Terrestrial Carbon Sequestration Track

Fifth Annual Conference on Carbon Capture & Sequestration

10 May 2006 – Alexandria, Virginia

Wednesday a.m.

Science & Technology

Wednesday p.m.

Potential, Economics, Implementation, Trading

Terrestrial Carbon Sequestration
Setting the Stage

Ken Andrasko, U.S. EPA

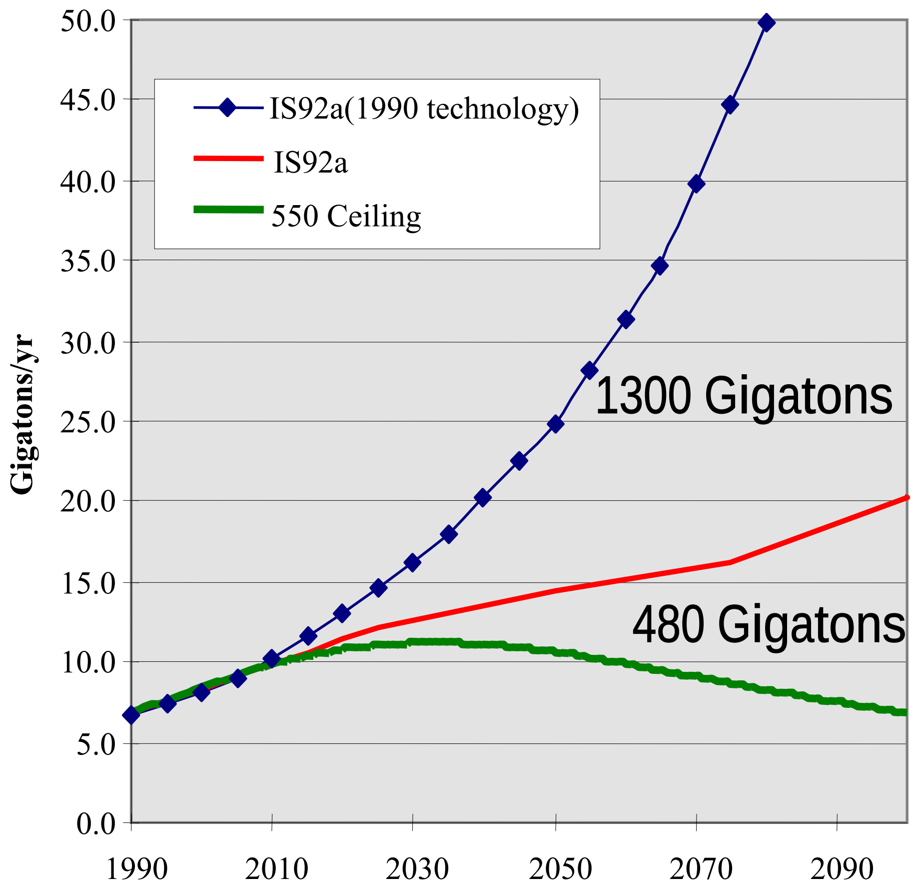
Robin Graham, Oak Ridge National Laboratory

F. Blaine Metting, Pacific NW National Laboratory

1. ***Soil Carbon Sequestration***
2. ***Carbon Sequestration in Forests***
3. ***Bioenergy Carbon Offset Potential***

