Can Low Stabilization Levels be Achieved Without Bioenergy with CO₂ Capture and Storage?

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Energy Supply with Negative Emissions
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Stanford University, Stanford, CA
Acknowledgements

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- The GCAM team

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OVERVIEW
Why are we interested in bioenergy with CCS?

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

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.
Two Key Questions

- Is it **technically** possible to limit radiative forcing to 2.6 Wm\(^{-2}\) in 2100 without bioenergy and CCS?
  - We do not consider political or economic feasibility.

- Do resource limits preclude successful deployment of either bioenergy or CCS or both?
  - Bioenergy is constrained by competition for land.
  - CCS is constrained by storage reservoirs.
THE PNNL GLOBAL CHANGE ASSESSMENT MODEL—GCAM
GCAM is an integrated assessment model

GCAM human Earth systems

- Open source model.
- Dynamic-recursive model.
- The GCAM human Earth systems model has Economic, Energy, Water and Land-use systems.

- Technologically detail.
- Emissions of 16 greenhouse gases & short-lived species
- 151 region land-use model.
- Runs through 2095 in 5-year time-steps (time step is variable).
CO$_2$ CAPTURE AND GEOLOGIC STORAGE
Maximum Practical Potential Geologic Storage Capacity

- Depleted Oil and Gas Basins
- Deep Saline Formations Off-shore
- Deep Saline Formations On-shore
Regional Distribution of Practical Geologic Storage Potential

- Africa
- Australia_NZ
- Canada
- China
- Eastern Europe
- Former Soviet Union
- India
- Japan
- Korea
- Latin America
- Middle East
- Southeast Asia
- USA
- Western Europe
Geographic and storage media distribution of potential practical geologic storage capacity
EXPERIMENTAL DESIGN
**Policy regimes**

**Idealized Accession**

- All regions initiate emissions mitigation simultaneously in the year 2020;
- The price of carbon emissions, both from industrial activities and land-use change, is equal in all regions and across all sectors in every period;
- The price of carbon rises at the rate of interest plus the average rate of removal of carbon by oceans, the Hotelling-Peck-Wan path (Hotelling, 1931; Peck and Wan, 1996).

**Delayed Accession**

<table>
<thead>
<tr>
<th>Year</th>
<th>Regions Joining Mitigation Regime</th>
<th>Years Between Joining &amp; Common Carbon Price</th>
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<tr>
<td>2015</td>
<td>Western Europe, Eastern Europe, Japan</td>
<td>NA</td>
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<tr>
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<td>Australia/NZ, Canada, China, Korea, USA</td>
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<tr>
<td>2050</td>
<td>India, L. America, Other South &amp; East Asia</td>
<td>20</td>
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<tr>
<td>2070</td>
<td>Africa, FSU, Middle East</td>
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An Additional Delay Scenario

► We created an additional scenario in which two regions never undertake emissions mitigation.

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## Technology Regimes

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<tr>
<th>Technology Set</th>
<th>CCS</th>
<th>Bioenergy</th>
<th>Nuclear Power</th>
<th>Other Technology</th>
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FEASIBILITY AND COST OF LIMITING RADIATIVE FORCING TO 2.6 WM$^{-2}$
Radiative Forcing Paths: All technologies and all policy regimes can reach 2.6 Wm$^{-2}$
When two regions never participated in emissions mitigation it was not possible to limit radiative forcing to 2.6 Wm$^{-2}$ for any technology suite.
Carbon Price in the Mitigation Coalition
Land Use Change Emissions
Cumulative Geologic Storage through 2100

- Unminable Coal Seams
- Depleted Oil Wells
- Depleted Gas Wells
- Deep Saline Reservoirs offShore
- Deep Saline Reservoirs onShore

PgCO₂

T1 (Ref) x Idealized
T2 (No Bio) x Idealized
T1 (Ref) x Delayed
T2 (No Bio) x Delayed

Maximum Potential
Land use Change—Net Cumulative Sequestration 2020 through 2100

Cumulative Terrestrial Sequestration

Baseline
NO BIO
NO CCS
NO BIO or CCS
NO BIO or CCS or NUCLEAR
Baseline (delay)
NO BIO (delay)
NO CCS (delay)
NO BIO or CCS (delay)
NO BIO or CCS or NUCLEAR (delay)
CCS Geologic Storage and Land use Sequestration
Cumulative 2020 through 2100
CCS Geologic Storage and Land use Sequestration: Cumulative 2020 through 2100
Final remarks

- We used the GCAM integrated assessment model to assess two questions:
  - Is it technically feasible to limit radiative forcing to 2.6 Wm\(^{-2}\) in 2100 without bioenergy and CCS? (We did not consider political or economic feasibility.)
  - Do resource limits preclude successful deployment of either bioenergy or CCS or both?
- We find the following:
  - A variety of technology regimes including technology portfolios that have neither Bioenergy, CCS, or nuclear power are technically feasible.
  - However, the lowest costs are found when bioenergy with CCS is available.
  - Delays in mitigation participation can raise costs substantially.
  - If two key regions never joined, then it was impossible to limit radiative forcing to 2.6 Wm\(^{-2}\) in 2100.
  - Neither limits to geologic storage or available land provided a meaningful constraint to limiting radiative forcing to 2.6 Wm\(^{-2}\) in 2100.
DISCUSSION