Bioenergy with CO_2 Capture and Geologic Storage

Joint Global Change Research Institute (JGCRI)

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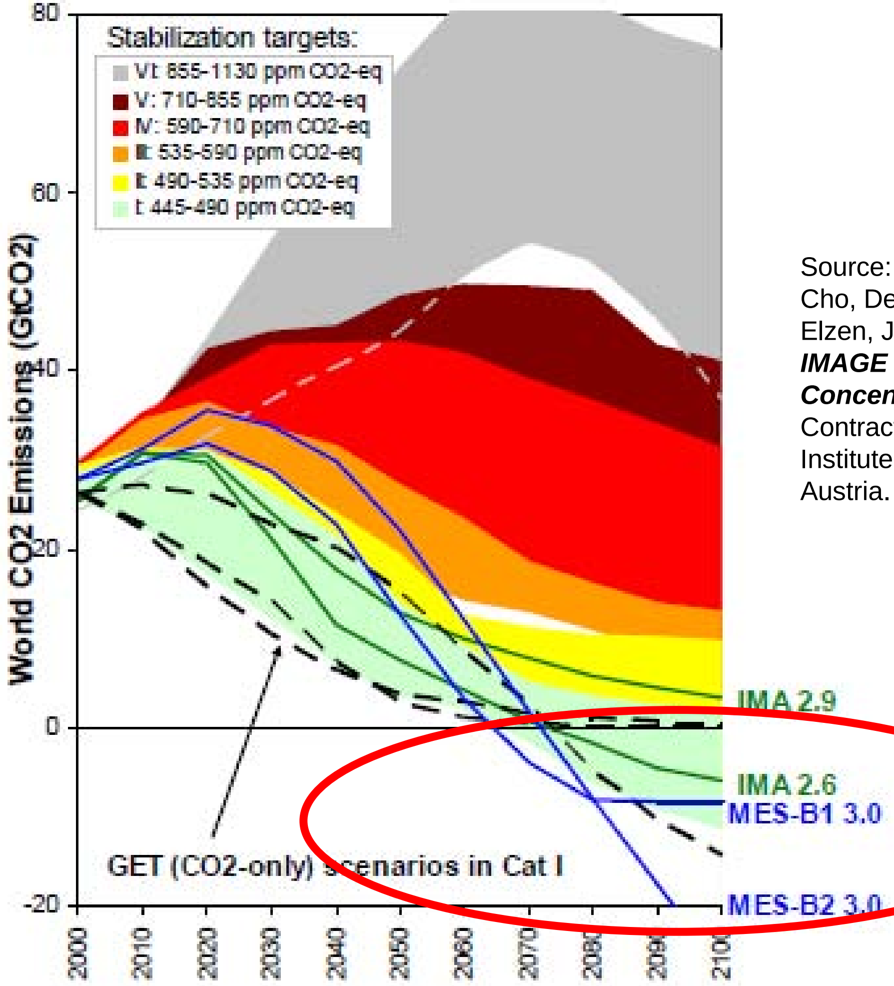
Why are we interested in bioenergy with CCS?

Why are we interested in bioenergy with CCS?

- ENERGY with NEGATIVE emissions are a major feature of the new low-climate-forcing scenarios.



Source: Rao, Shilpa, Keywan Riahi and Cheolhung Cho, Detlef van Vuuren, Elke Stehfest, Michel den Elzen, Jasper van Vliet and Morna Isaac. 2008. ***IMAGE and MESSAGE Scenarios Limiting GHG Concentrations to Low Levels***. Framework Contract ENV.C5/FRA/2006/0071. International Institute for Applied Systems Analysis, Laxenburg, Austria.

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Bioenergy and CCS

- Both bioenergy and CCS are technologies that exist today.
  - The combination of both is also being explored.
- CCS is not deployed at scale.
- Deployment of each depends on the institutional environment.
  - Carbon price
  - Institutional framework that facilitates a business model for deployment.

