Climate Stabilization, Agriculture and Land Use

Forestry and Agriculture Greenhouse Gas Modeling Forum

Workshop # 5: Meeting the Challenges of a Rapidly Changing Climate Policy Environment

National Conservation Training Center
Shepherdstown, West Virginia

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Office of Science
U.S. DEPARTMENT OF ENERGY

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Outline

- What's different about climate change?
- Agriculture, land use and energy
- Future challenges for modeling

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What's Different About Climate Change

The Role of Agriculture and Land Use Change in Climate Change

- Between ¼ and ⅓ of all anthropogenic emissions are associated with agriculture and land-use change.

  - Depending on the estimation procedures and methodology for computing contribution to radiative forcing.

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A Quick Cross-walk between W/m^2, CO_2-e and CO_2 Concentrations

- Carbon and CO_2
- 1 ton C = 44/12 tons CO_2

Radiative forcing (2005=2.36 W/m2)	CO_2 Equivalent Concentration (2005=435 ppm_e)	Atmospheric CO_2 Concentration (2005=381 ppm)
2.6 W/m^2	450 ppm_e	377 ppm
3.7 W/m^2	550 ppm_e	445 ppm
4.5 W/m^2	650 ppm_e	520 ppm

Climate Change Is A Unique Public Goods Problem

- Climate change is a public goods problem in that everyone benefits from the climate.
- But no individual person, nation, or **generation** can capture all of the benefits from their actions to manage the climate.
  - Acid deposition was regional
  - Stratospheric ozone was global, but the global population alive at the time of the Montreal Protocol were able to capture the benefits.
- Climate change is a **stock pollutant** problem. Benefits or damage are associated with the stock of greenhouse gases in the atmosphere, not the annual rate of emissions.

Gases with atmospheric sinks

- CH_4, N_2O, and other reactive gases have a well defined relationship between the annual rate of emission and the steady-state stock of the gas in the atmosphere.

- $$\text{Stock} = \text{Emissions Rate X } \left(\frac{1}{r}\right)$$

  - Where r = the annual removal rate.

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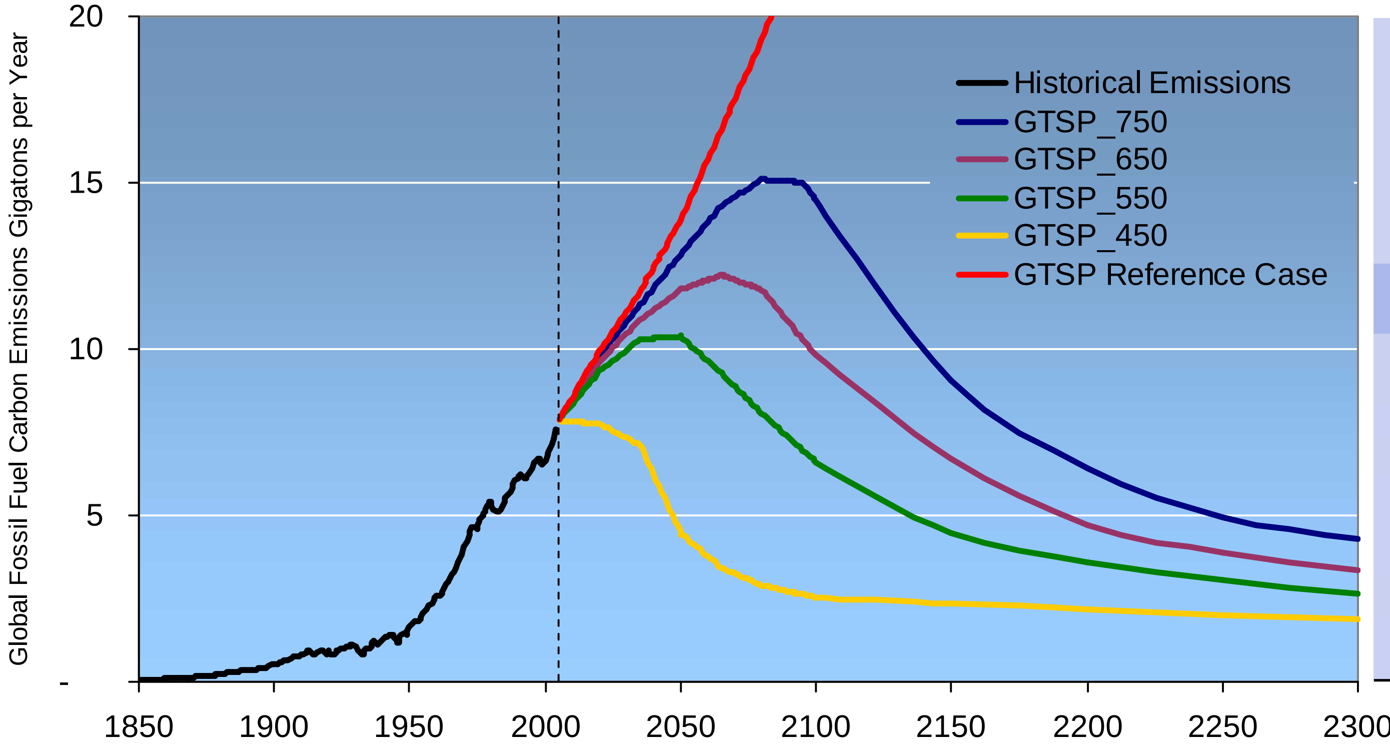
CO_2 is different

- Fossil fuels are an introduction of VERY OLD carbon into the fast carbon cycle.

- Some fraction of any change in fossil fuel plus terrestrial CO_2 emissions from human activities will reside in the atmosphere for 1000 years.
  - Today 80% of a ton of CO_2 released by human activities ends up in the ocean.
  - 20% of that ton remains in the atmosphere after 1000 years.

- Thus, stabilization of atmospheric CO_2 concentrations requires that emissions ultimately be driven to **zero**.

