content and particle size, oxygen ratio, and biomass residence time
  - Char yields potentially comparable to other options
  - Flexible, so can maximize energy or char production as needed.

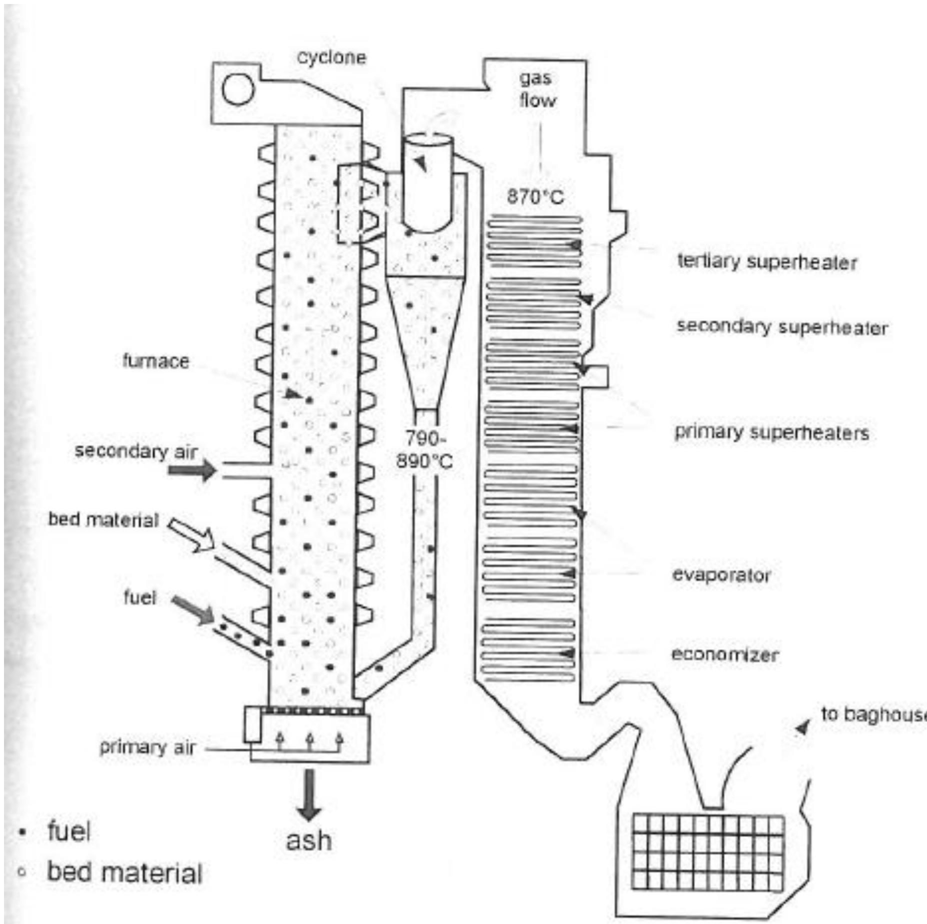
# Boilers in Washington State

- Two WA Ecology surveys have been done
- 1997 survey of all wood-waste boilers
  - 85 wood-waste boilers in 1997
  - burned 3.3 M tons wood annually
  - other feedstocks burned about 1/3 of time
  - 72% in lumber/wood products, 22% in pulp/paper products
  - Primarily spreader-stoker and pile burner (Dutch oven, fuel cell) boilers; only 3 fluidized-bed boilers
- 2009 survey of pulp/paper mill boilers only
  - 11 mills operational
  - Biomass boilers burn 1.4 M tons annually
  - Additional 0.3 M tons biomass needed to replace all fossil fuel
  - Mix of stoker-fired and fluidized-bed boilers
  - Recovery boilers use black liquor 2/3 of time, biomass for most of rest