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CO_2 Capture and Storage

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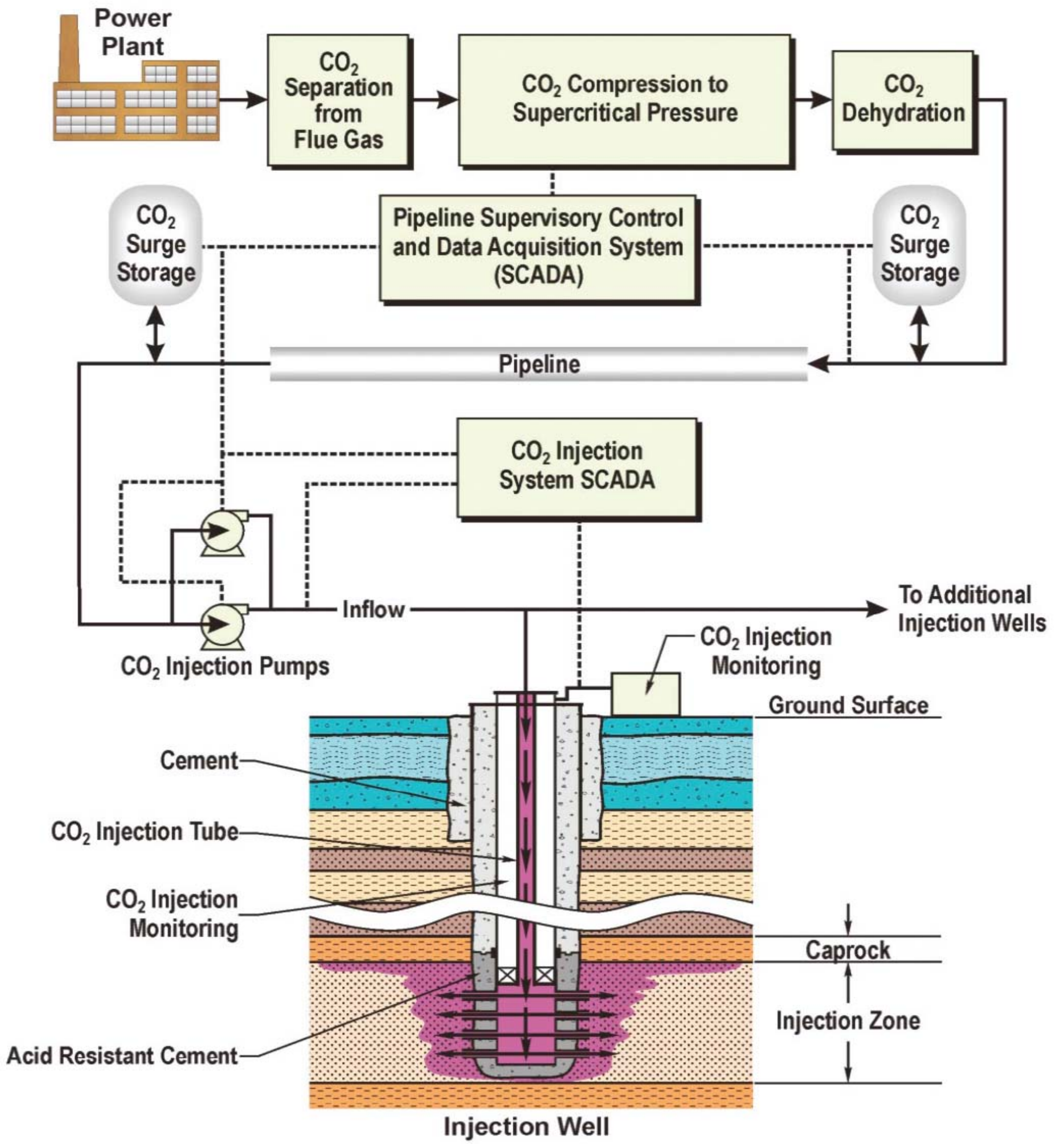
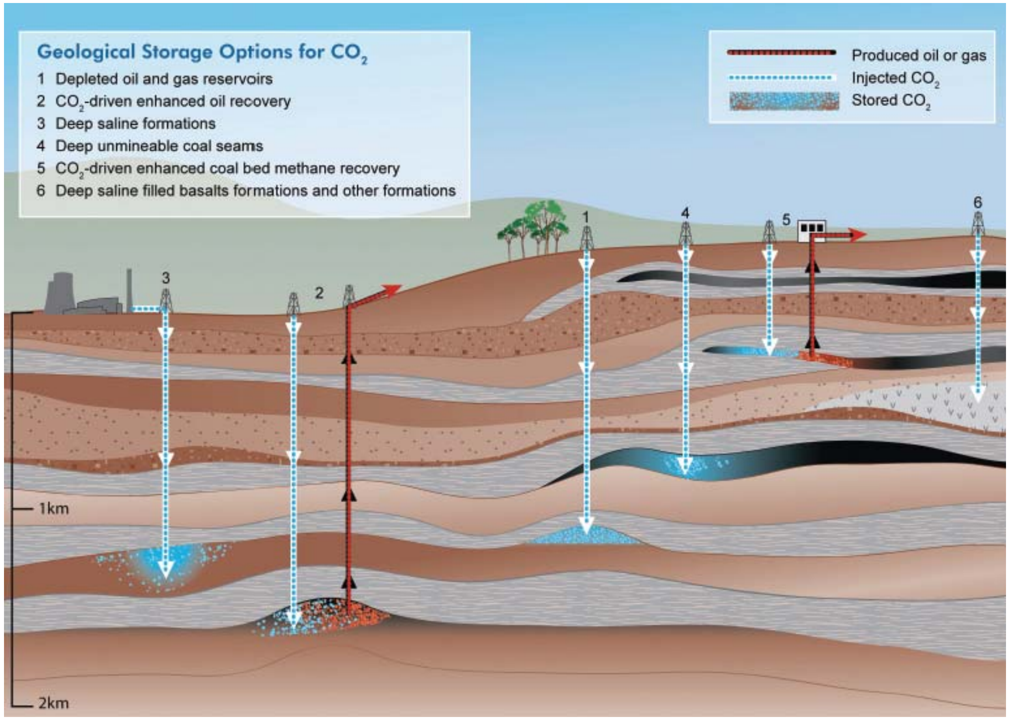
CO_2 Capture and Geologic Storage

- CO_2 capture and geologic storage (CCS).
  - Isolation of CO_2 from the exhaust gas stream.
  - Transport to an injection site.
  - Injection into a deep reservoir.



Potential CO_2 Storage Reservoirs

- Deep saline formations
- Depleted oil and gas fields
- CO_2 driven enhanced oil recovery
- Deep unminable coal seams
- CO_2 driven enhanced coal bed methane recovery
- Deep saline filled basalt formations and other formations.



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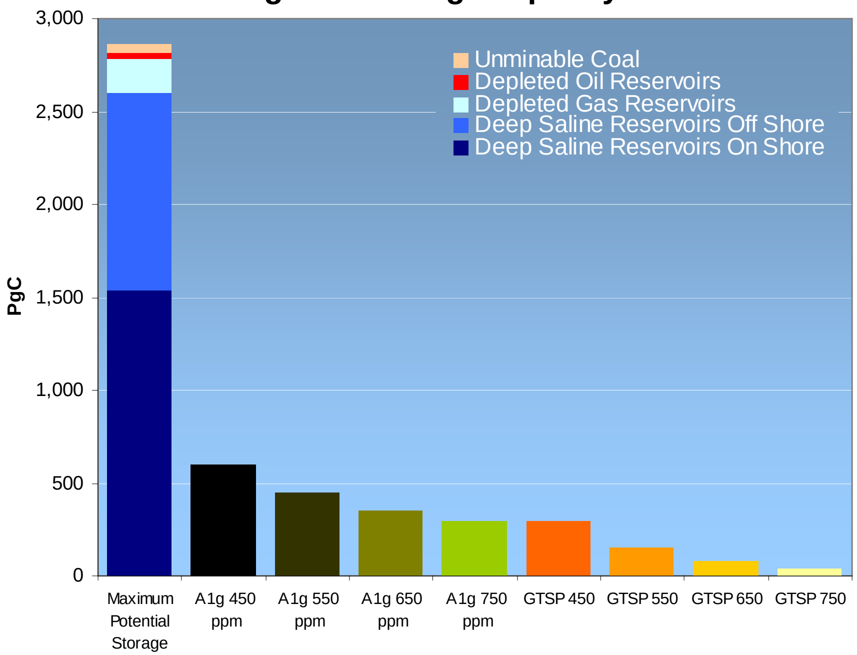
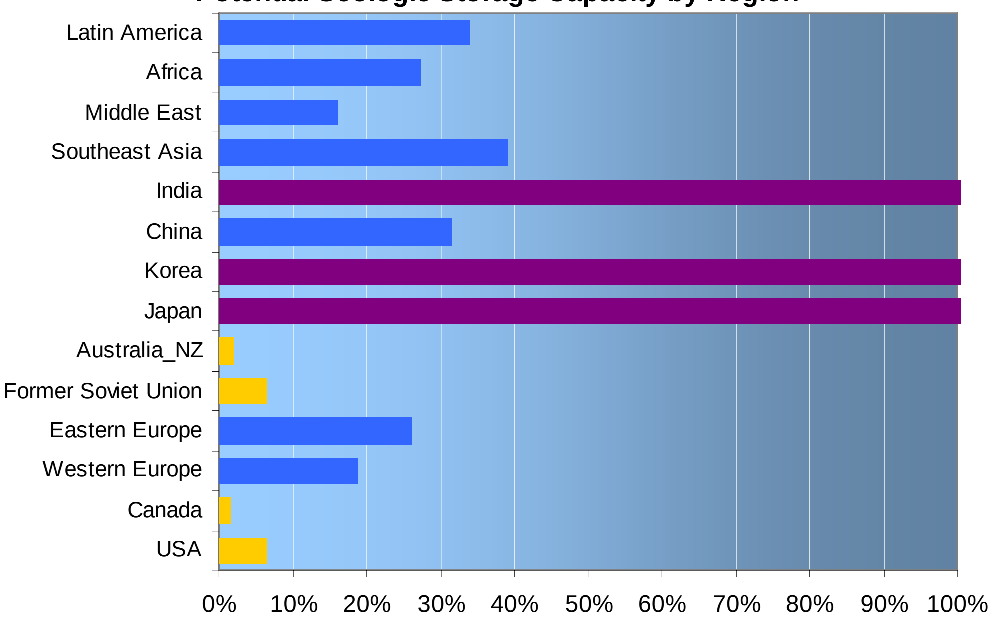
CCS and Cumulative Emissions