Climate change is a long-term strategic problem with implications for today



Fossil Fuel Carbon Emissions
Historic & 2005 to 2100

1750-2005	300 GtC
GTSP Ref	**1430 GtC**
750 ppm	**1200 GtC**
650 ppm	**1040 GtC**
550 ppm	**862 GtC**
450 ppm	**480 GtC**

- Stabilization of greenhouse gas **concentrations** is the goal of the Framework Convention on Climate Change.
- Stabilizing CO_2 **concentrations** at any level means that **global**, CO_2 emissions must peak and then decline forever.

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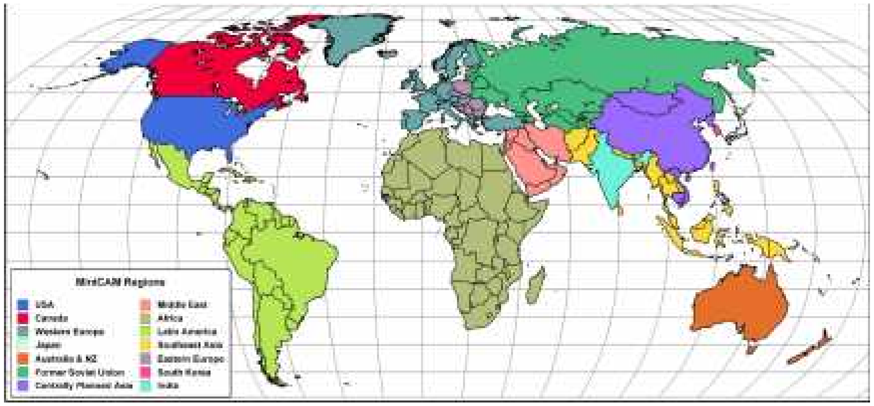
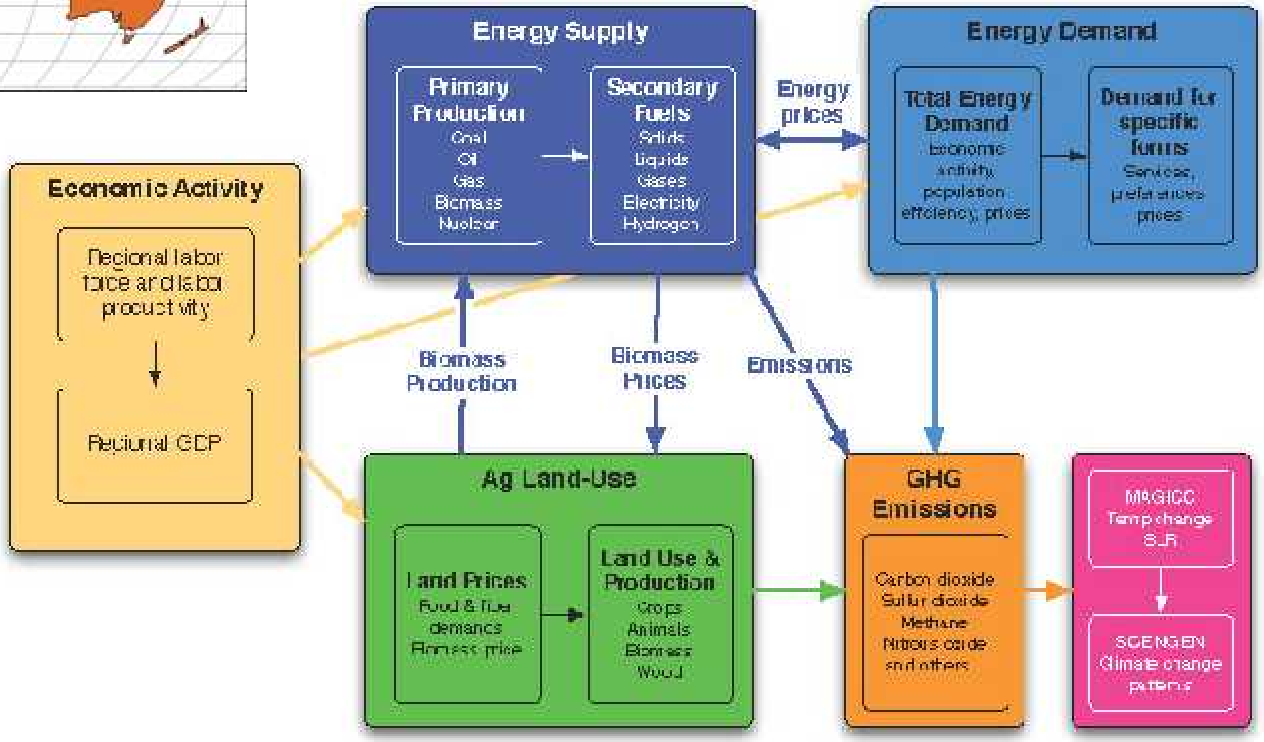
Agriculture, Land Use and Energy

Results from the MiniCAM Integrated Assessment Model



MiniCAM

- Energy-Agriculture-Economy Market Equilibrium
- 14 Global Regions – Fully Integrated
- Explicit Energy Technologies – All Regions



- Fully Integrated Agriculture and Land Use Model
  - 15 Greenhouse Gases and Short-lived Species
    - Typically Runs to 2100 in 15-year time steps

