

# Implications of Limiting CO<sub>2</sub> Concentrations for Land Use and Energy

Joint Global Change Research Institute (JGCRI)

Presented by  
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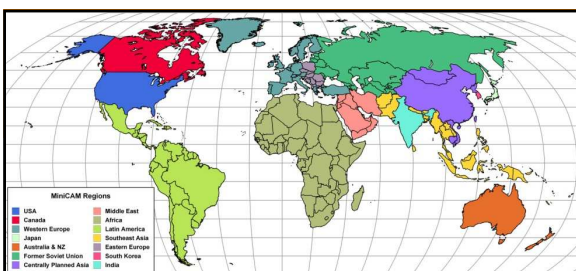
**MA Wise, KV Calvin, AM Thomson, LE Clarke, B Bond-Lamberty, RD Sands, SJ Smith, AC Janetos, JA Edmonds**

**June 17, 2009**



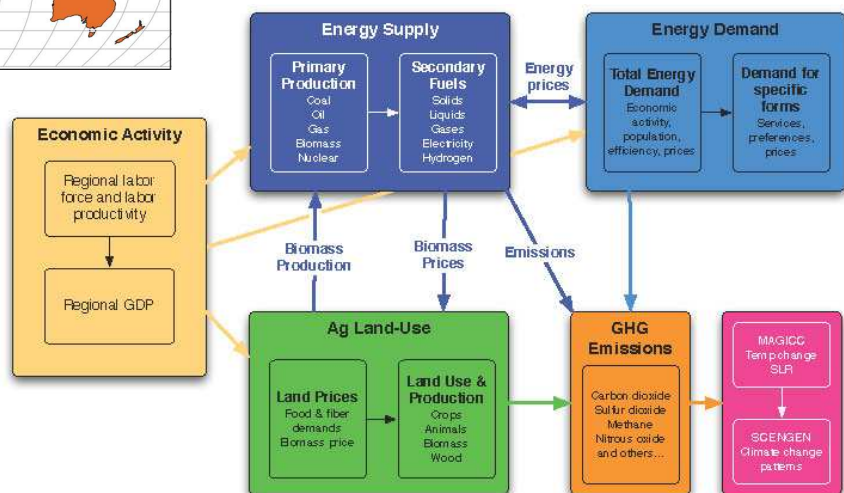
## Overview

- ▶ **There are approximately 2000 PgC in the terrestrial ecosystem. All human activities must be limited to about 500 PgC (2005 to 2095) to limit atmospheric CO<sub>2</sub> to 450 ppm.**
  - Where does bioenergy come from?
  - How important is the realized crop productivity growth rate?
  - What are the implications of pricing terrestrial carbon emissions?



