Economics of BioTechnology

Global Energy Technology Strategy Project—Steering Group Meeting

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Core Question
What role can biotechnology play in the energy system, particularly under a climate stabilization regime?

- Motivation
- Role of Biotechnology in the Energy System
- Potential Biomass Use Pathways
  - Ethanol and Transportation
  - Biomass CCS -- A transformative option?

Research Funders: GTSP, Energy Future Coalition, EPA
Biomass can play a potentially large role in the future energy system.
Motivation
Biotechnology and policy costs

End-use options are particularly valuable
Motivation
Biotechnology and policy costs

Cost of Stabilizing Climate Change

Individual Technologies

Binary Technologies Combinations

Multiple Technologies Combinations

Cost (Trillion $90US)
Role of Biotechnology in the Energy System

Almost all our energy is ultimately derived from 1) current solar irradiance, 2) fossil (past solar), or 3) nuclear forces (fission/fusion).

Focus here on biotechnology's role in facilitating use of solar irradiance.

Three principal options:

- **Intensification** — greater output from existing process
- **Expansion** — enable production in new areas
- **Cost Reduction** — production or transformation at lower cost

Different potential impacts:

- **Intensification & Expansion**
  
  *potentially*: increase ultimate role for biomass; reduce long-term costs; reduce pressure on unmanaged ecosystems

- **Cost Reduction**

  *potentially*: increase initial rate of penetration for biomass; reduce near-term costs
Biotechnology holds potential for wide application in any of the areas identified. Some options are:

**Commercial Biomass**

- **Intensification, Expansion, Cost Reduction**
  Significant near-term potential for cost reduction (hybrid poplar) and longer term options for intensification and expansion (salt tolerance)

**Agricultural Crops**

- **Intensification**
  Agricultural production will always be the largest land use — any gains in productivity here has large impacts for biomass supply.

*This could be biotechnology’s largest impact!*

*Arable land is a limited resource.*
Transformation

- **Cost Reduction**
  Production of ethanol or hydrogen. Conversion efficiencies are increasing, but have physical limits. Transformation costs are currently still high.

“Novel” Production Methods

- **Expansion**
  Algae/microbes, etc. in semi-airyd areas, use of waste heat, use of bio waste.
  Key to economic viability of new production methods is use of resources (land, waste) that are not otherwise of high value.

Economic characteristics are the principal determinant of the use of a technology.

Physical limits determine ultimate potential.
Biomass has a hard time competing with easy to transform petroleum. Biomass cost of $2.5/GJ ($40/T) cost means the feedstock cost of ethanol would be $5.80/GJ. (for Nth cellulosic conversion plant) Feedstock portion of gasoline cost is $4.70/GJ. Add to this a higher conversion cost for ethanol as compared to petroleum.

Competitive ethanol is a significant challenge with current technology.

Bio-refineries might help with initial penetration. But the scale of the energy system is far larger than that of high-value potential co-products. For the year 2000:
- Sorbitol demand: 571 million pounds
- Coal demand: 2,168,204 million pounds

Most biomass is combusted, not transformed.

### US 2000 Biomass Use (EJ)

<table>
<thead>
<tr>
<th>Sector</th>
<th>Wood &amp; by-products</th>
<th>Waste/Other</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Industry</td>
<td>1.7</td>
<td>0.2</td>
<td>1.9</td>
</tr>
<tr>
<td>Buildings</td>
<td>0.5</td>
<td>0.0</td>
<td>0.6</td>
</tr>
<tr>
<td>Transportation</td>
<td>-</td>
<td>0.1*</td>
<td>0.1</td>
</tr>
<tr>
<td>Electric Generation</td>
<td>0.1</td>
<td>0.3</td>
<td>0.5</td>
</tr>
<tr>
<td>Total Biomass Energy</td>
<td>2.4</td>
<td>0.6</td>
<td>3.0</td>
</tr>
</tbody>
</table>

*Ethanol used in transportation

Source: EIA (2002)
Biomass Energy Supply Pathways

What does it take to go from this:

Source: Object-oriented Energy and Climate Systems (O²jECTS) Framework
Biomass Energy Supply Pathways

To This:

Biomass to ethanol-powered transport pathway

Source: Object-oriented Energy and Climate Systems (O bjECTS) Framework
For a large expansion of ethanol use in transportation, the higher net energy efficiency of cellulosic conversion will be needed (particularly under a carbon policy).