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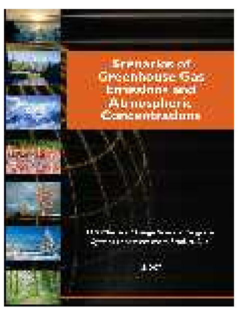
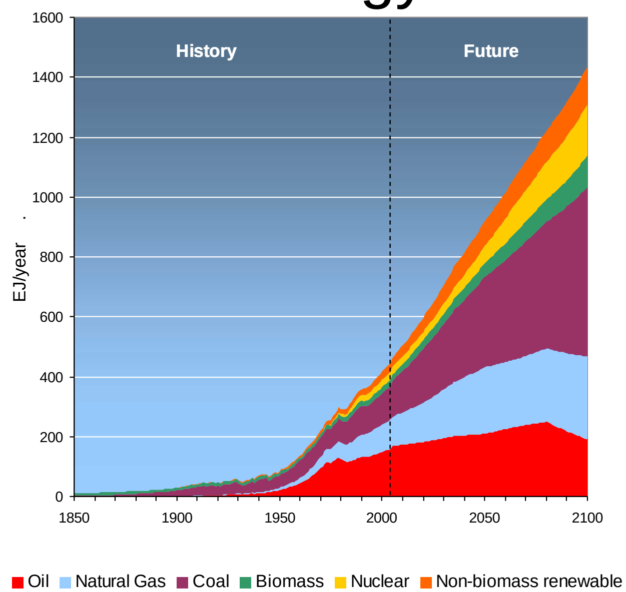
The MiniCAM Reference Scenario