## MiniCAM

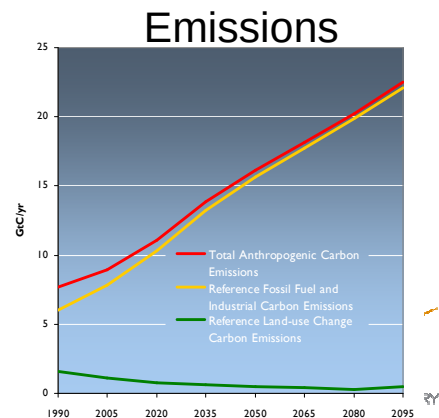
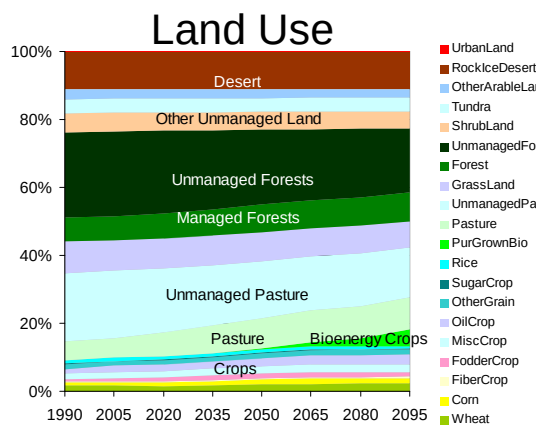
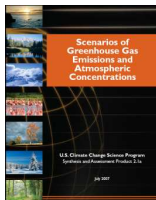
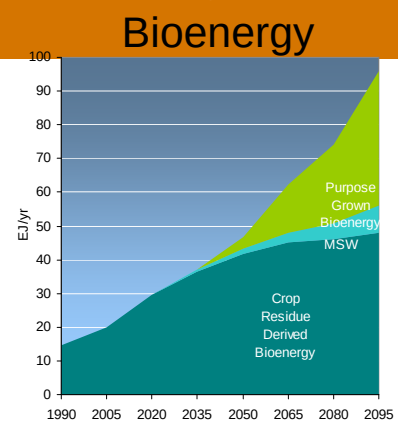
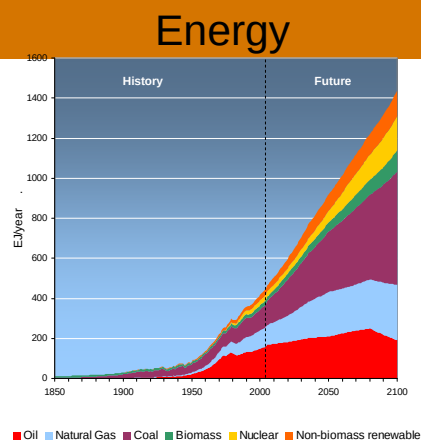
- ▶ Energy-Agriculture-Economy Market Equilibrium
- ▶ 14 Global Regions – Fully Integrated
- ▶ Explicit Energy Technologies – All Regions



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

# The MiniCAM Reference Scenario

Updated  
CCSP SAP  
2.1a  
scenario

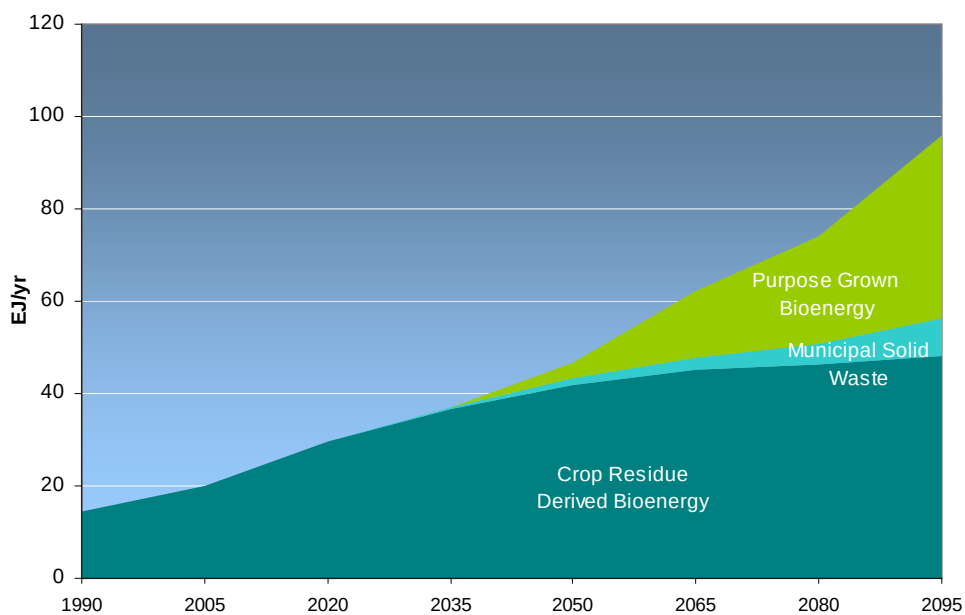


## Agriculture and Bioenergy Assumptions

- ▶ Bioenergy can be an important mitigation technology
- ▶ Four types of bioenergy
  1. Traditional—treated exogenously
  2. Municipal Solid Waste
  3. 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.
  4. 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.