Cumulative global CO_2 capture and maximum potential global storage capacity.



Ratio of Cumulative Emissions 1990 to 2095 to Maximum Potential Geologic Storage Capacity by Region



- Cumulative emissions from MiniCAM CCSP SAP 2.1a
- Potential geologic storage from Dooley et al. (2004) and subsequent updates.

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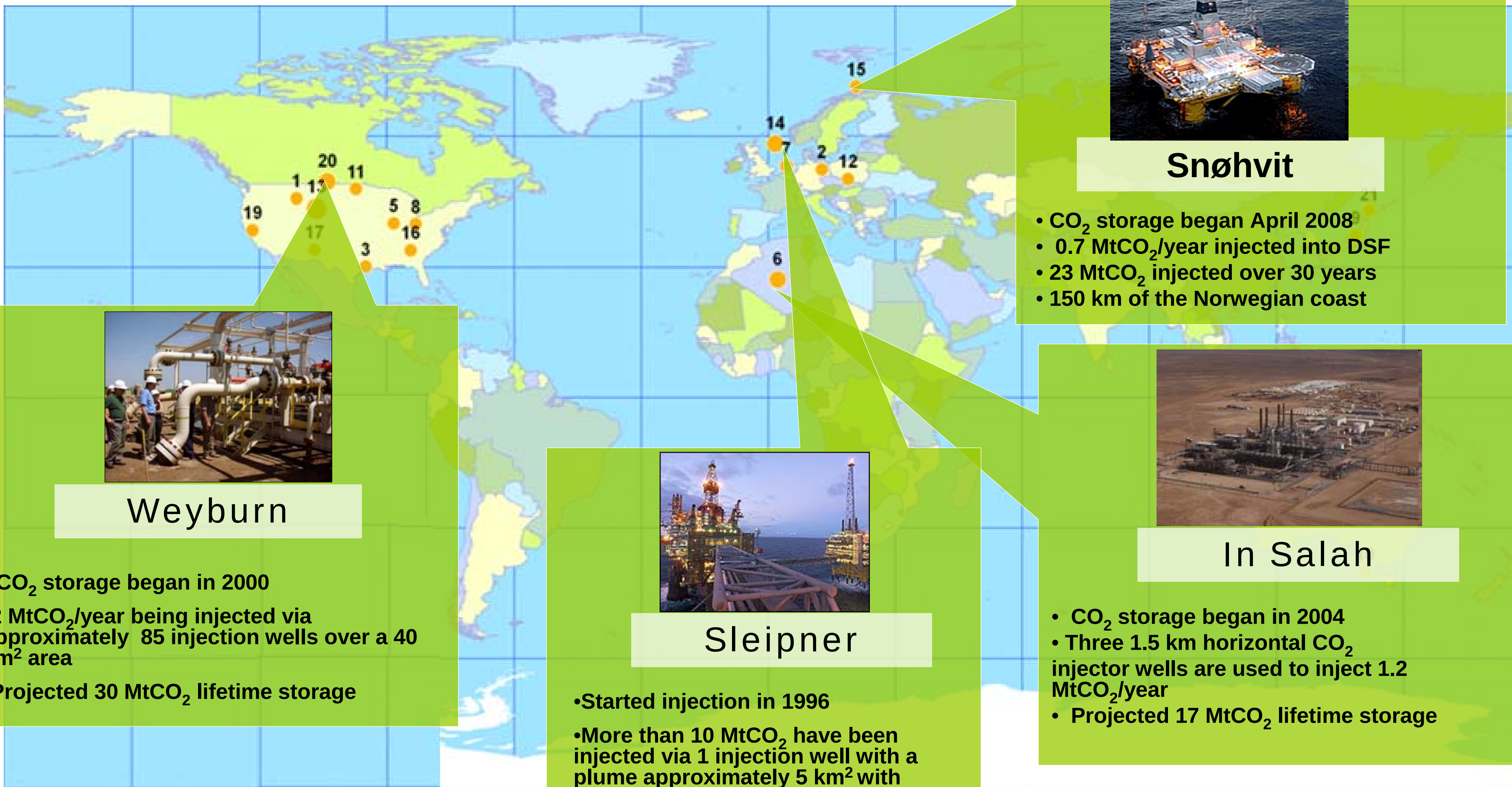
Present State of CCS Technology

- CCS systems have been used with coal and gas power generation systems since the 1970's. (But not at scale.)
- 3,900 miles of CO_2 transport systems.
- CO_2 has been used with EOR for 35 years.
- CCS can potentially be applied to a wide range of industrial systems ranging from fossil fuel power generation (coal, gas and oil), cement kilns, refineries, chemical manufacture, etc.
- There are 4 end-to-end commercial systems in place today.

Four Sites with CO_2 Capture-to-Storage-to-MMV



Snøhvit

- CO_2 storage began April 2008
- 0.7 $MtCO_2$/year injected into DSF
- 23 $MtCO_2$ injected over 30 years
- 150 km of the Norwegian coast

Weyburn

- CO_2 storage began in 2000
- 2 $MtCO_2$/year being injected via approximately 85 injection wells over a 40 km^2 area
- Projected 30 $MtCO_2$ lifetime storage

Sleipner

- Started injection in 1996
- More than 10 $MtCO_2$ have been injected via 1 injection well with a plume approximately 5 km^2 with
- Projected 20 $MtCO_2$ lifetime storage
- 150 km of the Norwegian coast

In Salah

- CO_2 storage began in 2004
- Three 1.5 km horizontal CO_2 injector wells are used to inject 1.2 $MtCO_2$/year
- Projected 17 $MtCO_2$ lifetime storage

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Institutional arrangement for CCS

- CCS is a CO_2 emissions mitigation technology.
  - It raises capital costs by 50%.
  - It takes a substantial fraction of a power plant's power production to run.
- There is no business model for deploying CCS without either a significant positive price on carbon, or a regulatory requirement.
  - New plants would be cheapest.
  - Retrofits are possible at extra cost.
- For most of the world's carbon emissions, the price of carbon is zero.
- The regulatory model that governs CCS for most of the world's carbon emissions is still under development.
  - Exceptions exist, e.g. Norway
  - Significant progress in many parts of the OECD in defining CCS rules.

