GTSP

Global Energy Technology Strategy Program

# Economics of BioTechnology

## Global Energy Technology Strategy Project— *Steering Group Meeting*

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# Outline

## Core Question

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

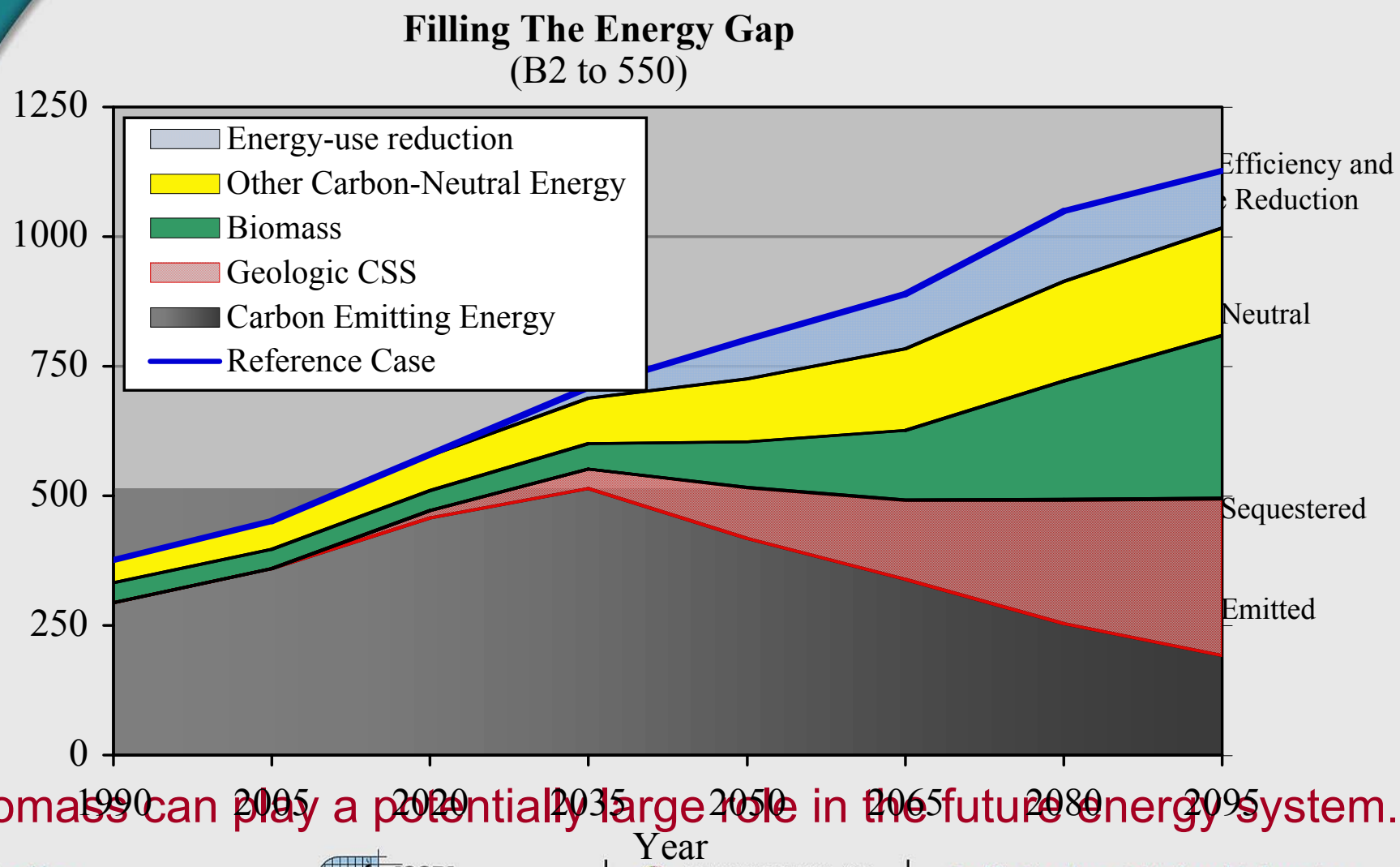
- Motivation
- Role of Biotechnology in the Energy System
- Potential Biomass Use Pathways
  - Ethanol and Transportation
  - Biomass CCS -- A transformative option?