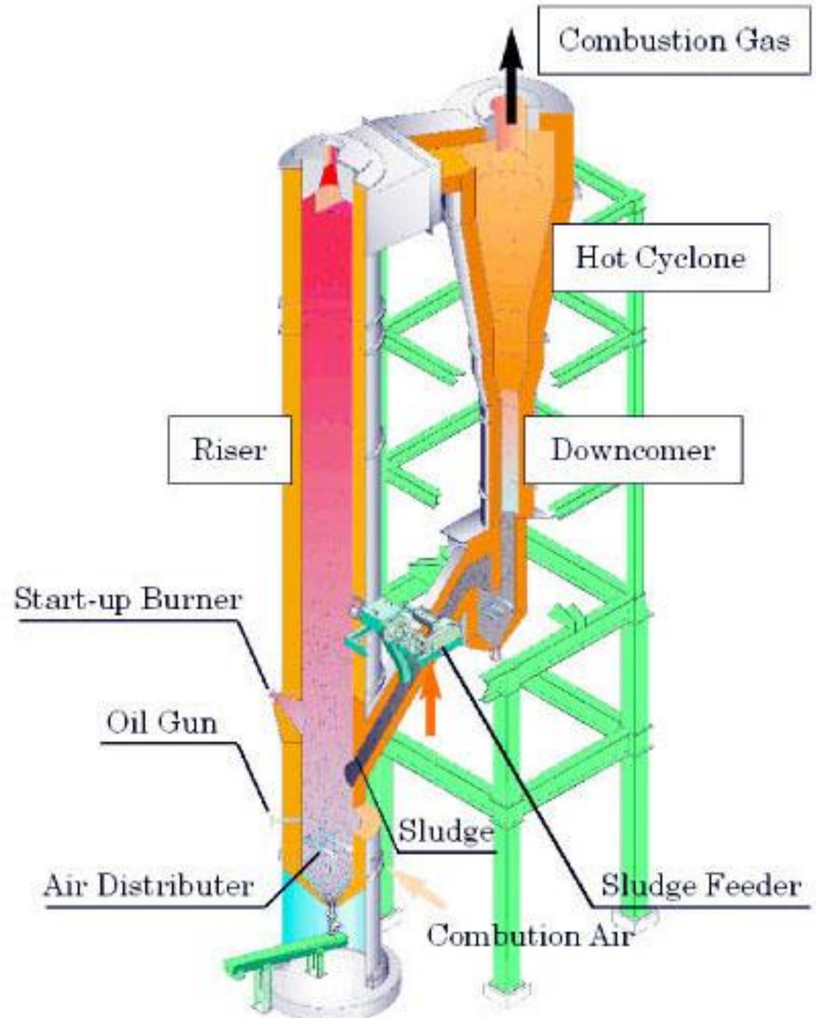
# Stoker-fired Boiler



# Fluidized-Bed Boilers




Bubbling -Bed




Circulating

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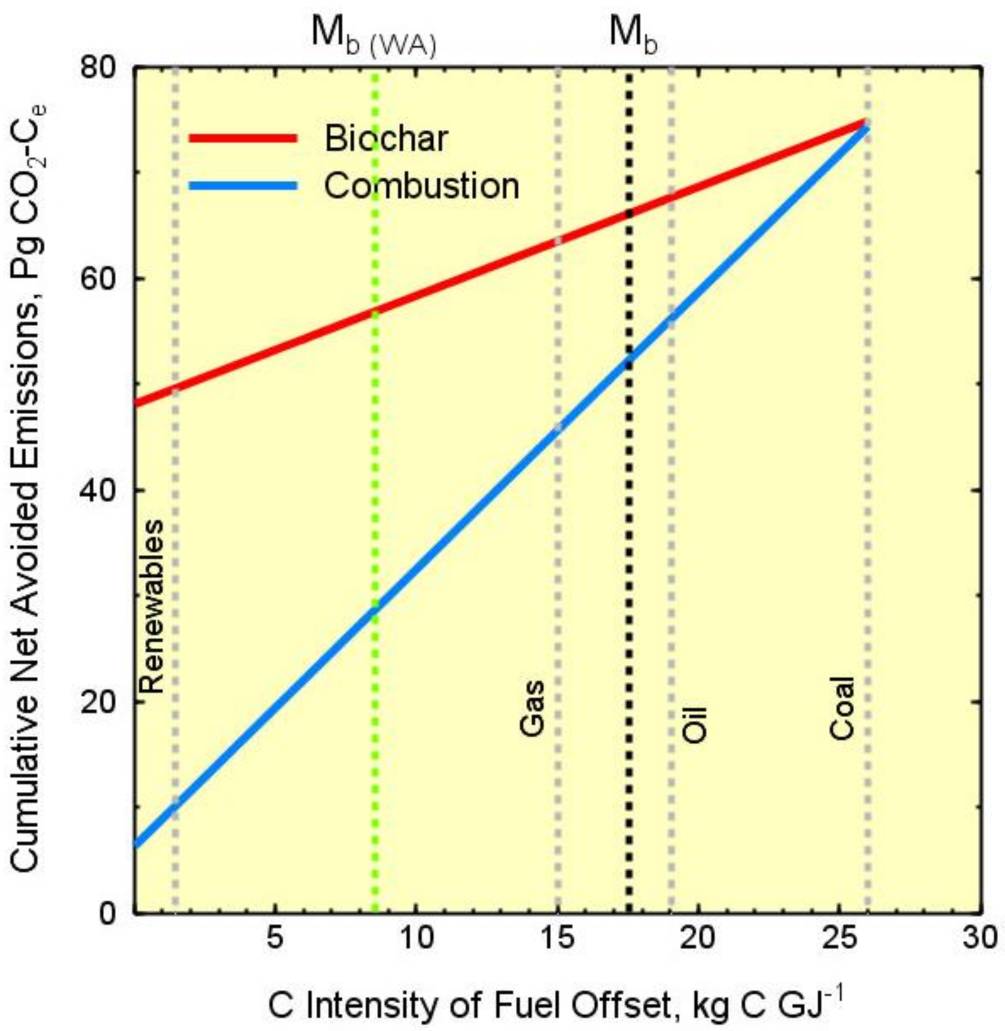
# Biochar is twice as effective as bioenergy for climate change mitigation in Washington




JE Amonette 23Aug2016

after Woolf et al. (2010)

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# Carbon Budgets and Assumptions

- Produced biochar contains 58% C
- 1.1 t C offset/t C fixed as biochar (energy and primary productivity enhancements)
- 1 t $CO_2$ offset requires 1.02 bdt biomass
- Available biomass suggests 1.3-2.2 Mt biochar produced annually
- 2.2 Mt/yr x 100 years = 0.52 Pg $CO_2$ offset
- = 0.07 ppm $CO_2$ drawdown (0.02-0.03 ppm after degassing)

# Biochar storage capacity

- 50 t biochar C (86 t biochar) applied to top 15 cm of agronomic lands
- 86 t biochar * 3.1 Mha = 265 Mt biochar maximum storage capacity
- 220 Mt biochar produced over 100 years
- Washington has a 120-year capacity for biochar and a maximum offset of 0.62 Pg $CO_2$ (ca. 0.08 ppm)
- Application to forested and pasture lands (11 Mha) and at greater depths could increase total drawdown by as much as 10-fold.

# Conclusions

- Drawdown of atmospheric $CO_2$ is essential, but will require removal of all emitted (i.e., ca. 500 Pg C) due to buffering from oceans and land stocks
- Washington state is well-positioned to demonstrate large-scale economical production of biochar using existing boilers with slight modifications to maximize char production
- This large-scale production could increase agricultural productivity, improve water-use efficiency, and stimulate a new industry
- Total drawdown in Washington state over a century is on the order of 0.62 Pg $CO_2$, but could be as much as 6 Pg $CO_2$ with application to agronomic, forested, and pasture lands and development of deep injection technology.