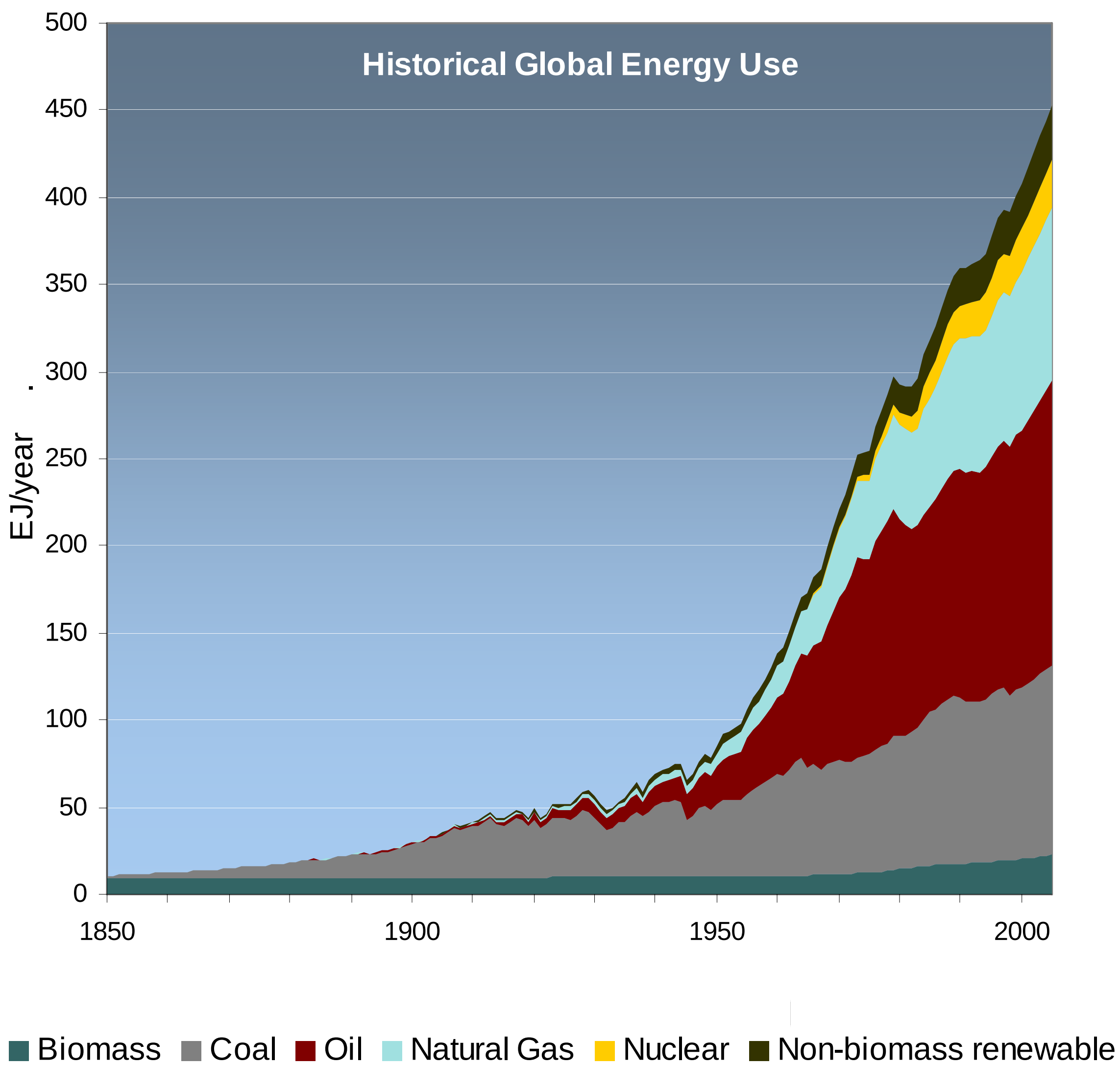
Bioenergy

Bioenergy

- Bioenergy is derived from plant material—a very young hydrocarbon.
  - Bioenergy derives its carbon from the air.
  - If the plant material is oxidized, then there in no NET change in carbon in the atmosphere. Though there are indirect emissions to be discussed shortly.
- Bioenergy is generally considered a renewable energy form.
- Bioenergy was the dominant preindustrial energy form.
  - It was supplanted by higher energy density forms, e.g. fossil fuels and nuclear power.
- It is still used today, e.g. the pulp and paper industry but also traditional bioenergy use in developing regions.
- It is a major source of liquid fuel in Brazil today.

Bioenergy today

- There is more bioenergy used today than when it was the dominant energy form.
- Bioenergy is not cheap and without a subsidy, it does not compete effectively with energy forms such as fossil fuels.
- The relative attractiveness of bioenergy use could be dramatically different if under a carbon price regime.



Indirect Land-use Change Emissions (ILUC)

- Bioenergy production requires land, a limited resource.
- Any number of papers have identified the problem of indirect land-use emissions (ILUC).
  - Fargione et al. (2008); Searchinger et al. (2008); Edmonds et al. (2003); and Wise et al. (2009).
- ILCU occurs when a major new demand for land is introduced in the face of a fixed land resource.
  - Increased demand for land for purpose-grown bioenergy crops results in higher rental rates for crops and potentially expansion into “unmanaged” lands.
- Crutzen et al. (2008) also raised the question of expanded non-CO_2 GHG emissions, most notably as a consequence of N_2O from fertilizer applications.

ILUC and Limiting Atmospheric CO_2 Concentrations

- There are more than 2000 billion tons of carbon in terrestrial ecosystems including soils and above ground plants.
- Limiting atmospheric CO_2 concentrations to low levels, e.g. 450 or 550 ppm implies limits for total anthropogenic carbon emissions.
  - 450 ppm $\Rightarrow$ ~500 PgC (2005 to 2100)
  - 550 ppm $\Rightarrow$ ~800 PgC (2005 to 2100)
  - Note that these concentrations are NOT CO_2-equivalent

- The extent of ILUC depends on the policy environment.

BioCCS

Carbon Pricing

- CCS only deploys in the presence of either a carbon price of a regulatory requirement.
- Purpose-grown bioenergy production is enhanced by the presence of a carbon price.
- The BioCCS combination produces a negative emission
  - Need for a mechanism that allows for payment for negative emission.
  - Note that negative global emission scenarios not only produce no revenue, but are a net public expenditure.