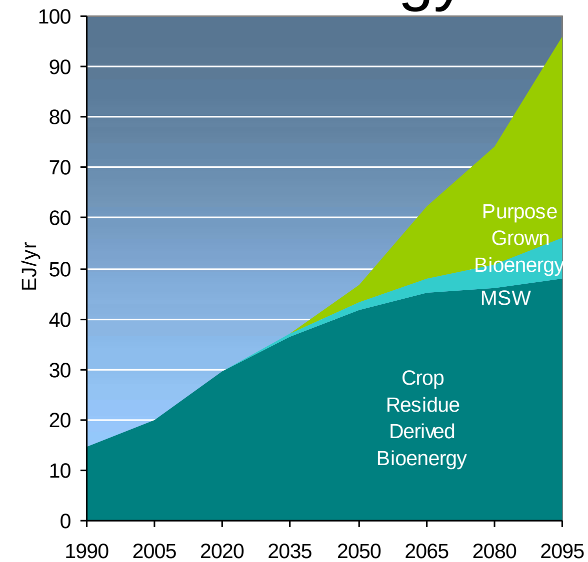
Updated CCSP SAP 2.1a scenario



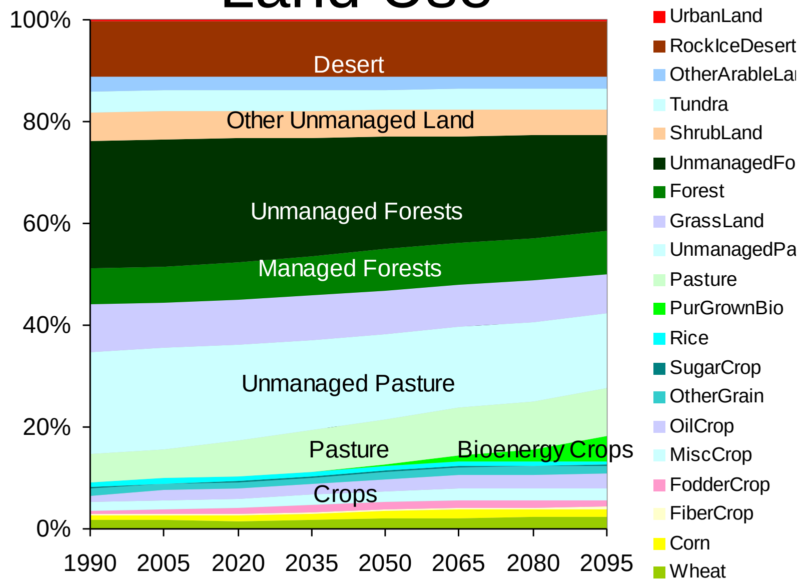
Energy



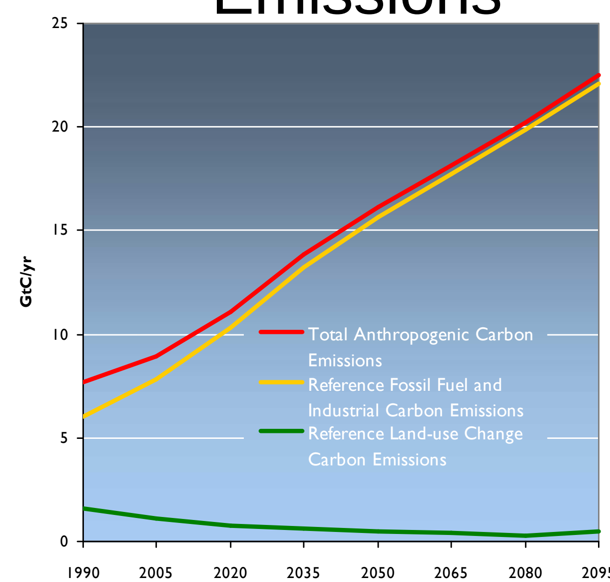
Bioenergy



Land Use



Emissions

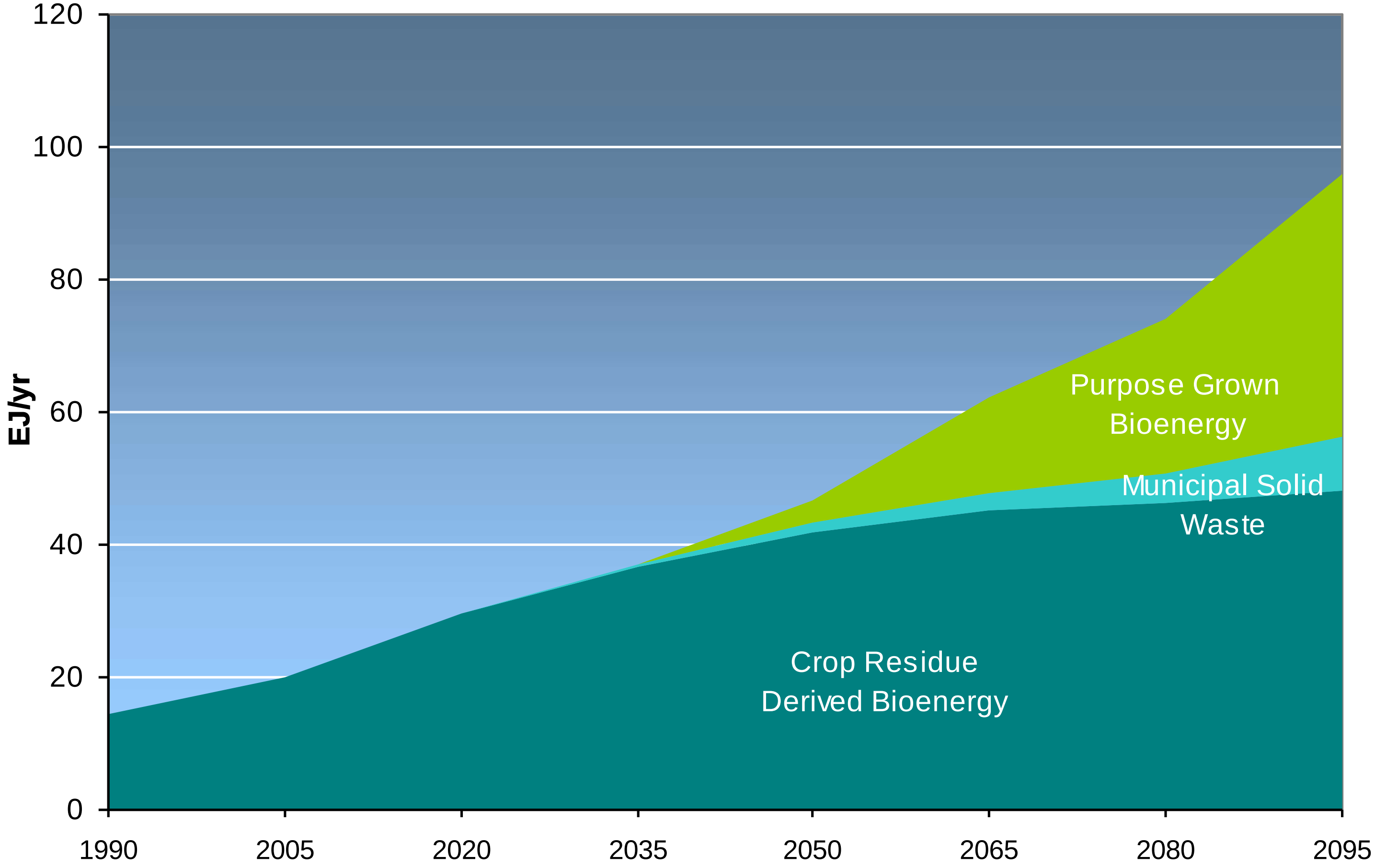


Agriculture and Bioenergy Assumptions

- Bioenergy can be an important mitigation technology
- Three types of bioenergy
  1. Traditional—treated exogenously
  2. Co-products, e.g. bark and waste in pulp and paper, but also crop residues,
     - Depend on production of the primary product.
     - Have a price-sensitive availability curve.
  3. Purpose-grown bioenergy crops—high productivity **cellulosic bioenergy** crops—not corn.

- Agricultural crop productivity growth rates
  - Reference scenario—productivity growth declines to **~0.25%/yr by 2050** everywhere.

Reference Scenario Bioenergy—dominated by crop residues and municipal waste



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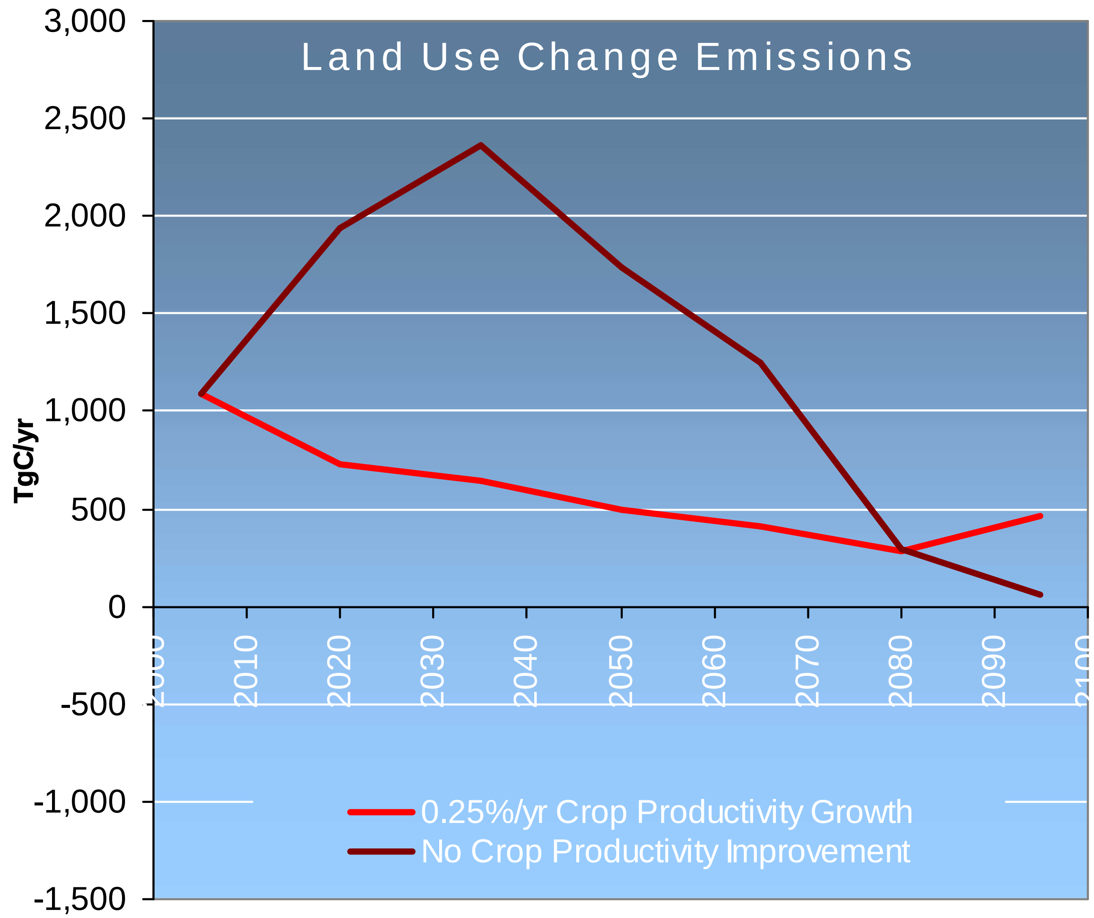
How important is the realized crop productivity growth rate?