Global Carbon Management

Technologies in the Current R&D Pipeline Are Not Enough



Where today's technology will take us

Where our current aspirations for technology will take us

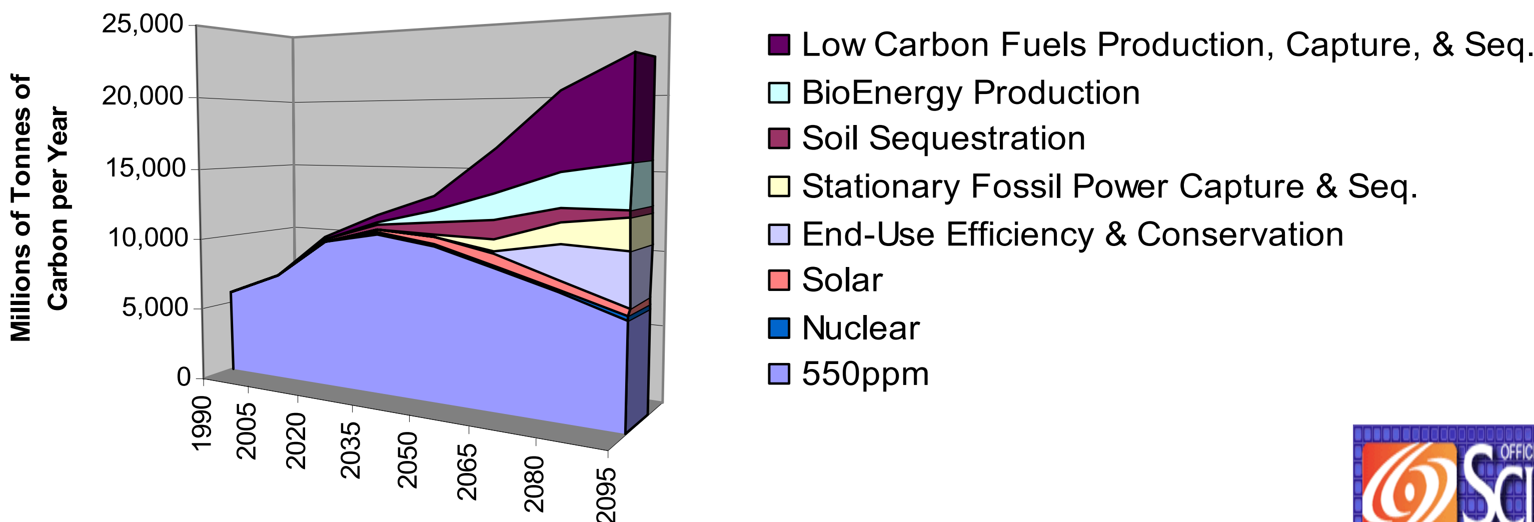
Where we need to go to stabilize carbon

OFFICE OF SCIENCE
U.S. DEPARTMENT of ENERGY

Carbon Management

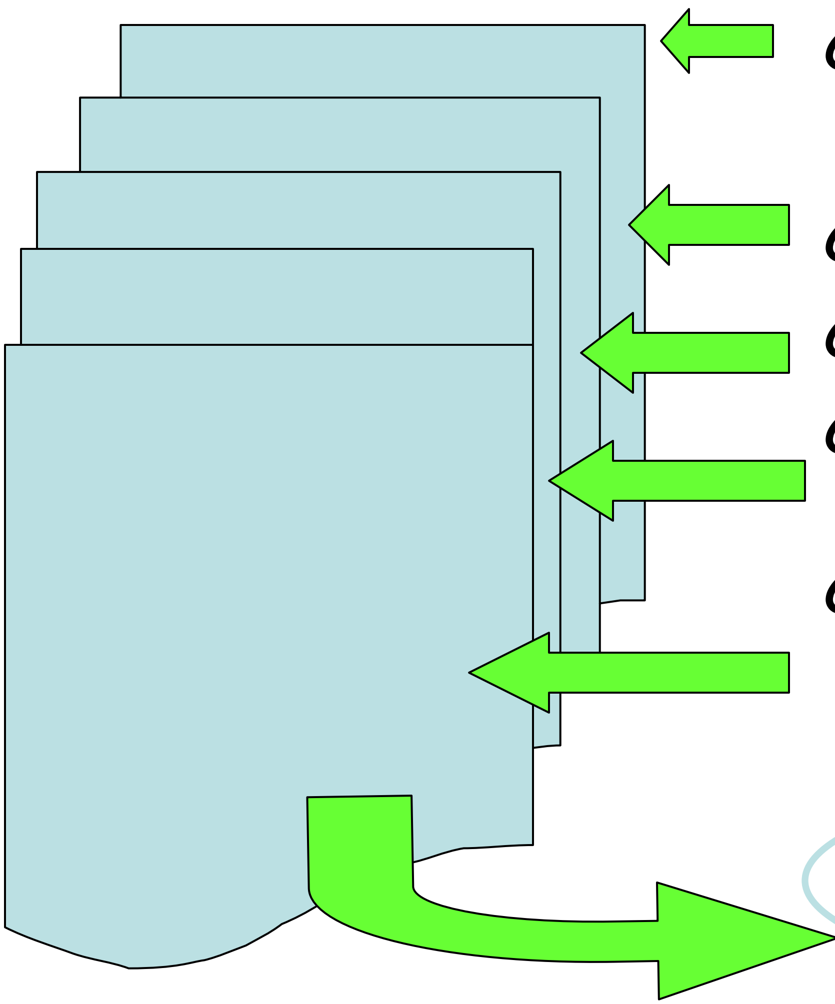
~ Gigaton Carbon Impact of Technology Systems

	Global	United States
Low-Carbon Fuels Production, Capture, & Sequestration	186	27
BioEnergy	90	15
Terrestrial & Soil Sequestration	51	6
Stationary Fossil Power Capture & Sequestration	51	5
Energy Efficiency	42	14
Solar	34	0
Conservation ("Doing with Less")	17	12
Nuclear	13	0



OFFICE OF SCIENCE U.S. DEPARTMENT of ENERGY

We Need to Evaluate Options Using Multiple Criteria, beyond Biophysical Potential