Carbon Pricing in for Two Contrasting Scenarios

- Immediate, universal participation by all regions to limit CO_2 concentrations in 2095.
- 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.

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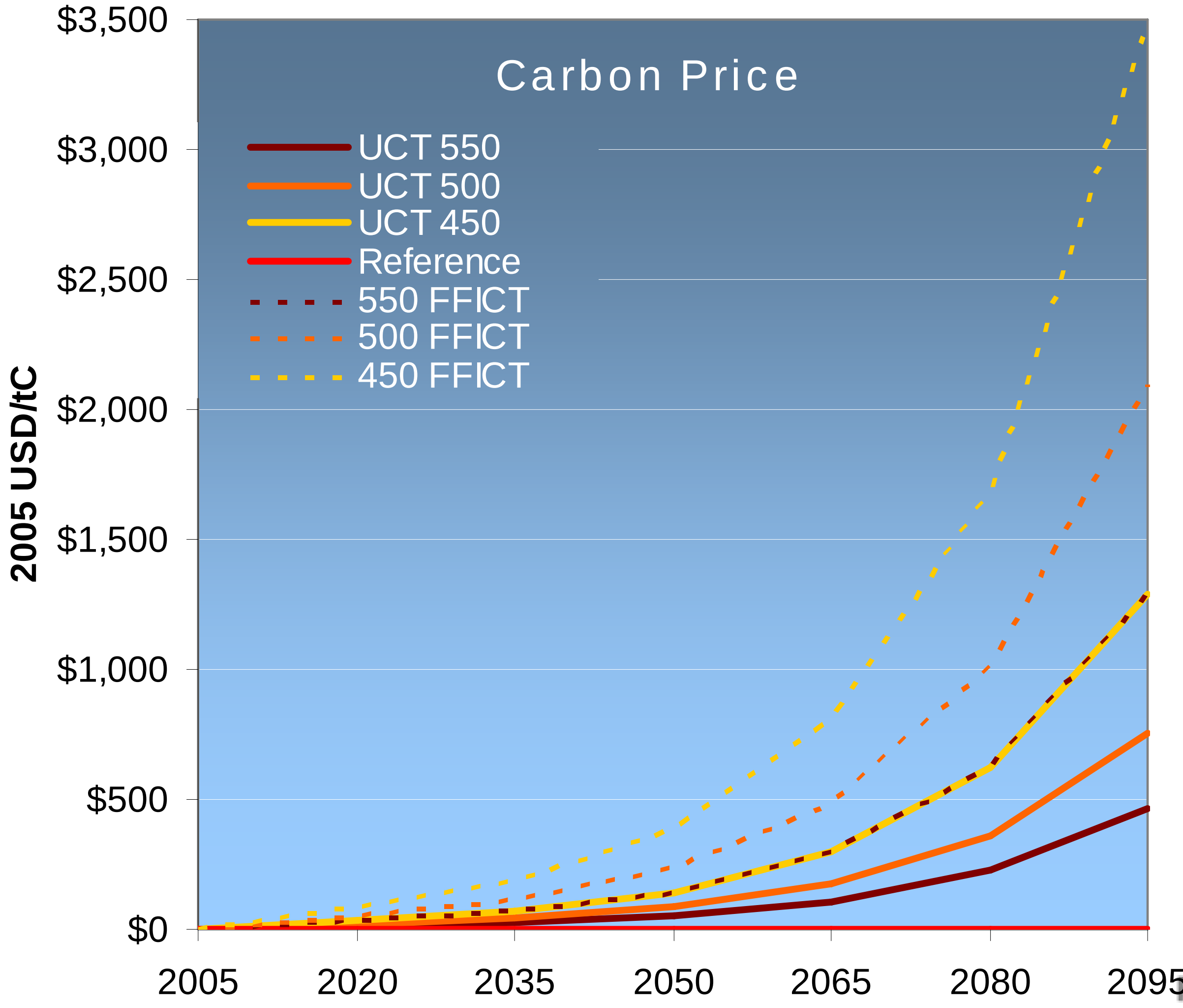
Carbon Prices: FFICT and UCT



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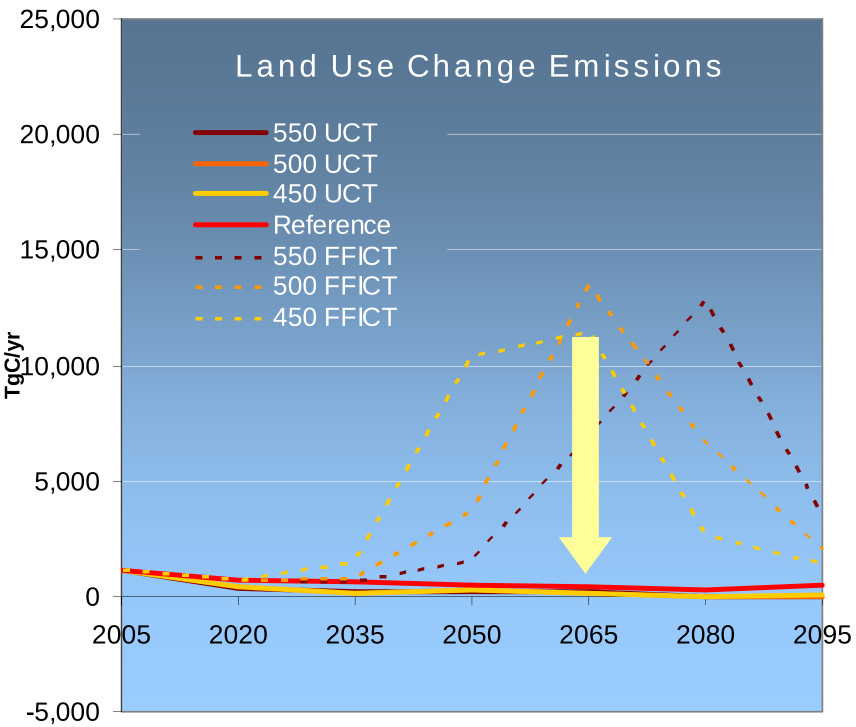
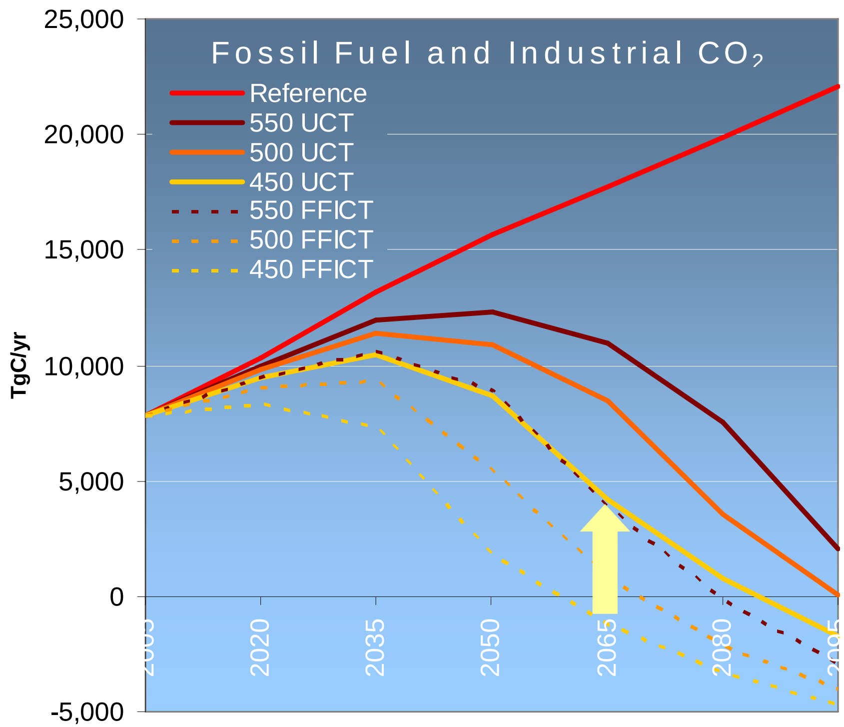
Net Land Use Change Emissions & Fossil Fuel and Industrial CO_2 Emissions