**Where does bioenergy come from?**

## Reference Scenario Bioenergy—dominated by crop residues and municipal waste



**How important is the realized crop  
productivity growth rate?**

## How important is the realized crop productivity growth rate?

- ▶ 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 two scenarios in terms of land-use change emissions.

# Land Use Change Emissions and Crop Productivity

## ► Cumulative Emissions 2005 to 2095

■ 0.25%/yr crop productivity growth:

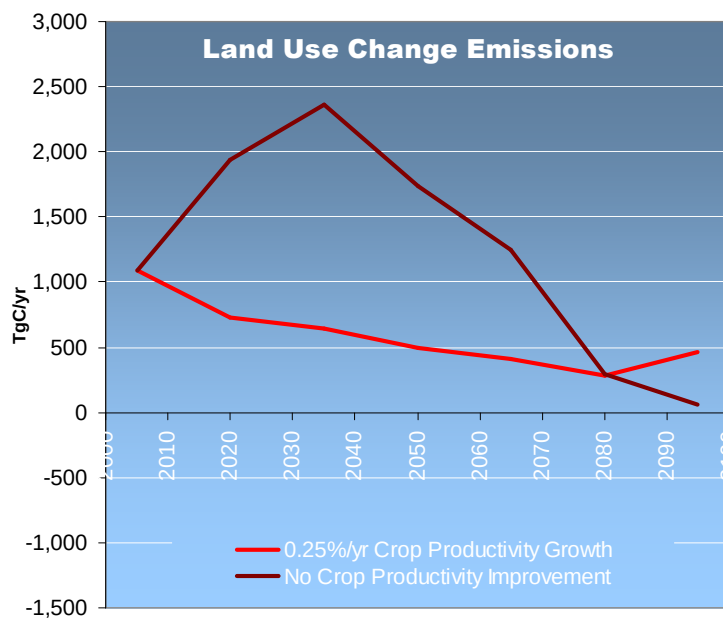
● **50 PgC**

■ No crop productivity growth:

● **122 PgC**

■ Difference

● **72 PgC**



**What are the implications of pricing  
terrestrial carbon emissions?**

# Carbon Pricing

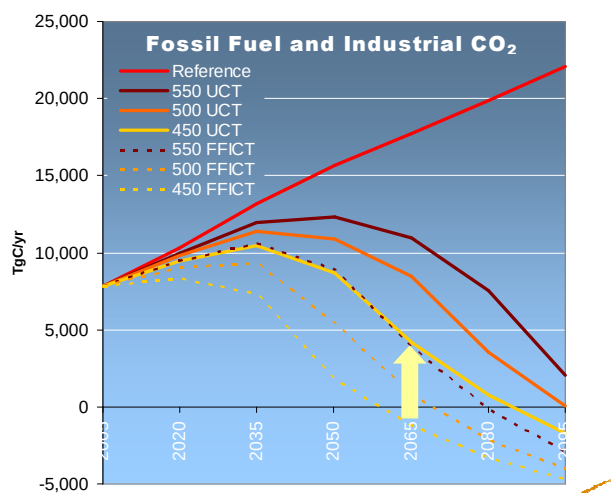
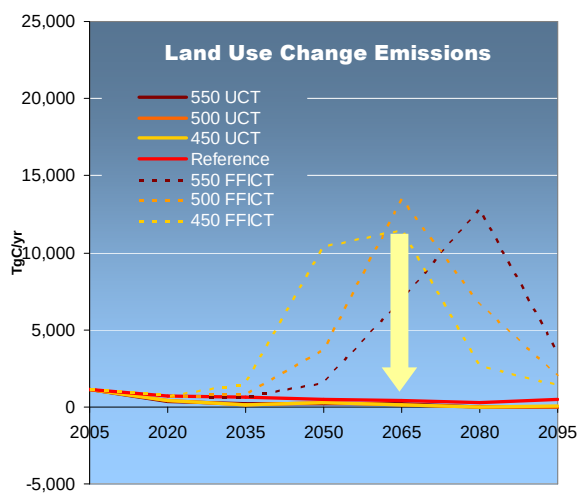
## Two alternative carbon pricing regimes