Criterion 1: Biophysical Potential

- Saturation of C in pools

Criterion 2: Economic Potential

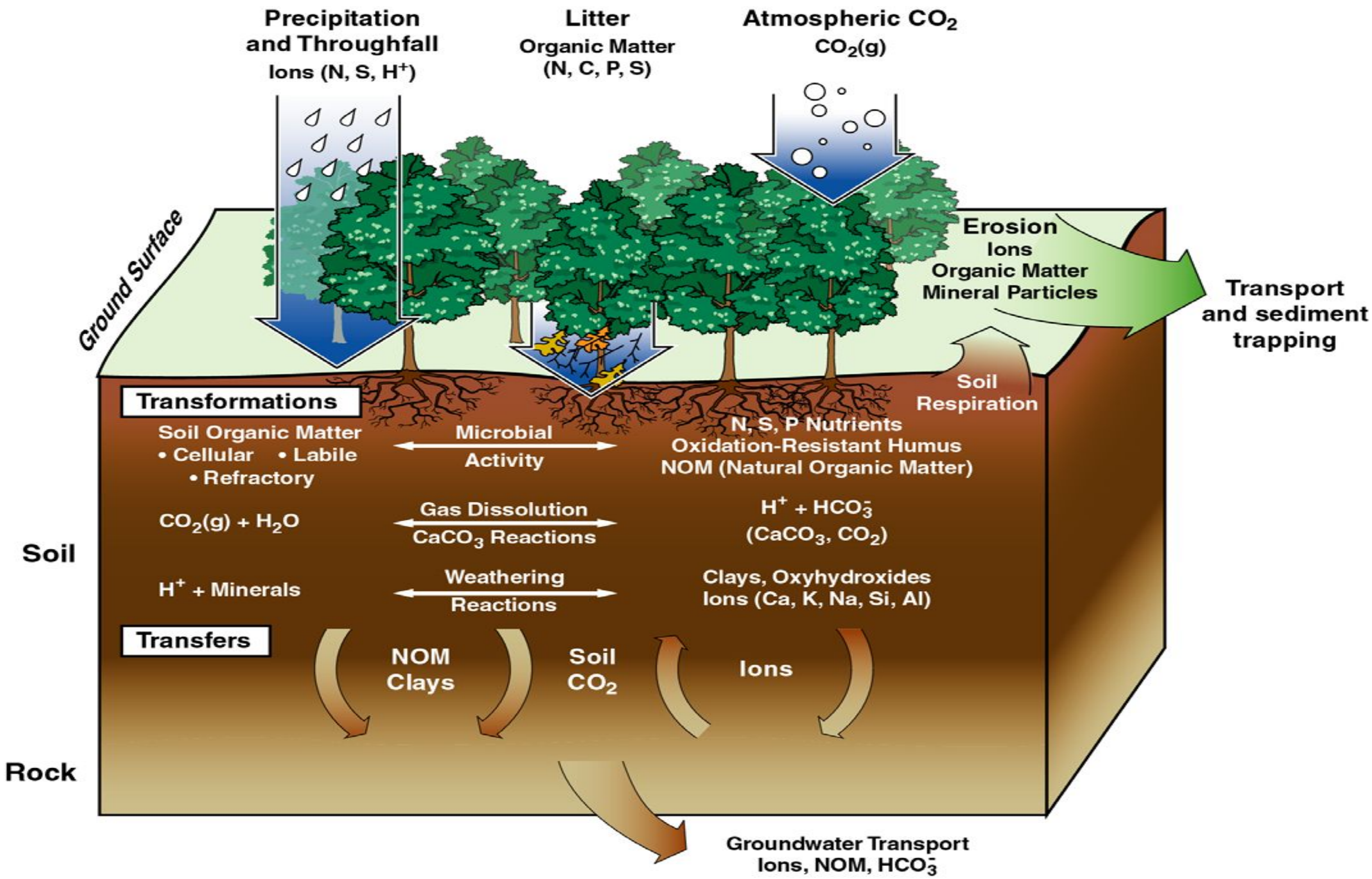
Criterion 3: Competitive Potential

Criterion 4: Adjustments for leakage, reversib.

Criterion 5: Limited no. of co-effects (water Q)