For a given CO_2 concentration limit

- In the UTC regime ILUC disappears as an issue.
- In the FFICT regime high carbon prices drive bioenergy demands and ILUC





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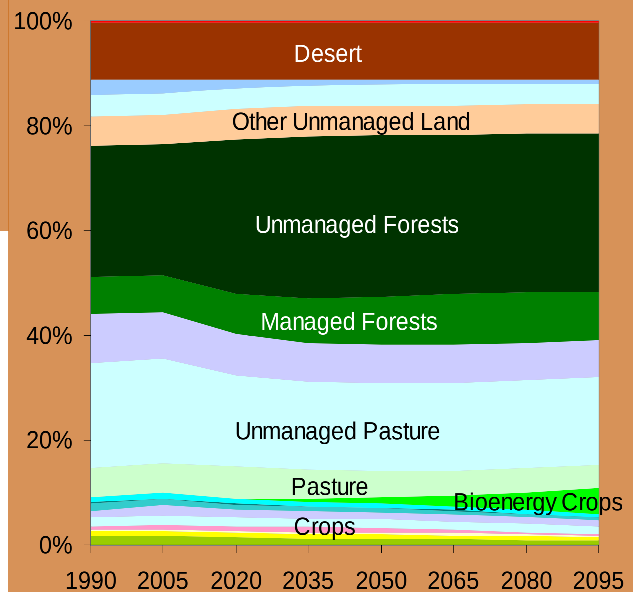
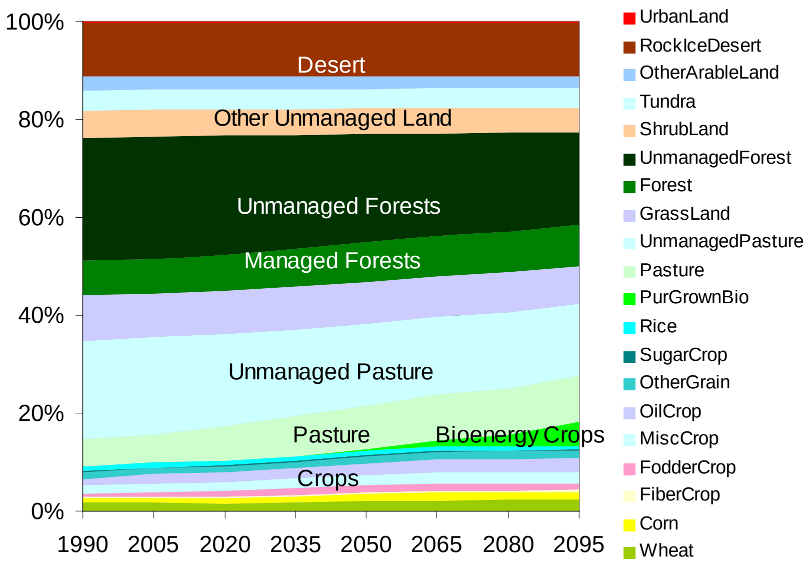
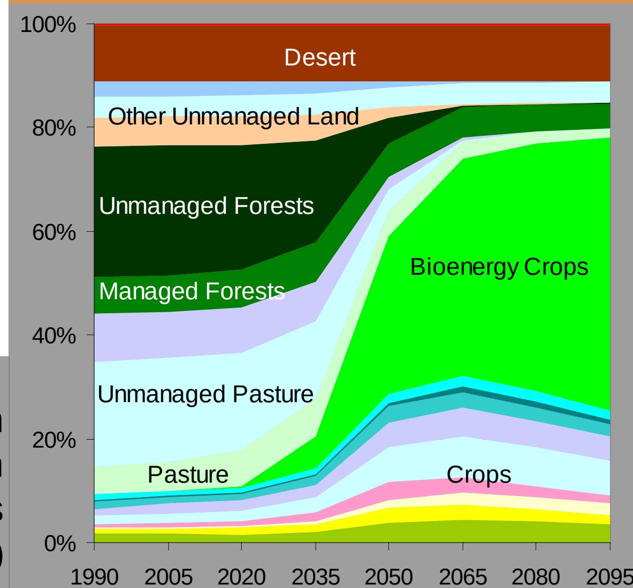
Land use: 450 ppm atmospheric CO_2