- Continued crop productivity growth is as important as many energy technologies—larger in aggregate than a Pacala-Socolow “Wedge”.
  - We re-run the reference scenario with a fixed crop productivity assumption and compare to the reference scenario which assumes that crop productivity converges to 0.25%/yr in 2050.
  - We then compare the four scenarios in terms of land-use, crop prices, land-use change emissions, and bioenergy production.

Land Use Change Emissions and Crop Productivity

- Cumulative Emissions 2005 to 2095
  - 0.25%/yr crop productivity growth:
    - 50 PgC
  - No crop productivity growth:
    - 122 PgC
  - Difference
    - 72 PgC



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Bioenergy in the Context of Climate Stabilization

Carbon Pricing

Two alternative carbon pricing regimes

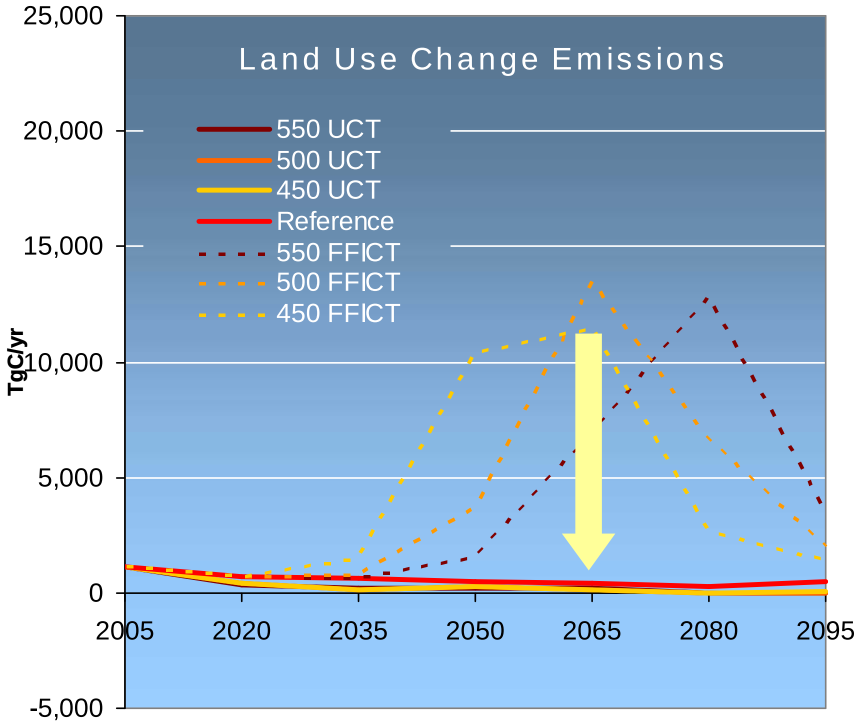
1. Fossil fuel and industrial carbon tax (FFICT)—in this regime only fossil fuel and industrial carbon emissions are valued. Bioenergy is treated as having no net carbon. Terrestrial carbon is valued at **zero**.

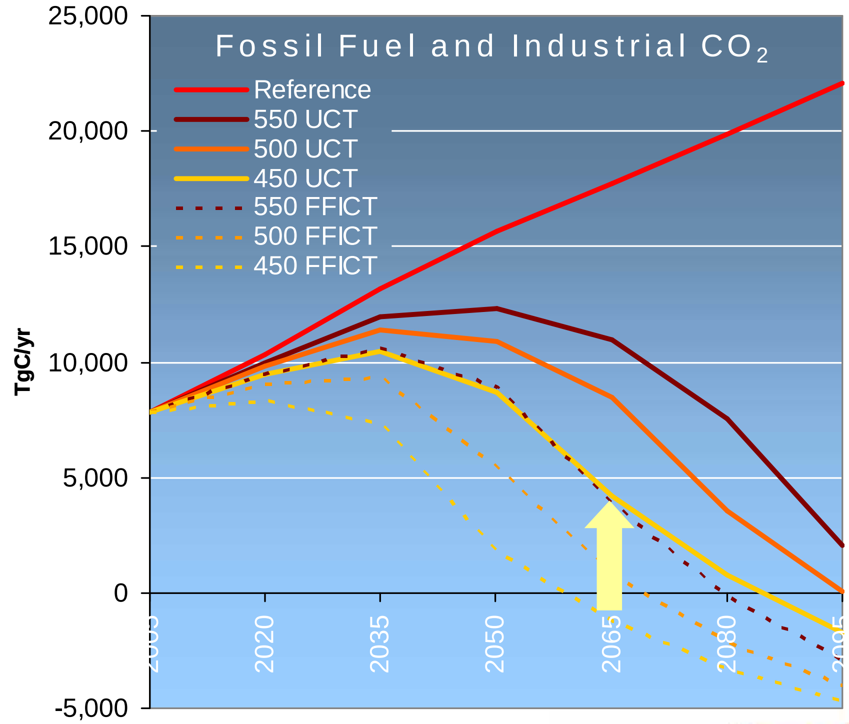
2. Universal carbon tax (UCT)—in this regime all carbon is valued equally regardless of either its origins or the activity that introduces it to (or removes it from) the atmosphere.