- 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<sub>2</sub> Emissions

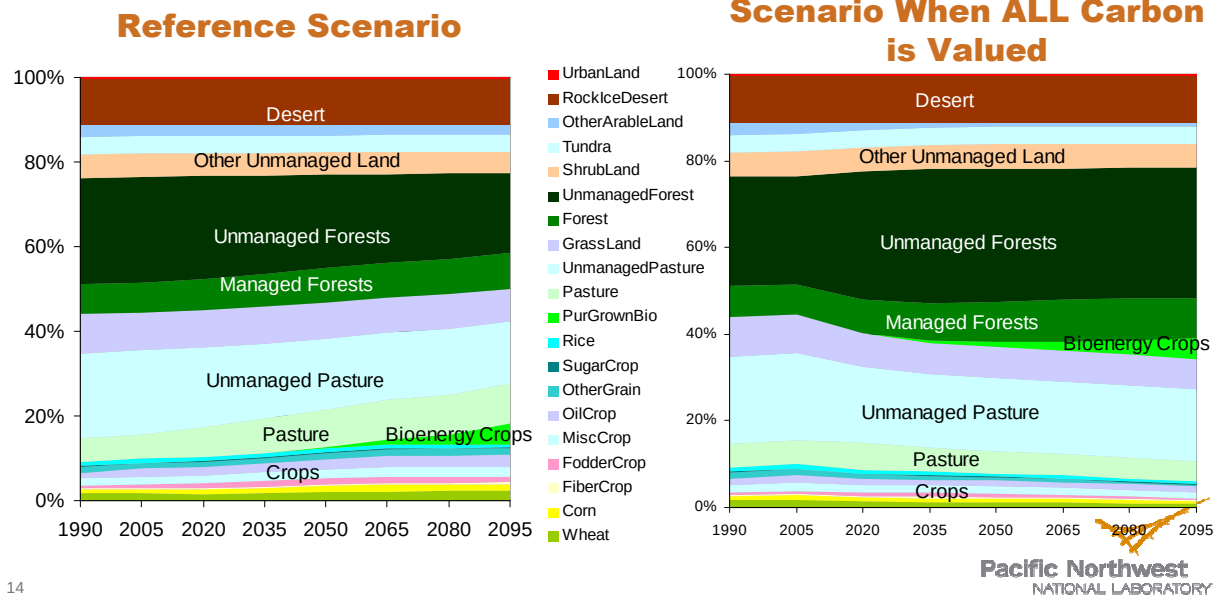
For a given CO<sub>2</sub> concentration limit

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



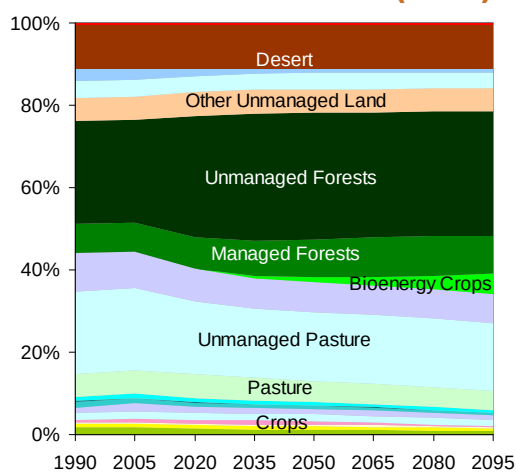
# The Land Use Implications of Stabilizing at 450 ppm When Terrestrial Carbon is Valued (UCT)