Consider competitive mix of options, by region, by C price

1. Soil Carbon Sequestration

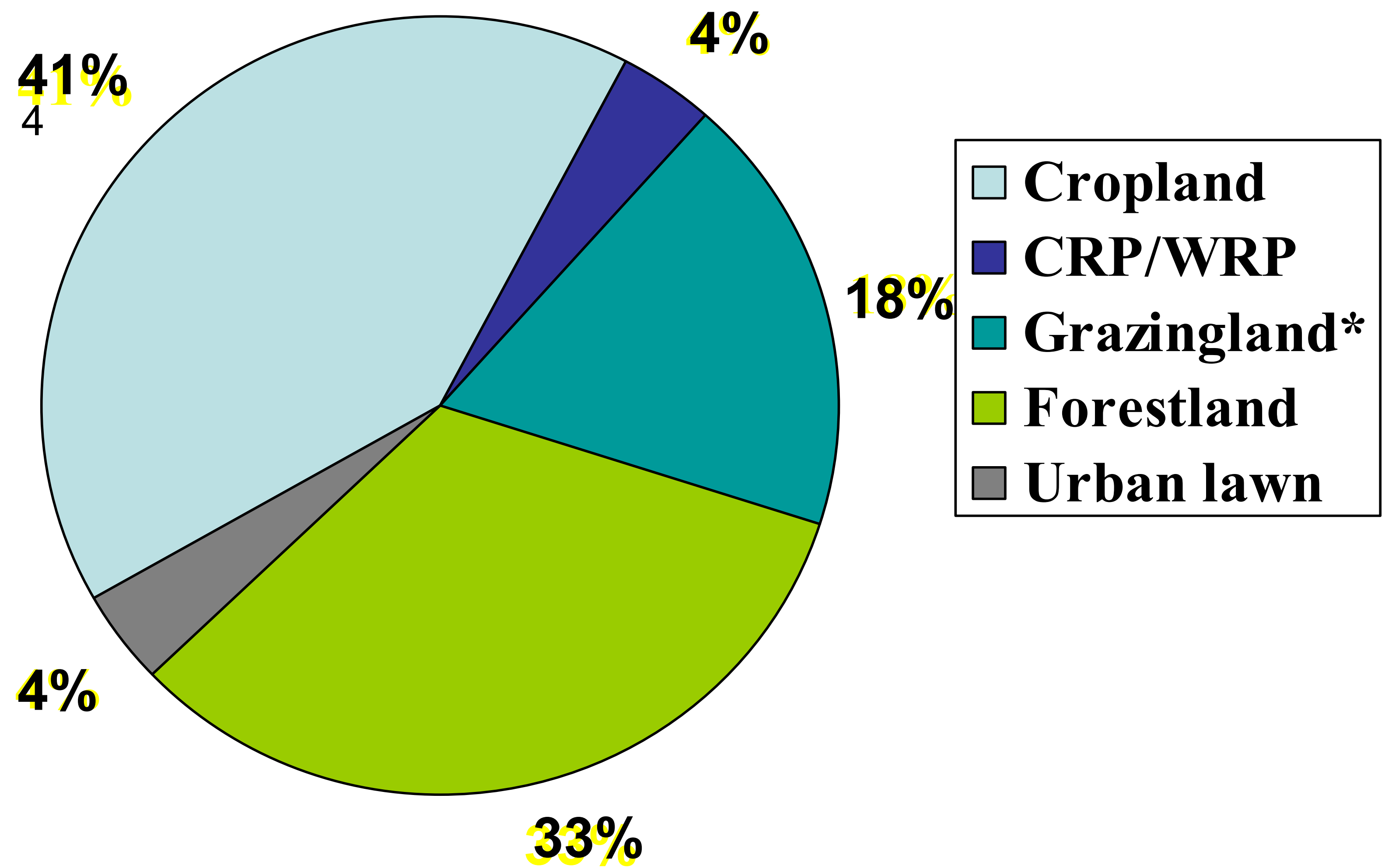


Soil Carbon Opportunity

- Historic loss of soil C of 55 Gt = 7% current atmospheric load
- Opportunity is to restore lost C & enhance sequestration
- Enhancement by
  - Increase above-ground inputs
  - Increase below-ground inputs
  - Modify the quality of the inputs
  - Increase proportion of soil C in long-lived pools
  - Land use practices
- Land use
  - Revert marginal lands to natural vegetation
  - Restore degraded lands
  - Adopt best management practices on prime agricultural lands
  - Erosion control
  - Biofuel crops on idle lands
- Global century-scale opportunity > 50 Gt
  @ peak rate ~ 1 Gt/yr in early decades

U.S. Soil C Sequestration Potential

by Land Category (% of 322 MMT C/yr)