# Acknowledgments

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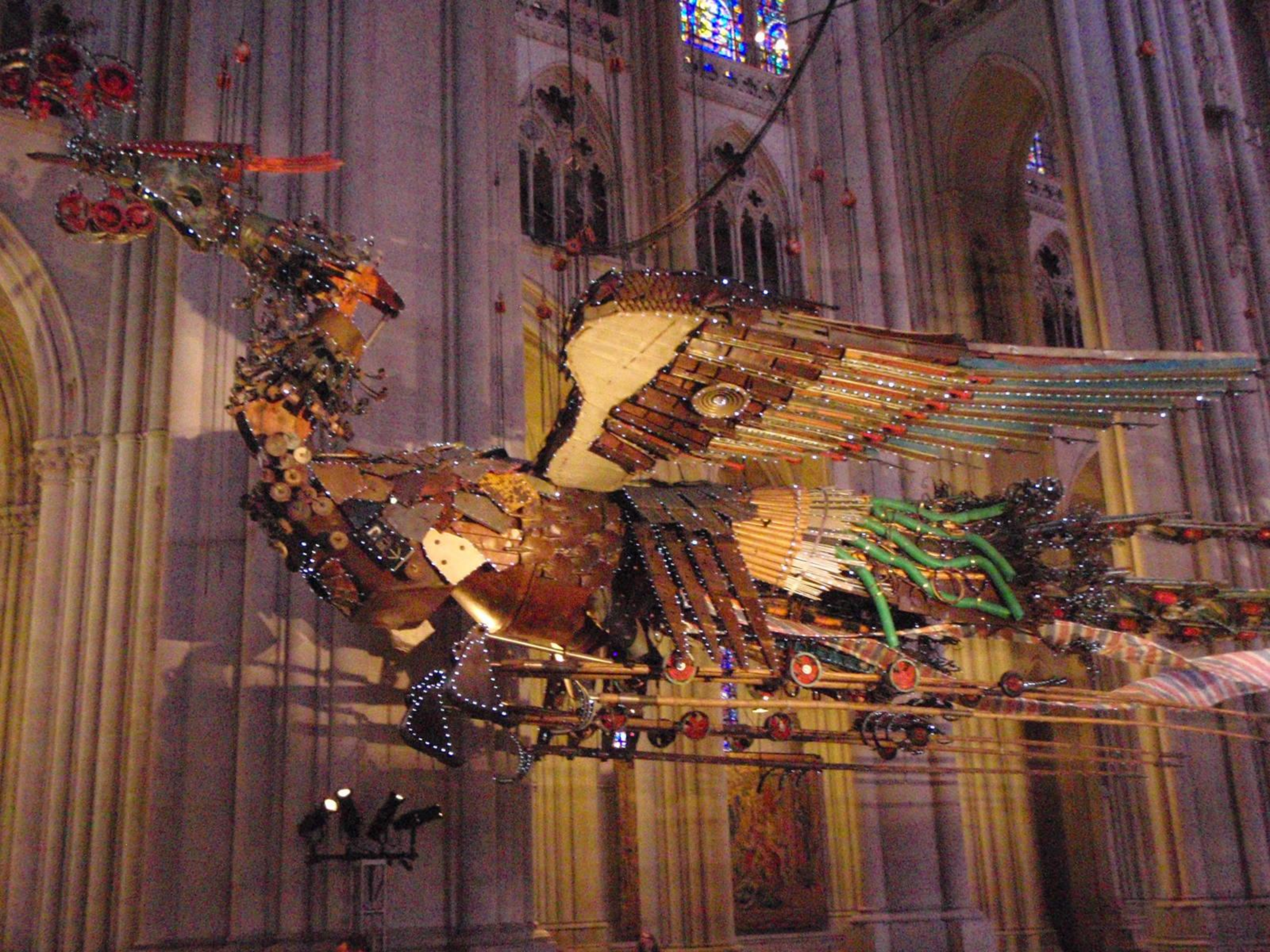