Net Land Use Change Emissions & Fossil Fuel and Industrial CO_2 Emissions

For a given CO_2 concentration limit

- Valuing carbon suppresses land use change emissions.
- Valuing carbon also increases fossil fuel and industrial emissions





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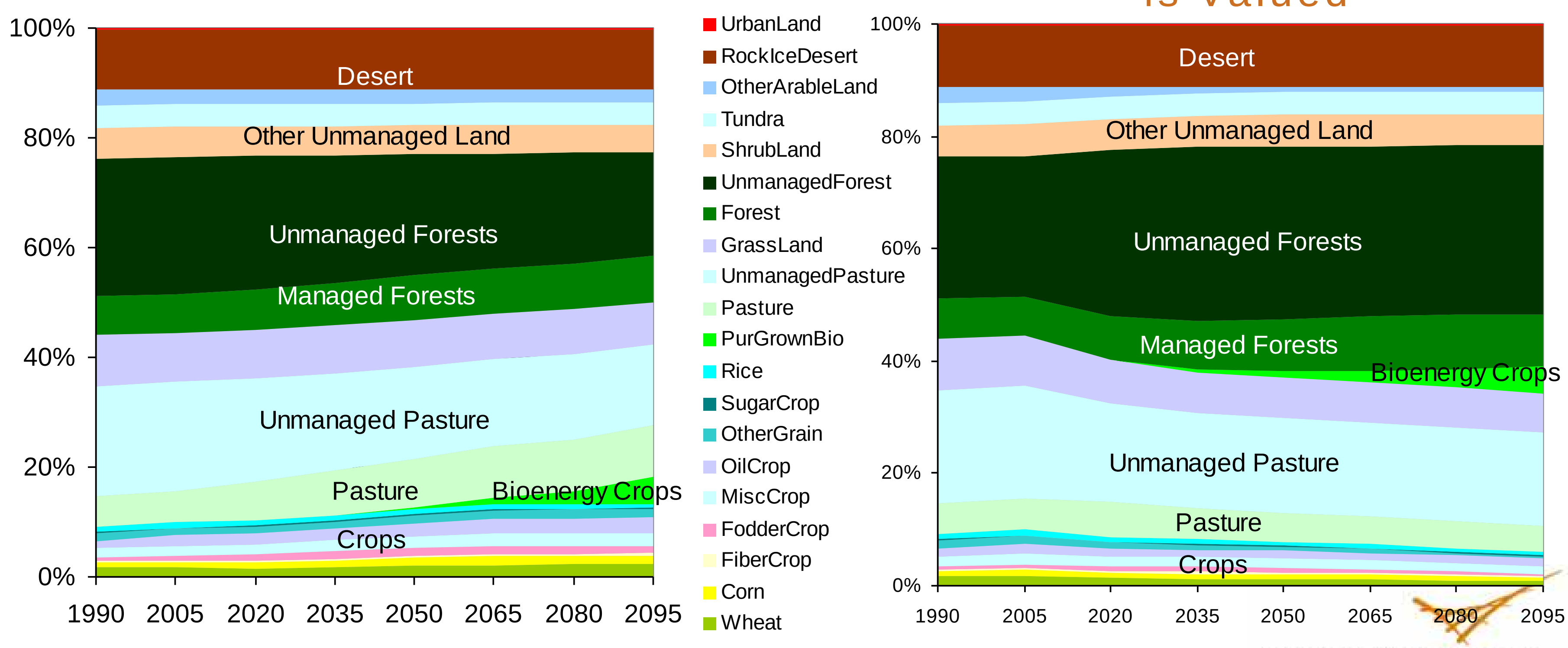
The Land Use Implications of Stabilizing at 450 ppm When Terrestrial Carbon is Valued (UCT)

- Unmanaged ecosystems expand relative to the reference scenario.
- But, crop land declines.

Reference Scenario / **450 ppm Stabilization Scenario When ALL Carbon is Valued**



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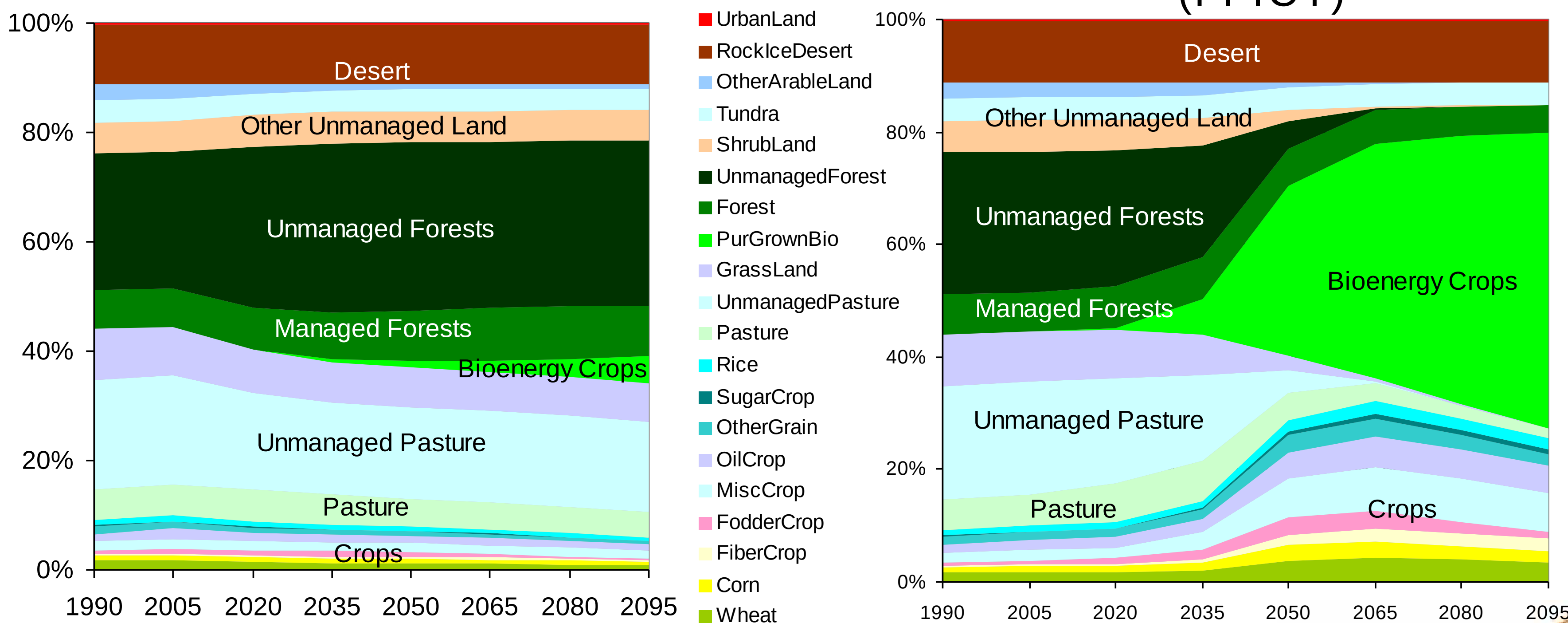
The Land Use Implications of Stabilizing at 450 ppm When Terrestrial Carbon is NOT Valued (FFICT)