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

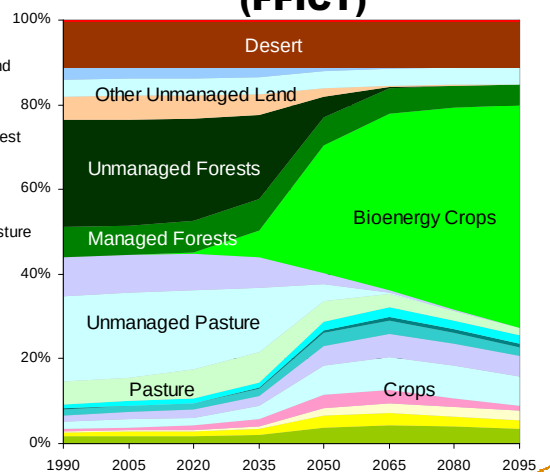


# The Land Use Implications of Stabilizing at 450 ppm When Terrestrial Carbon is NOT Valued (FFICT)

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



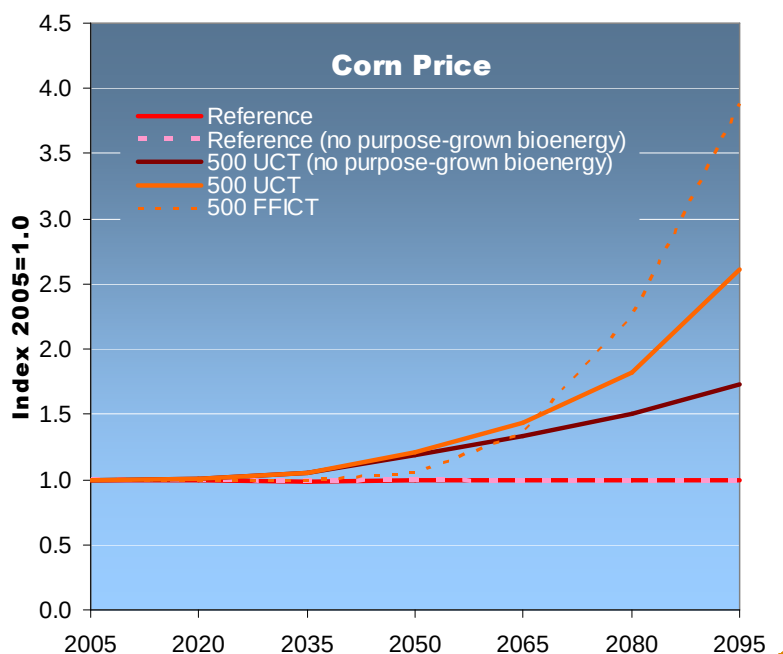
**450 ppm Stabilization Scenario When Terrestrial Carbon is NOT Valued (FFICT)**



## 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.



## Conclusions

- ▶ Where does bioenergy come from?
  - Crop residues and waste streams are an important source of bioenergy.
- ▶ How important is the realized crop productivity growth rate?
  - 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.
- ▶ What are the implications of pricing terrestrial carbon emissions? Waste streams are an important source of bioenergy.
  - We find that relative to a reference scenario, a larger stock of unmanaged ecosystems and managed forests is desirable.
  - Valuing terrestrial carbon emissions reduces carbon prices and allows for increased fossil fuel & industrial carbon emissions when limiting climate change, relative to a world where terrestrial carbon emissions are ignored.

Wise, MA, KV Calvin, AM Thomson, LE Clarke, B Bond-Lamberty, RD Sands, SJ Smith, AC Janetos, JA Edmonds. 2009. "Implications of Limiting CO<sub>2</sub> Concentrations for Land Use and Energy." *Science*. 324:1183-1186. May 29, 2009.

<http://www.sciencemag.org/cgi/content/full/324/5931/1183>