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



Reference Scenario



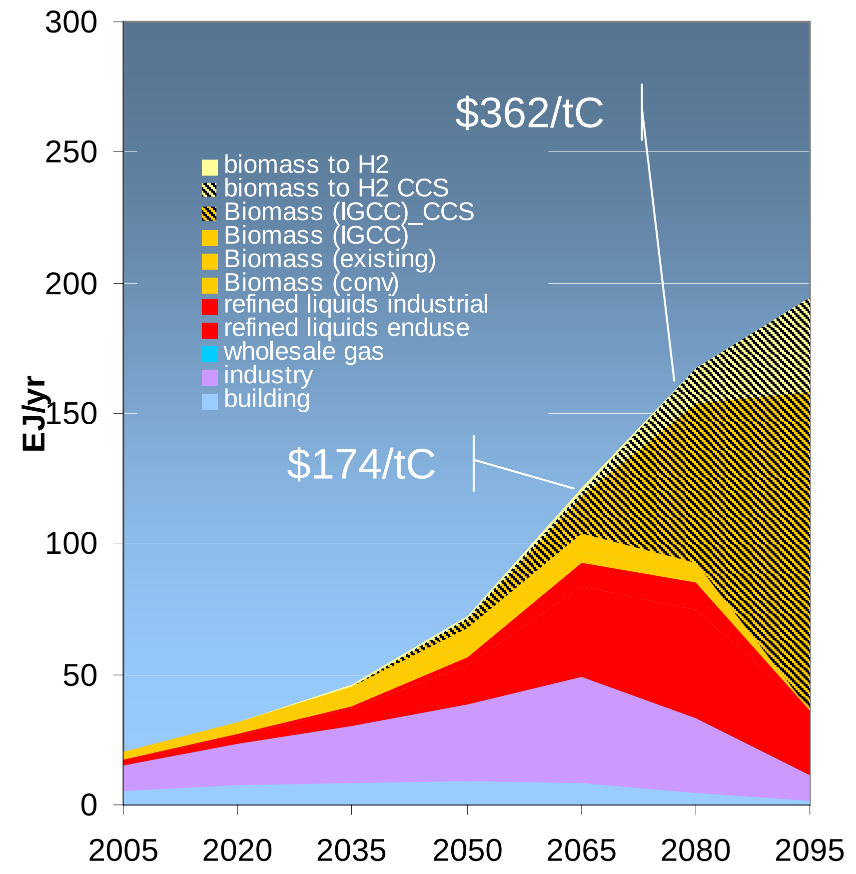


450 ppm Stabilization Scenario When Terrestrial Carbon is NOT Valued (FFICT)

Where does the bioenergy go? Carbon taxes and bioenergy use

- Bioenergy can play many roles in climate stabilization:
  - Provider of liquid fuels for transportation ( ), or
  - If CO_2 capture and storage (CCS) is an available technology, bioenergy could be used in power generation with CCS ( ) and provide a means of achieving negative global CO_2 emissions.
  - Bioenergy with CCS is a key technology for achieving low climate stabilization levels.

UCT 500 ppm



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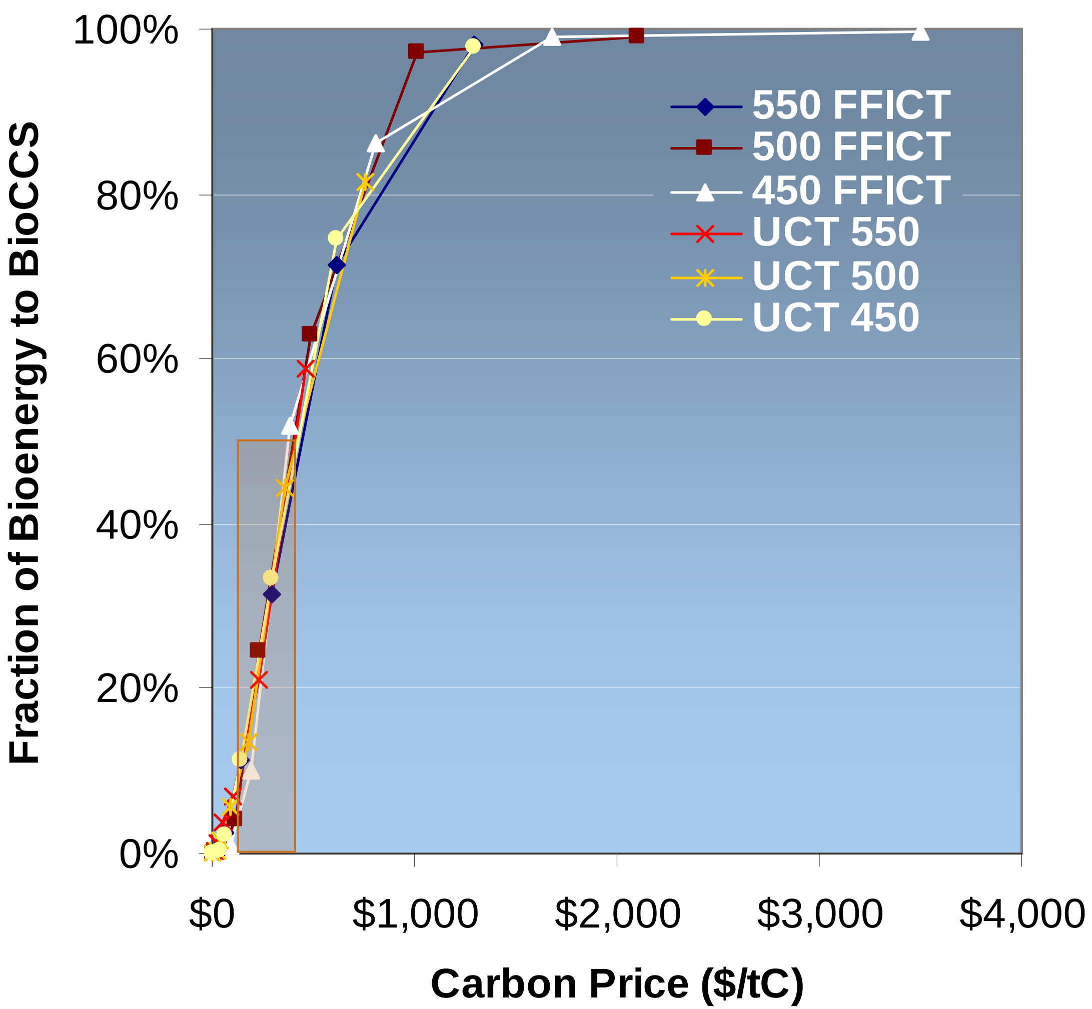
BioCCS and carbon prices