Science & Technology Needs for Enhanced Soil C Sequestration

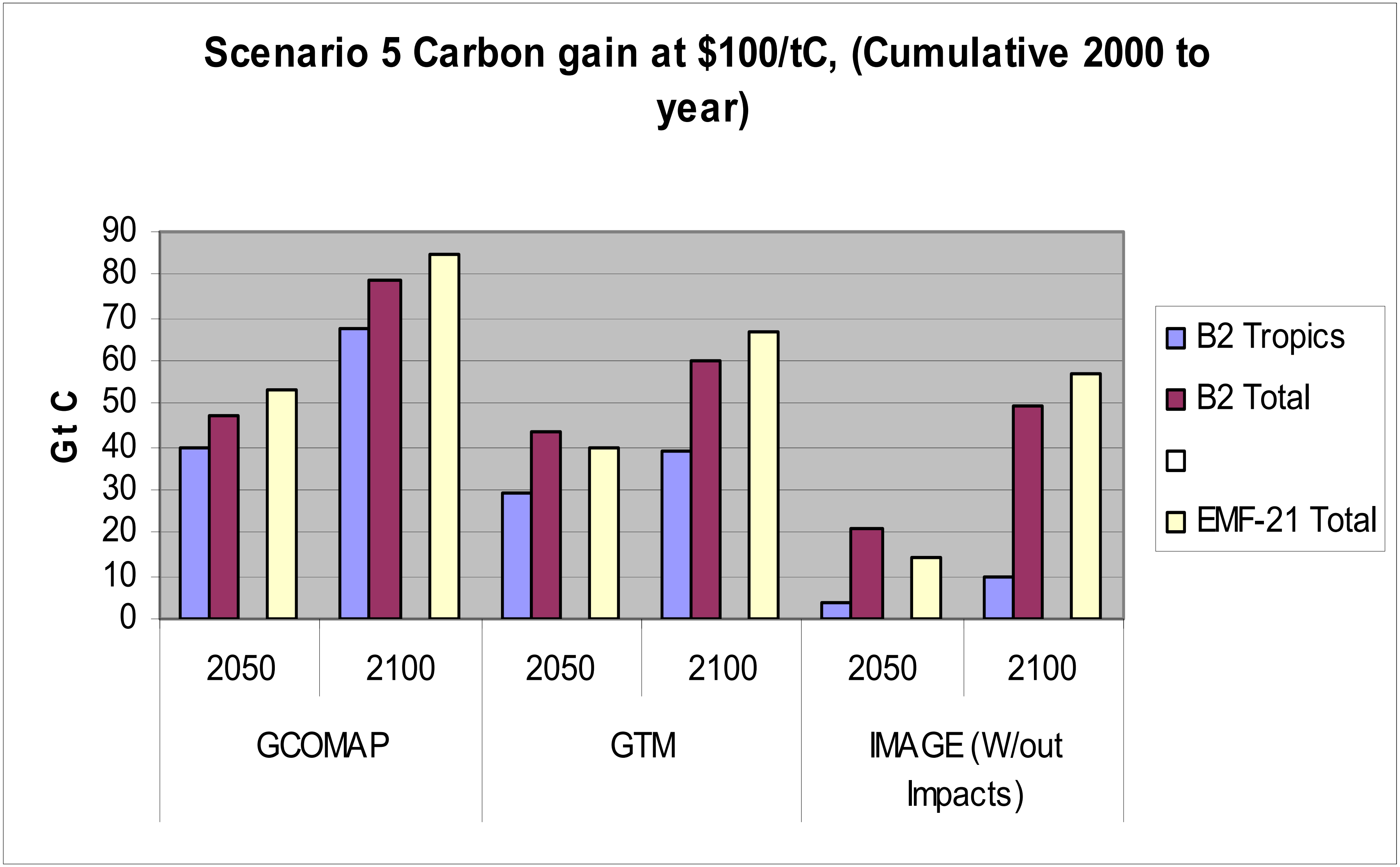
- Improved measurement and monitoring technologies
- Predictive understanding of biological, chemical and physical mechanisms controlling soil C dynamics
- Integrative models that address multiple spatial and temporal scales
- Understanding of climate change impacts on C sequestration
- Understanding of ecosystem response to enhanced soil C sequestration

2. Forest Carbon Sequestration

- **What GHG mitigation options in forestry make GHG and economic sense, by region?**
- **What are the GHG and co-benefits, /acre?**
- **Under what biophysical land, carbon market, & policy conditions could GHG benefits be realized?**
- **How would alternate eligibility and accounting rules for forestry activities affect landowners & mitigation potential?**
- **How could sinks technical issues (eg, baseline setting, additionality, leakage, reversibility) be addressed, & how does that affect GHG benefits accounting?**

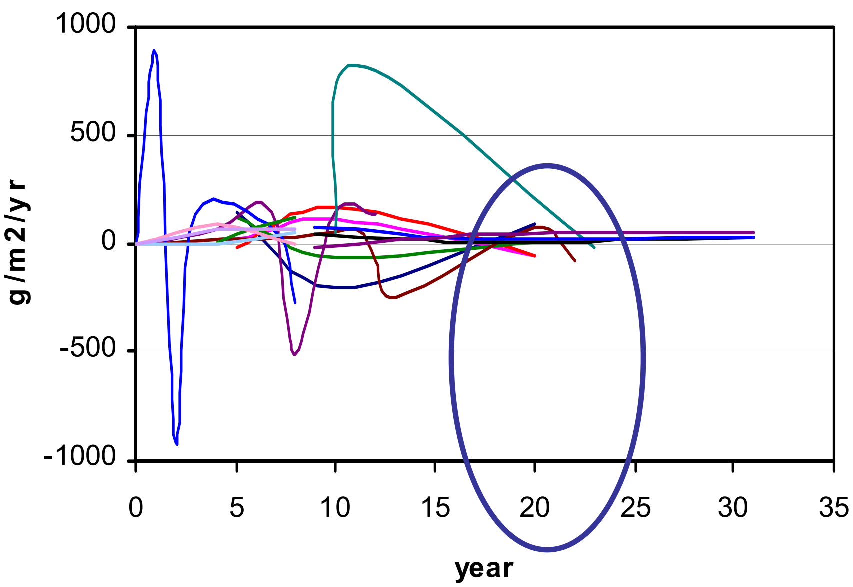
Global Forestry Sequestration Potential for 3 Models: Tropics in 2050: 4-40 GtC, Global Total 2050: 21 – 48 GtC