*Research Funders: GTSP, Energy Future Coalition, EPA*

# Motivation

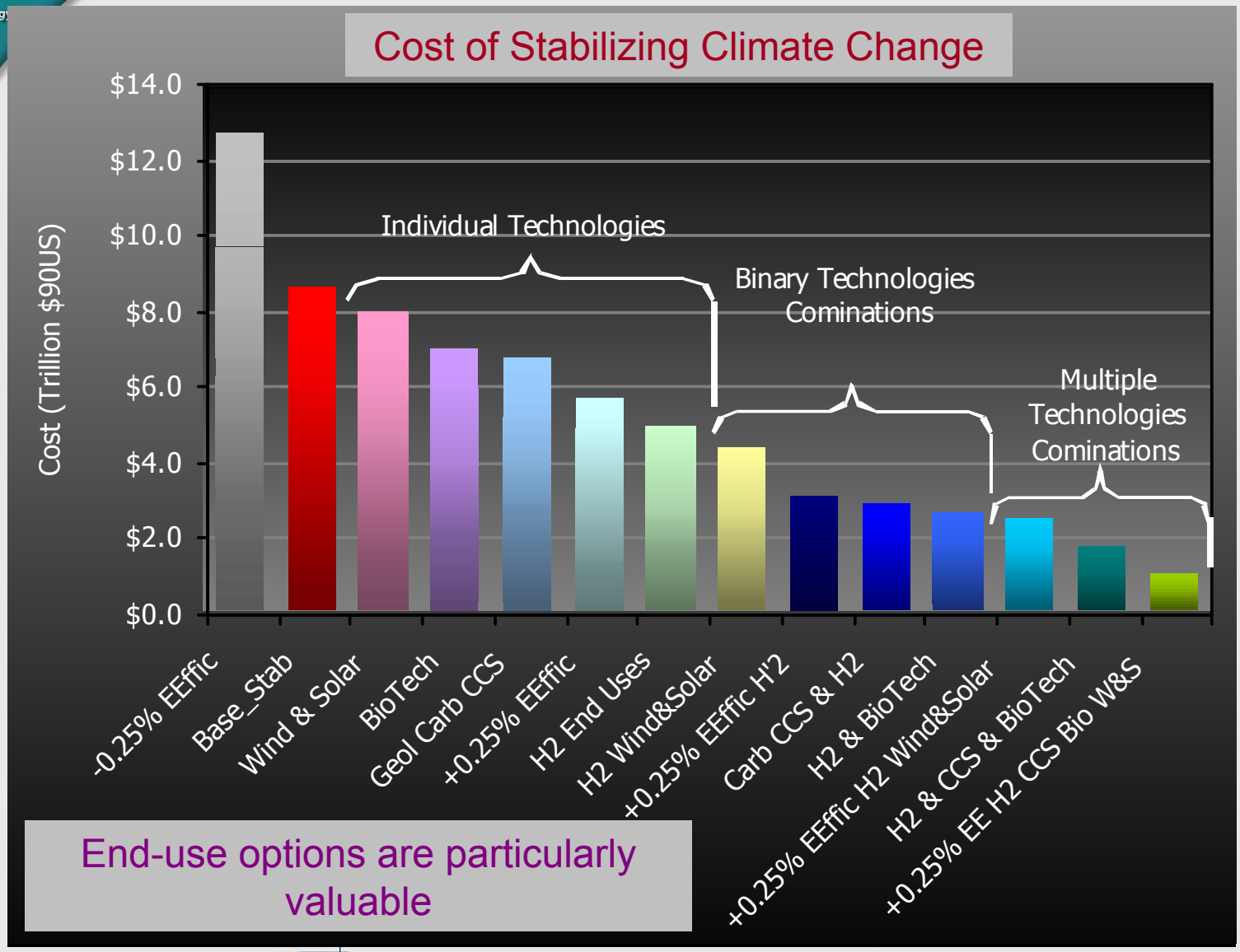
## Role of carbon neutral energy

*Carbon Neutral