450 ppm Stabilization Scenario When ALL Carbon is Valued (UCT)

450 ppm Stabilization Scenario When Terrestrial Carbon is NOT Valued (FFICT)



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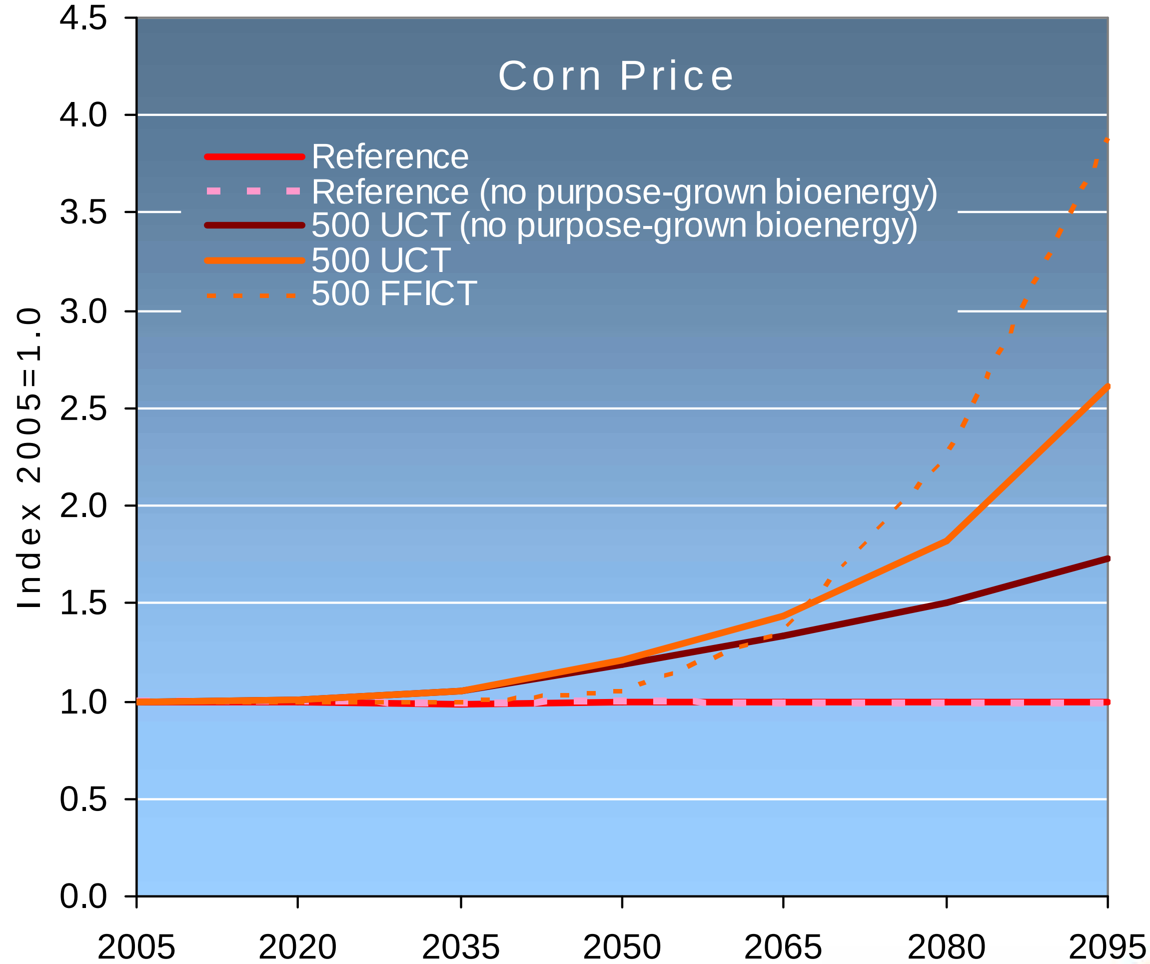
Corn Price When Carbon Is Valued But No Bioenergy Is Produced

- Significant crop price escalation occurs if carbon is valued, **even in the absence of purpose grown bioenergy production**.
  - Prior to 2040 the influence of bioenergy is negligible.
  - Prior to 2040 crop price escalation, relative to the reference scenario, is predominantly driven by the value of carbon.



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Summing Up Bioenergy

- There are approximately 2000 PgC in the terrestrial ecosystem.
  - At a price of $100/tC and an interest rate of 5%/y it provides an annual service of carbon storage of approximately $10 trillion/y. Approximately the same service as the U.S. GDP.
- We find that relative to a reference scenario, a larger stock of unmanaged ecosystems and managed forests is desirable
- We find that improving conventional crop productivity has the potential to reduce land-use change emissions by tens of billions of tons of carbon over the 21st century.
- Waste streams are an important source of bioenergy.
- Bioenergy combined with CCS is potentially a very powerful technology for addressing climate change opening the door for NEGATIVE global emissions and VERY Low Carbon Societies.