Source: EMF 21 scenario results



Issue: Saturation of Sequestration in Ag Soils and Forests

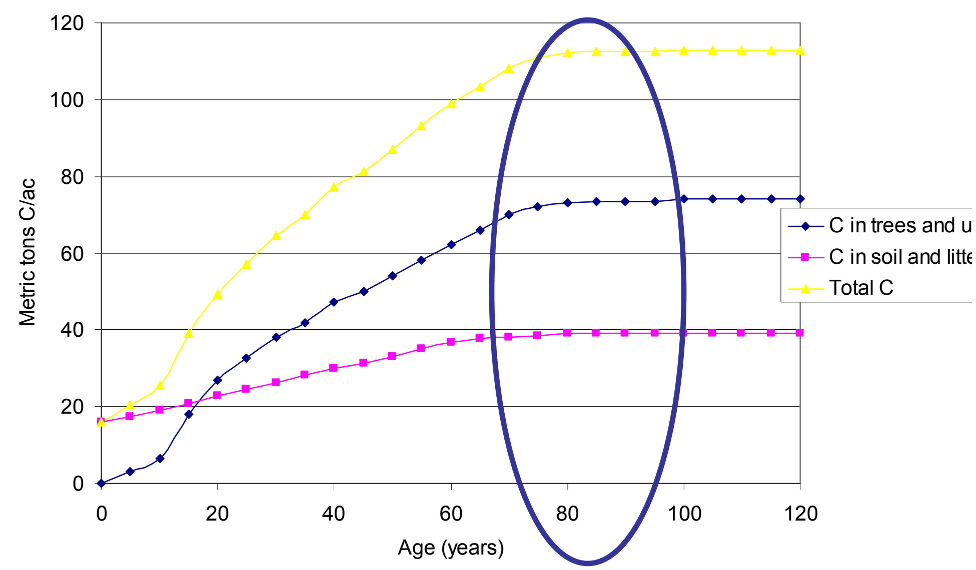
Results – C accumulation vs. time with change from conventional till to no-till



West and Post, Oak Ridge NL

Note saturation by year 20

Figure 2. Cumulative Carbon sequestration in a Southeastern U.S. pine plantation
Source: Data Drawn form Birdsey (1996)



Birdsey et al, USFS, FORCARB

Note saturation by year 80

Source: McCarl, 2002

Forest Sequestration Research Needs & Challenges

- Reduce measurement, monitoring, & transaction costs
- Design implementation approaches to address bundling of many land parcels efficiently
- Understand regional effects of sequestration options, programs, and effect of carbon price quantities
- Site and design sequestration projects to avoid leakage
- Develop methods to avoid reversibility of GHG benefits through fire, etc. (permanence issues)
- Quantify co-benefits & co-effects (e.g., erosion, biodiversity, water quality): will affect competitive mix & location of offsets.
- GHG program guidance decisions (eg, baselines, monitoring protocols) have big, unknown effect on efficiency of activities

3. Bioenergy Carbon Offset Potential

Energy potential

		2050	2100
Electricity (PWh/yr)		**63-132**	**98-225**
Liquid Fuels (EJ/yr)		**171-361**	**217-613**

World estimates of technical bioenergy potential based on IPCC land-use scenarios. Electricity and liquid fuels are not additive *(M. Hoojwijk et al. 2005)*

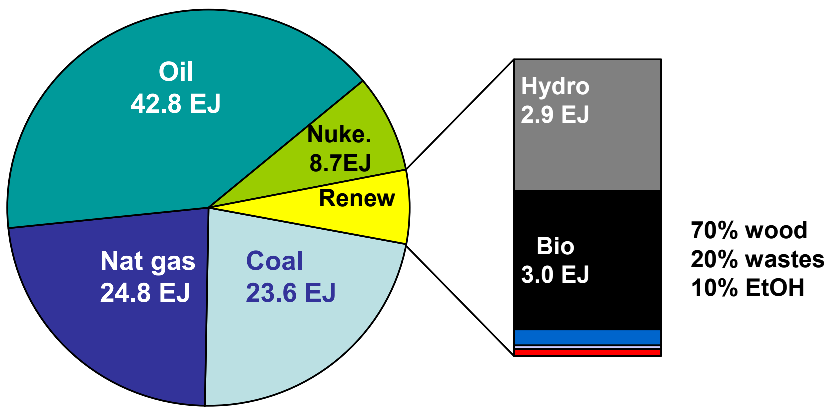
Carbon offset potential

		2050	2100
Electricity (GT/yr)		**6.7 to 14.5**	**10.4 to 23.8**
Liquid Fuels (GT/yr)		**4.1 to 14.1**	**8.4 to 23.9**