Energy is at a premium under a carbon policy*

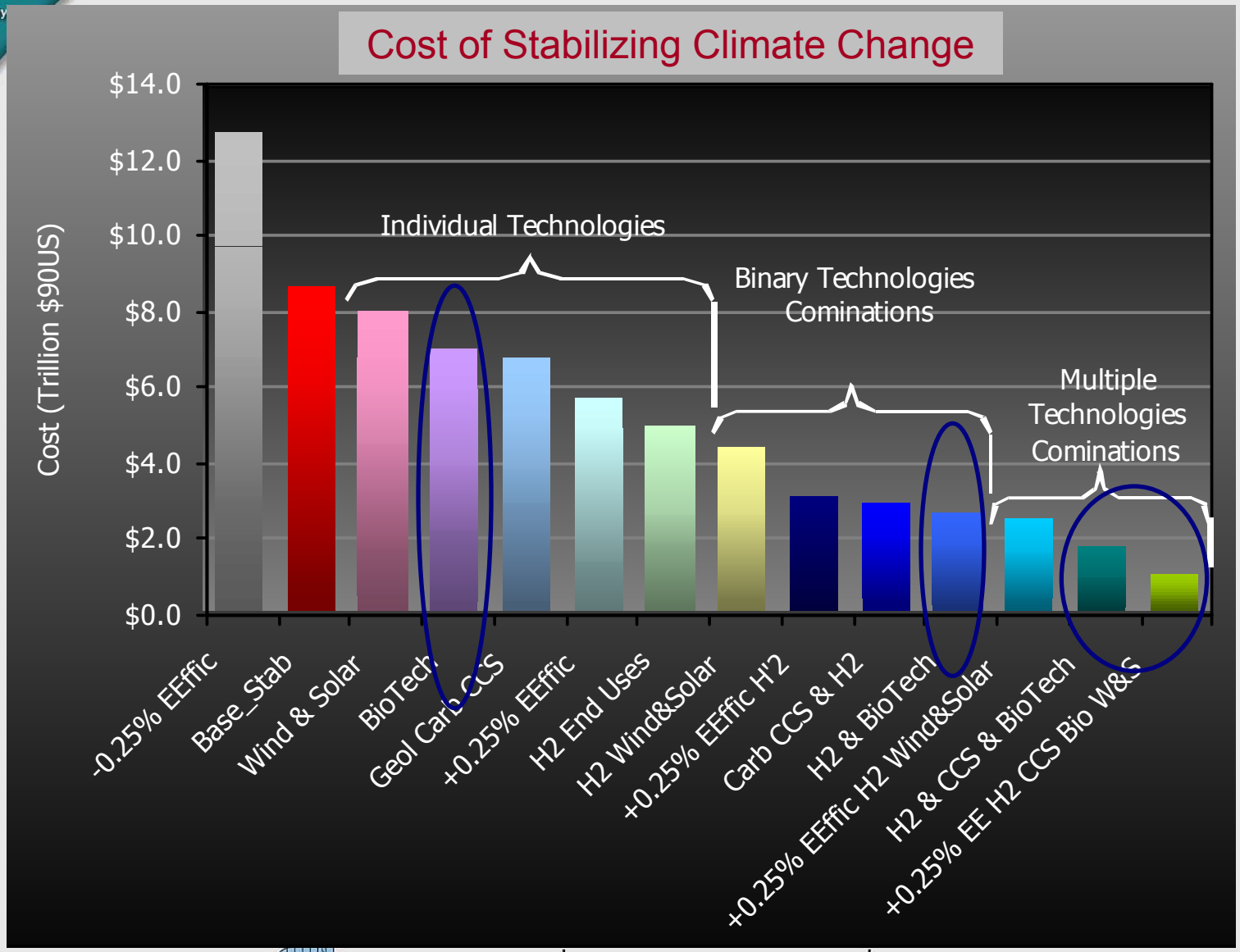



Biomass can play a potentially large role in the future energy system.