Research Frontiers

Significant Work Remains

- Exploring policy
  - Accession regimes.
  - Non-price mechanisms
  - Offsets
- Terrestrial carbon cycle.
- CO_2 fertilization effect.
- Climate change impacts.
  - Temperature, precipitation, pests, etc.
- Water resources.
  - Availability & competing demands.

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A technical report on "The Implications of Limiting CO_2 Concentrations for Agriculture, Land Use, Land-use Change Emissions and Bioenergy" can be found on our website at:

http://www.pnl.gov/gtsp/publications/2009/200902_co2_landuse.pdf

END

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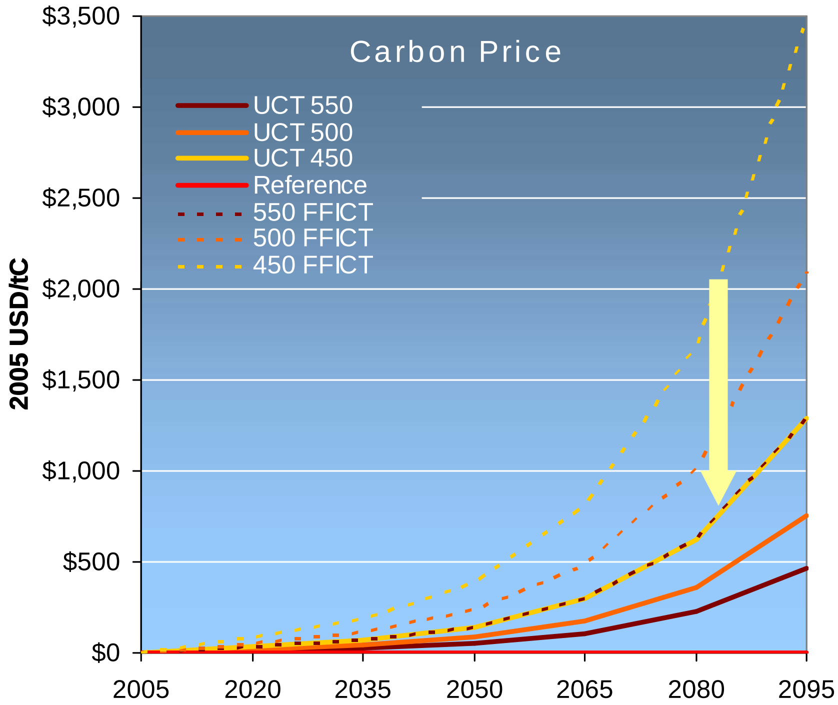
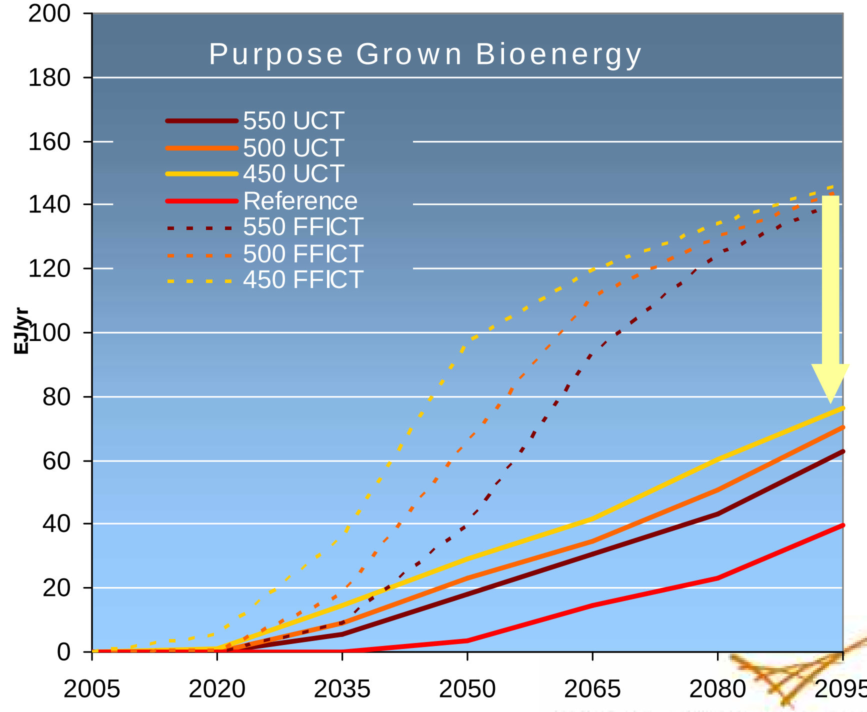
Carbon Price & Bioenergy When Terrestrial Carbon is NOT Valued (FFICT)

Valuing all carbon, including terrestrial carbon

- Dramatically reduces the price of carbon.
- Cuts the price at 450 ppm in half!
- Reduces the amount of bioenergy production in the long term, but increases near-term bioenergy supply, relative to the case in which terrestrial carbon was not valued.





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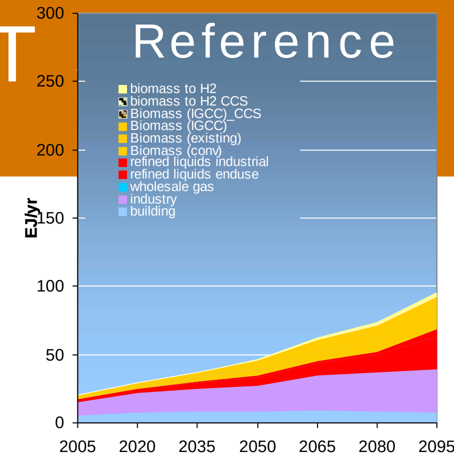
Bioenergy Use: FFICT and UCT ppm Scenarios



- SUBSTANTIALLY LESS BIOENERGY PRODUCTION OCCURS THAN WHEN TERRESTRIAL CARBON IS NOT VALUED.
- **Most bioenergy still goes to electricity production with CCS** in the concentration limit scenarios.