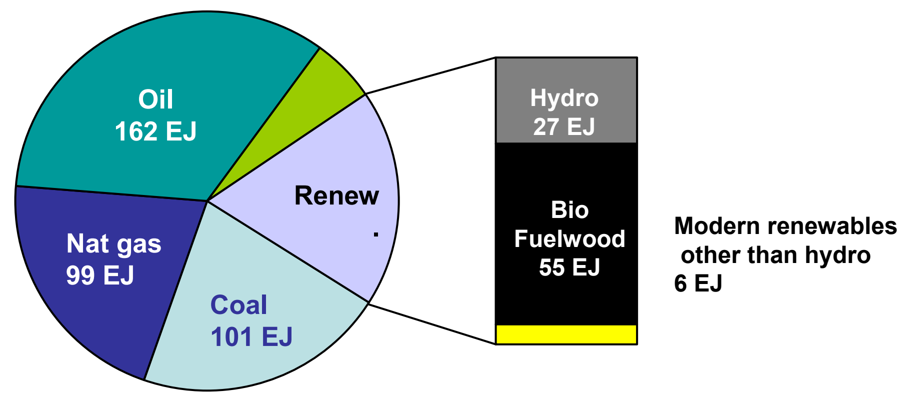
World estimates of GT carbon offset. Assumes 18GJ/ton biomass and carbon offset of 0.236 T C/T biomass for gasoline substitution and 0.385 T C/ T biomass for coal to electricity substitution. Derived from M. Hoojwijk et al 2005 and Graham et al 1992.

Current Bioenergy use

2004 US Energy Consumption 105 EJ



2003 World Energy Consumption 470 EJ



In 2004, US produced 3 billion gallons of EtOH, virtually all from corn grain. US used 136 billion gallons of gasoline. US also produced 36 million gallons of biodiesel but consumed 40.7 billion gallons. Black liquor from the pulp and paper industry was the primary source of the US bioenergy.

US goal is 8 billion gallons of EtOH, 4 EJ power & heat and 28 Tg of bio-based chemicals by 2030 (US Bioenergy Act of 2000)

Quantifying greenhouse gas benefits from displacing Fossil Fuels

Net bioenergy emissions- net fossil fuel emissions = Benefit

Bioenergy GHG benefit depends on

- Energy type – transport fuel, electricity, heat
- Fossil fuel – coal, natural gas, oil
- Technologies used to create both the fossil and bio-based energy.

Challenging because a single biofeedstock e.g. maize will be merchandized into many products - EtOH, protein, oil, starch, etc.

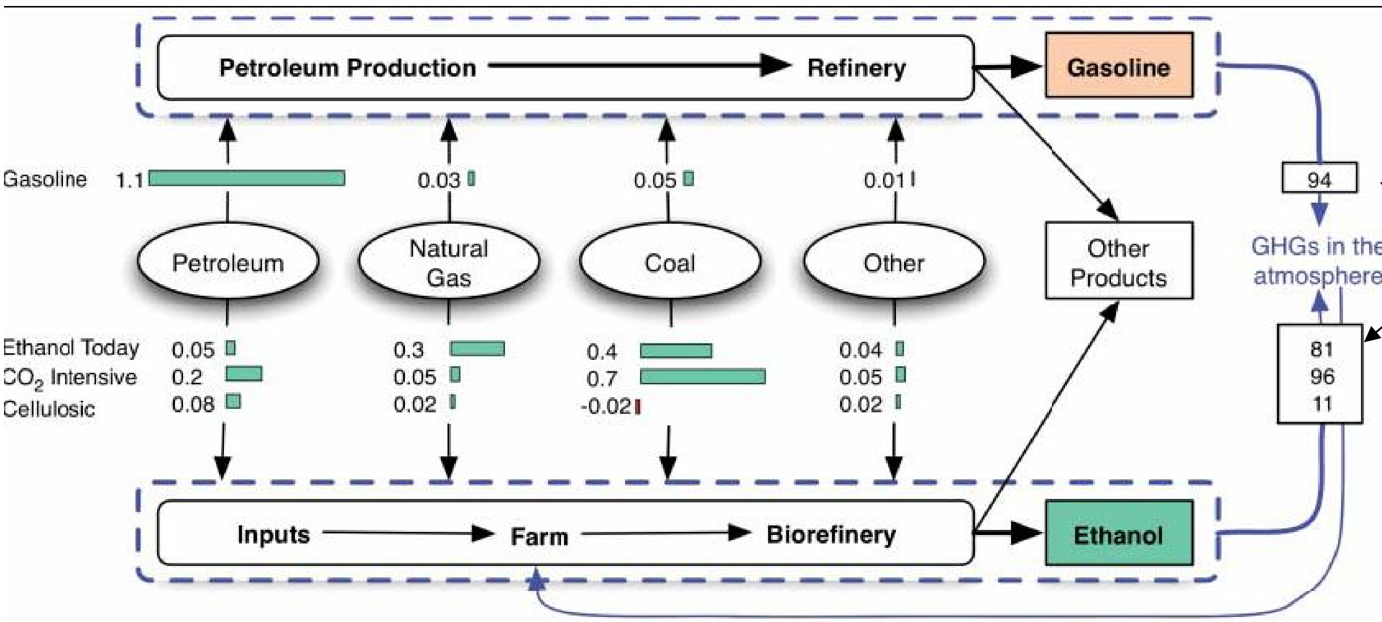
Need to take a <u>life cycle approach</u> – e.g., from well to tailpipe or bare field to transmission line.

Comparison done based on appropriate fuel unit- Net emissions/mile driven or kWh or MBtu heat per ha in production.