# Motivation
## Biotechnology and policy costs



# Motivation
## Biotechnology and policy costs



# 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
# Energy Supply Applications I

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.

*Arable land is a limited resource.*

***This could be biotechnology's largest impact!***

# Biotechnology
# Energy Supply Applications II

## 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-aird 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 Energy Supply Pathways

Most biomass is combusted, not transformed

US 2000 Biomass Use (EJ)

| Sector | Wood & by-products | Waste/Other | Total |
|---|---|---|---|
| Industry | 1.7 | 0.2 | 1.9 |
| Buildings | 0.5 | 0.0 | 0.6 |
| Transportation | - | 0.1* | 0.1 |
| Electric Generation | 0.1 | 0.3 | 0.5 |
| Total Biomass Energy | 2.4 | 0.6 | 3.0 |

*Ethanol used in transportation

Source: EIA (2002)

*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**

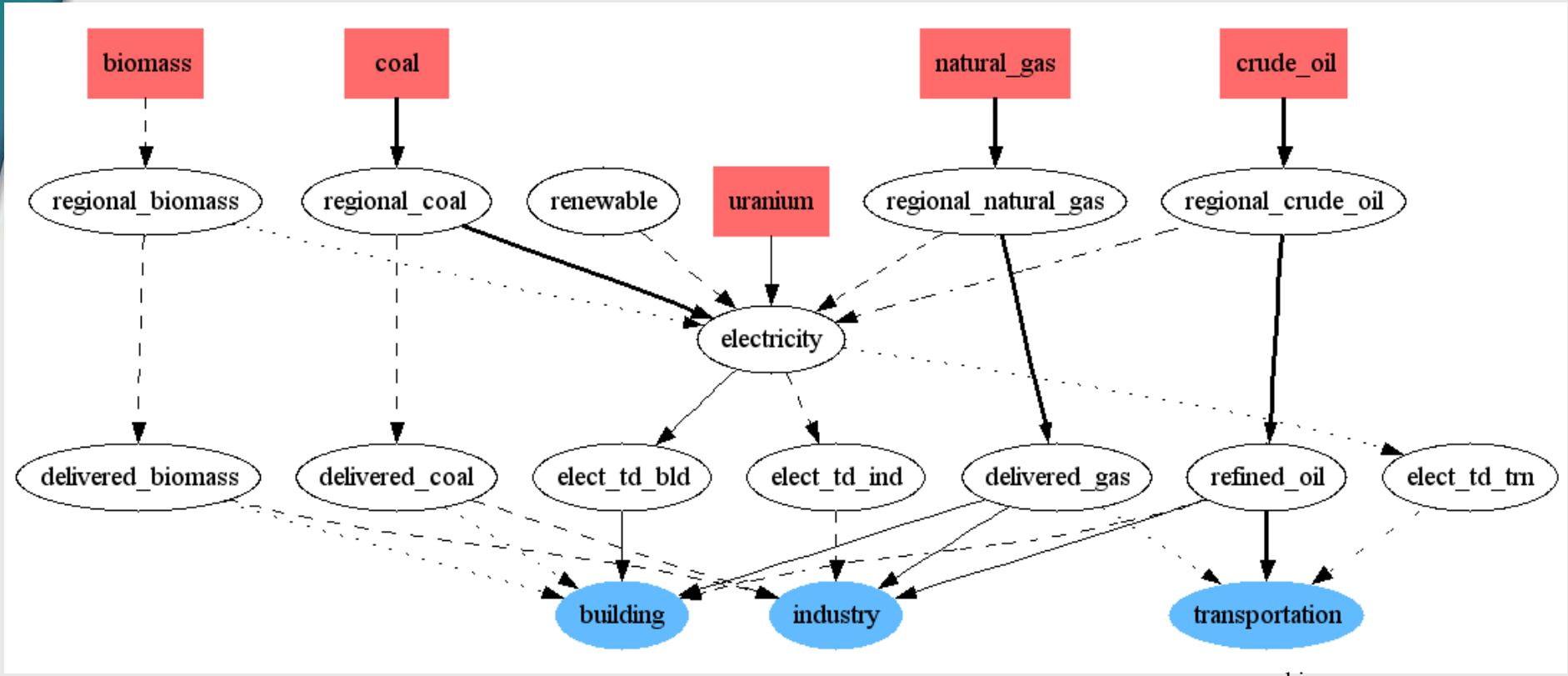
But the scale of the energy system is far larger than that of high-value potential co-products. For the year 2000:

Sorbitol demand: 571 million pounds

Coal demand: 2,168,204 million pounds

# Biomass
# Energy Supply Pathways

What does it take to go from this:

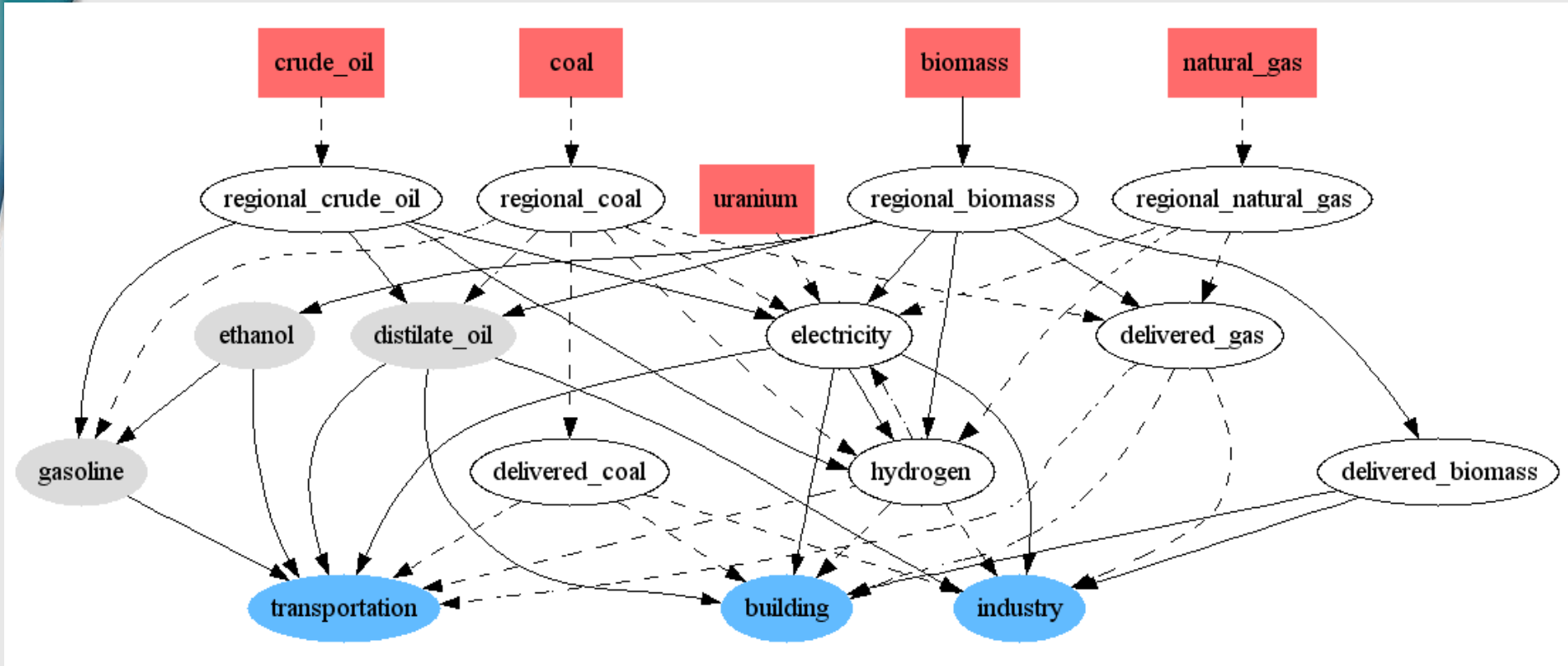



Source: Object-oriented Energy and Climate Systems (O^bjECTS) Framework