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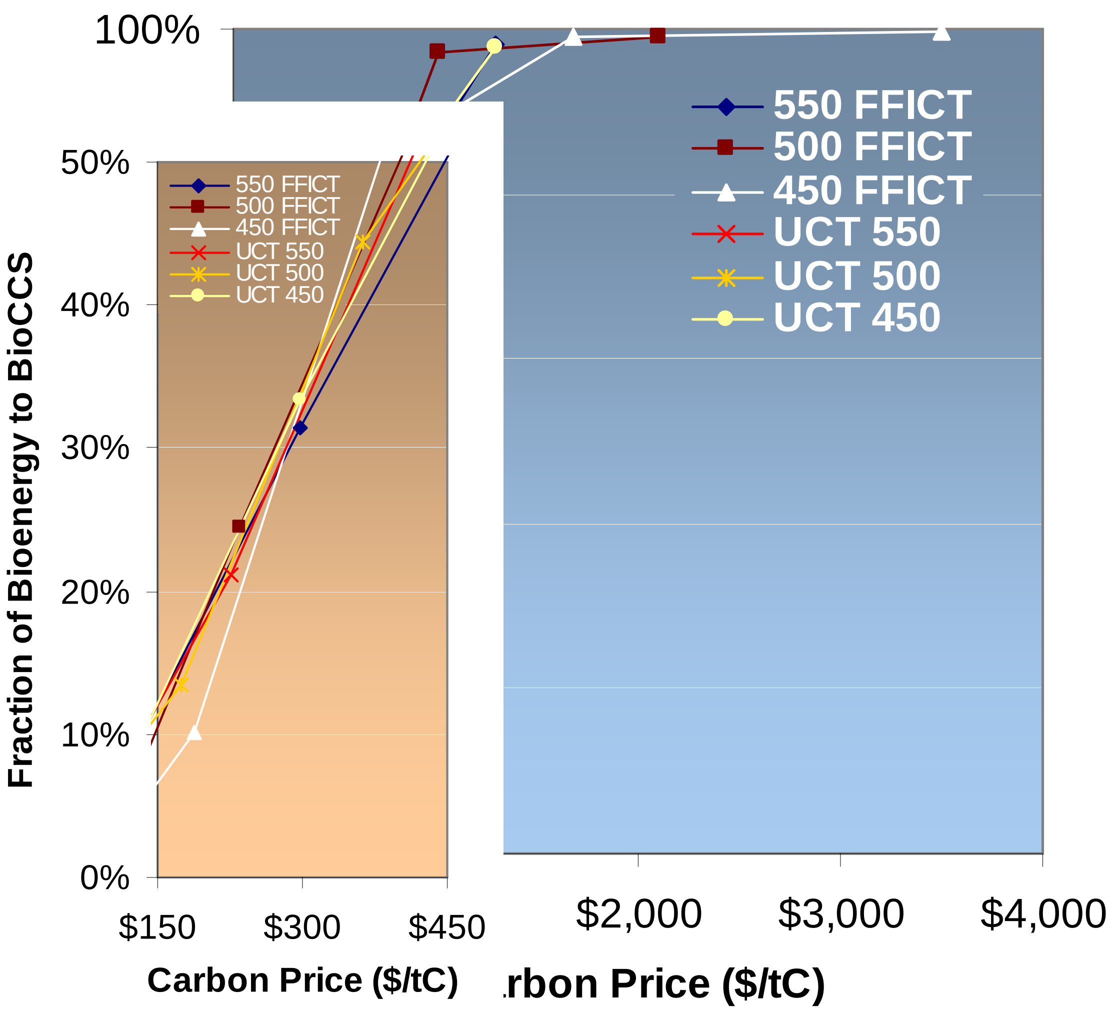
BioCCS and carbon prices



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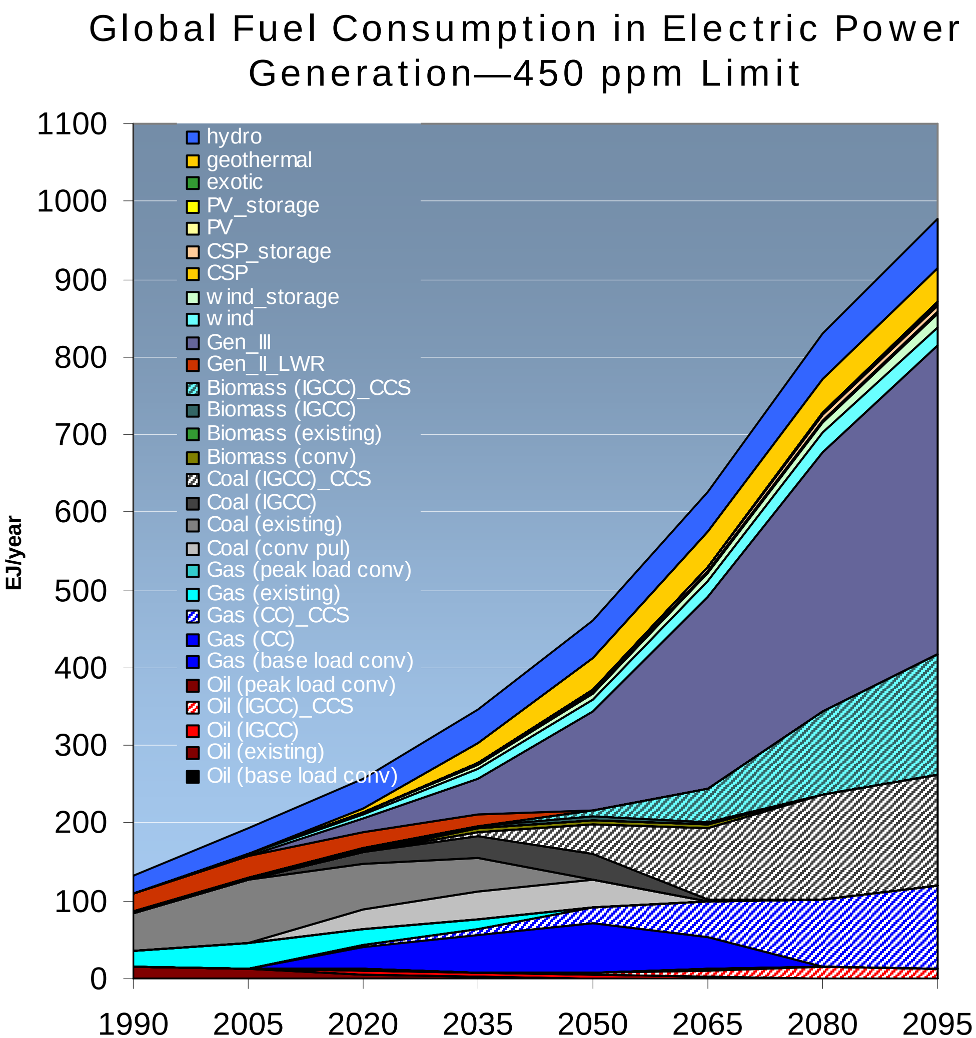
BioCCS and Electric Power Generation



- BioCCS in electricity is a minor energy form in the first half of the century.
  - Even in the 450 ppm case
- Total BioCCS energy use for power production in 2095
  - 16% of total for the 450 ppm case

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Final Thoughts

- BioCCS holds the potential to deliver negative carbon emissions and energy.
- While the “seeds” of BioCCS are with us now, much needs to change before the potential of this technology could be realized:
  - A price on carbon (and a payment for negative emissions)
  - Institutions that recognize CCS and manage risks
  - Institutions that manage indirect land-use carbon emissions (ILUC).
- Even with the realization of the many conditions for success, the higher cost of BioCCS—relative to CCS with fossil fuels—places it at least 15 years behind fossil fuel CCS in deployment in our scenarios.

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

A GTSP special report on CCS can be found at:
http://**WWW.PNL.GOV/GTSP**/docs/ccs_report.pdf

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