Controversy over GHG benefits of bioenergy comes from how the system boundaries were drawn to do the analysis

Impact of conversion technology and biofeedstock on carbon offset potentials

An EJ of corn grain ethanol currently displaces 0.04 GT C-CO_2 equivalent
An EJ of cellulosic ethanol would displaces 0.23 GT C-CO_2 equivalent



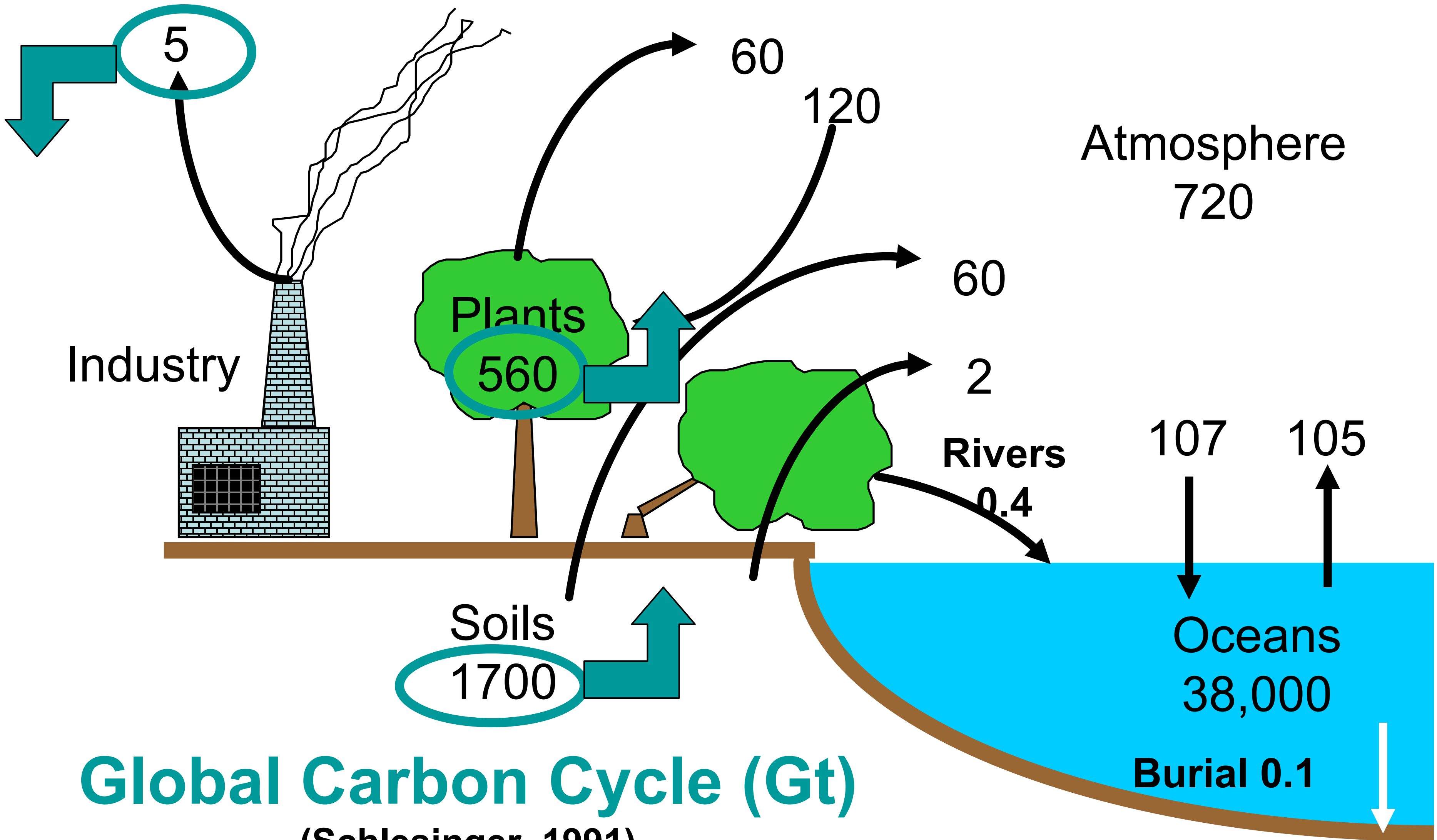
Kg CO_2/MJ fuel

Farrell et al .2006. Ethanol can contribute to Energy and Environmental Goals. Science 311:506-508

Science & Technology Needs for Bioenergy

- Cellulosic crops are largely still "wild". They have not been bred or engineered to maximize their bioenergy or carbon offse potential
  - Yield - total and (cellulose & hemicellulose)
  - Material quality w/ regards harvesting, disease resistance, bioprocessing, thermomechanical processing
  - Poplar genome just sequenced (no other tree sequenced) .
  - Most grasses are challenging to sequence and annotate
  - Potential to enhance soil carbon sequestration
- Large room for improvements in cellulosic bioconversion to fuels.
- Need for improvement in gasification technology for biomass

Terrestrial Carbon Sequestration technologies can shape this cycle



Global Carbon Cycle (Gt)

(Schlesinger, 1991)