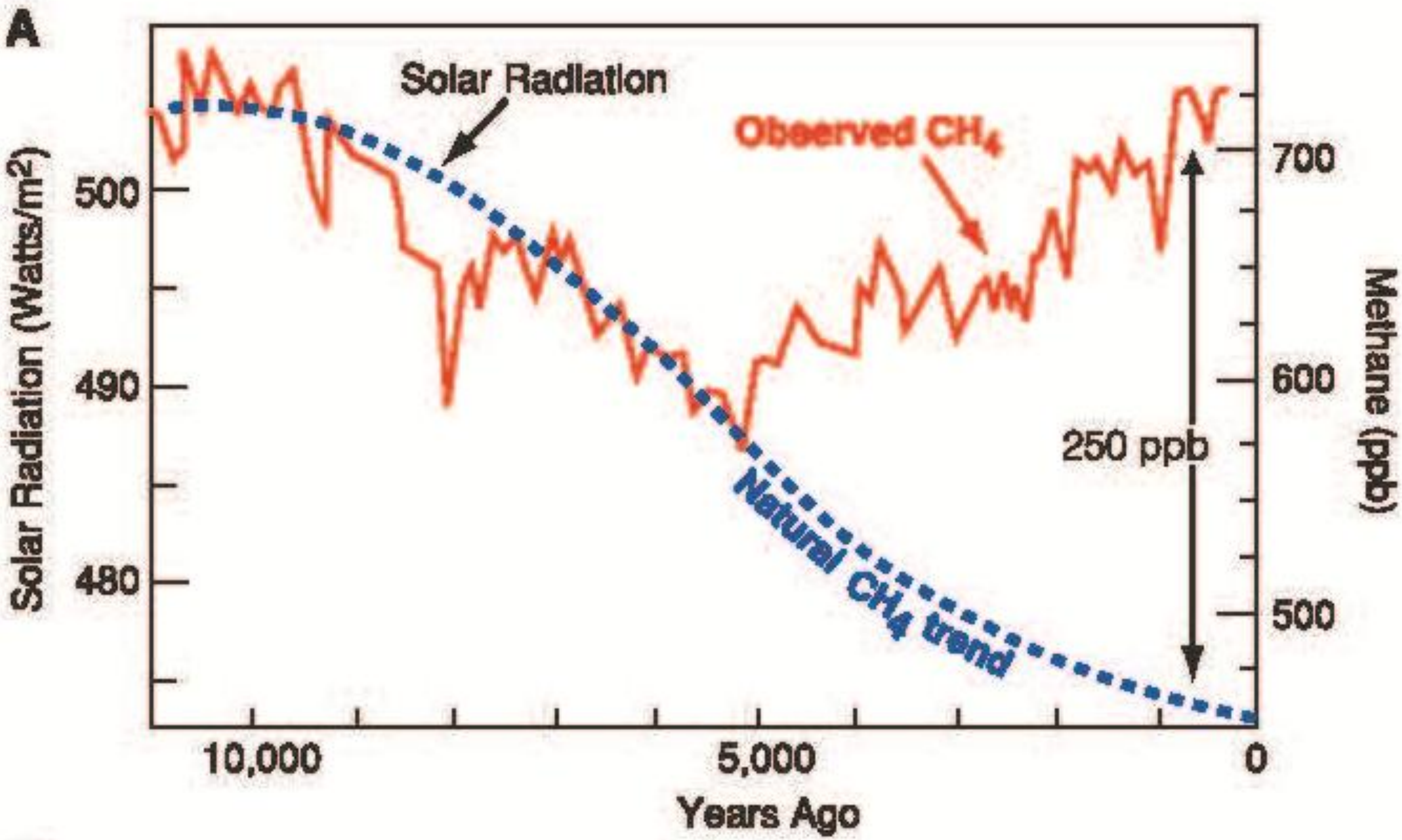
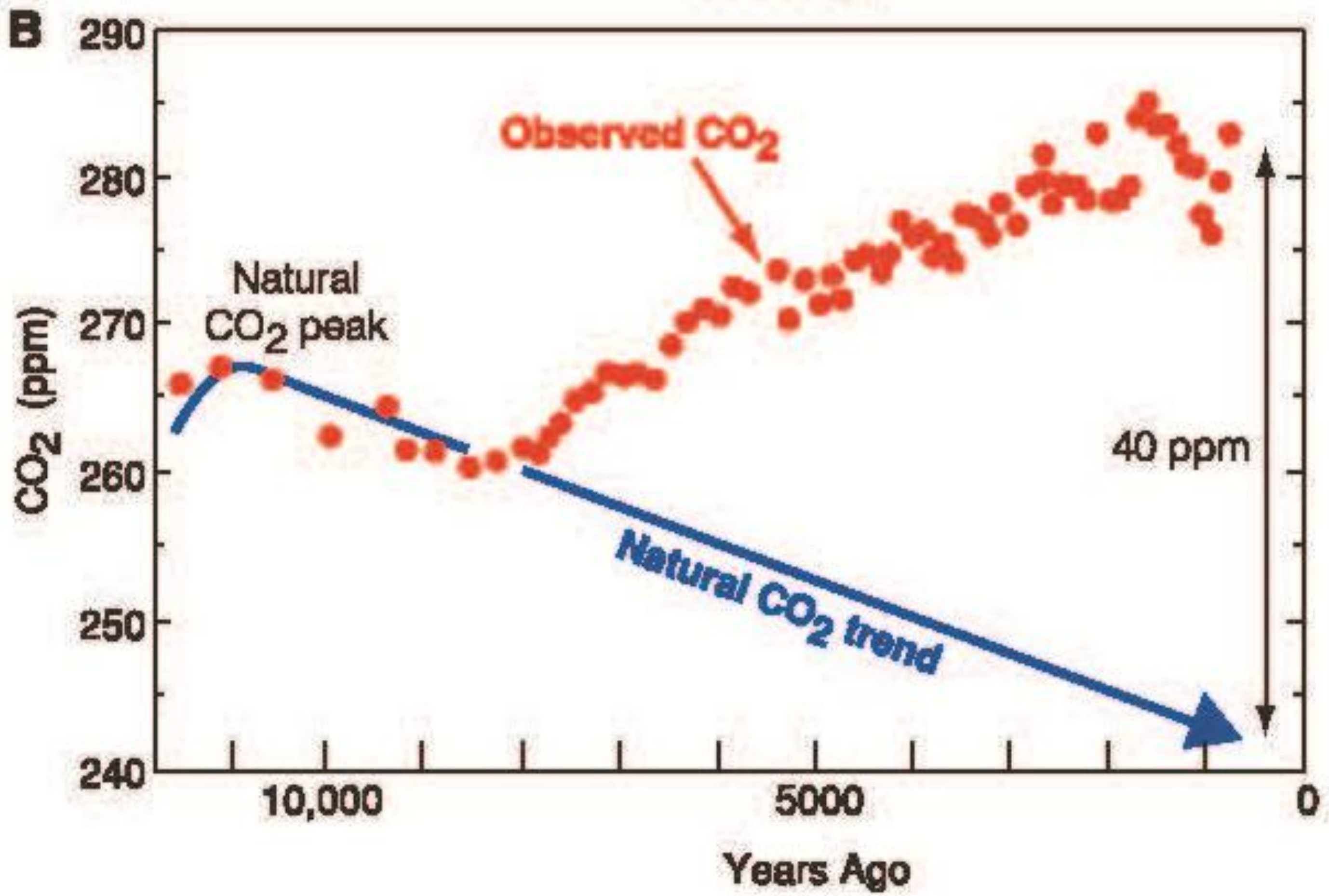


# Anthropogenic Methane




Ruddiman et al., 2007

# Anthropogenic Carbon Dioxide




Ruddiman et al., 2007