Key questions:
- Total cost (particularly for reference case)?
- Can production of co-products free additional land for biofuel production?
- Where can biotechnology make a difference?

There are few estimates of the economics of this production processes.
With few ethanol cars or supporting infrastructure:

Most biomass is either combusted or used as a hydrogen feedstock (assuming H2 demand exists).
Use of a fuel depends on demand technologies and supporting infrastructure:

Biomass Use (USA)
WRE 550 (Ethanol Vehicles)

If vehicles using biofuels (and distribution) are available, then most biomass is used as an ethanol feedstock).

This is a fairly (overly?) optimistic case for near-term Ethanol use.
Most transportation is still powered by fossil fuels – even in a carbon policy case. Is such a system feasible or desirable? Is H₂ a better option? Or some other use?
Biomass combustion processes offer advantage of simplicity and relatively low cost. 

* Biomass used to produce electricity is attractive, but does not offer large long-term cost savings for a policy case since there are other low or no-carbon electric generation options and potentially other higher value uses for Biomass.

However

Biomass coupled with carbon capture and storage (CCS) offers the potential for negative emissions. This makes this technology potentially very attractive.

Modeling this option requires new methodologies in order to incorporate the carbon credit received by a biomass CCS plant. We have examined this behavior of biomass CCS in a competitive electric market using a “toy” spreadsheet model.
Biomass with Carbon Capture and Storage

Biomass CCS would be similar to a coal plant with CCS.

- Conventional combustion turbine with CO\textsubscript{2} flue gas separation
- Integrated biomass gasification, combined-cycle CO\textsubscript{2} separation

Since there is no penalty for emitting biomass, the biomass CCS plant receives a credit for its sequestered carbon.

Sectors emitting carbon pay a permit price for their emissions. A portion of these permits go to biomass CCS plants as a credit.

The credit received is proportional to the carbon price.

As the carbon price increases the aggregate electricity price can decrease.

As the electricity price drops sufficiently it becomes attractive to simply sequester biomass derived carbon.

This option acts to stabilizes electricity prices.
Biomass CCS

Regime I
Carbon venting technologies decrease.

Regime II
Biomass CCS progressively out competes other low and no carbon technologies.

Regime III
At high carbon prices direct biomass sequestration without electric generation is competitive.

Results from a “toy” model without full energy system feedbacks.
Biomass CCS

At high carbon prices direct sequestration of biomass carbon (without electric generation) competes for biomass supply.

This drives biomass prices up, and tends to stabilize the share of biomass electric generation with CCS.

Terrestrial sequestration options would still come at low carbon prices (not shown).
Biomass with CCS

Biomass electric with CCS is highly competitive due to

- **Generation Cost**
  Because biomass with CCS receives a carbon credit it can produce electricity at lower cost than other options.

- **Electricity Cost**
  The decrease in the aggregate electricity price will lower the ability of other options to compete.

This is likely to significantly lower policy costs

Negative emissions allows greater emissions from sectors with more expensive mitigation options, particularly transportation.

This would be a continuous emissions offset (in contrast to terrestrial sequestration)

Impact depends on potential biomass supply

The scope of this technology is directly proportional to the ability to sustainably produce biomass fuels.

Land conversion to biomass plantations could offset some of these gains.

Also being examined in Europe

C. Azar (Göteborg)
D. van Vuuren (RIVM/MNP)
Biotechnology can play an important role in the energy system by enhancing the supply of carbon-neutral energy.

- The modes by which this takes place depend on technological performance and infrastructure.
  Technology cost analysis to date, for example biomass to ethanol, is somewhat limited.

- The availability of suitable land and future productivity of (non-energy) food and fiber crops are critical determinants of the potential biomass contribution.

- Biomass with carbon capture and storage has significant potential to lower policy costs
  Next step — analysis within the integrated modeling framework.
Discussion