# Biomass Energy Supply Pathways

## To This:

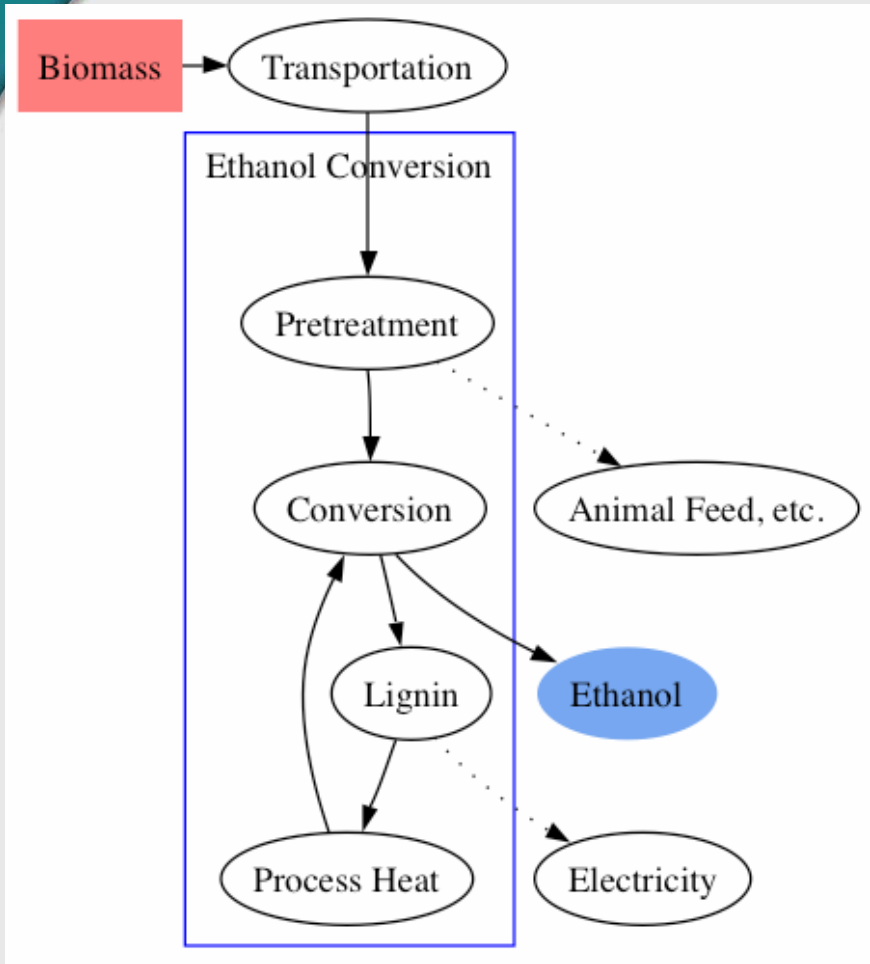
Biomass to ethanol-powered transport pathway




Source: Object-oriented Energy and Climate Systems (O$^{bj}$ECTS) Framework

# Cellulosic Conversion

**Ethanol Production Process**




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).

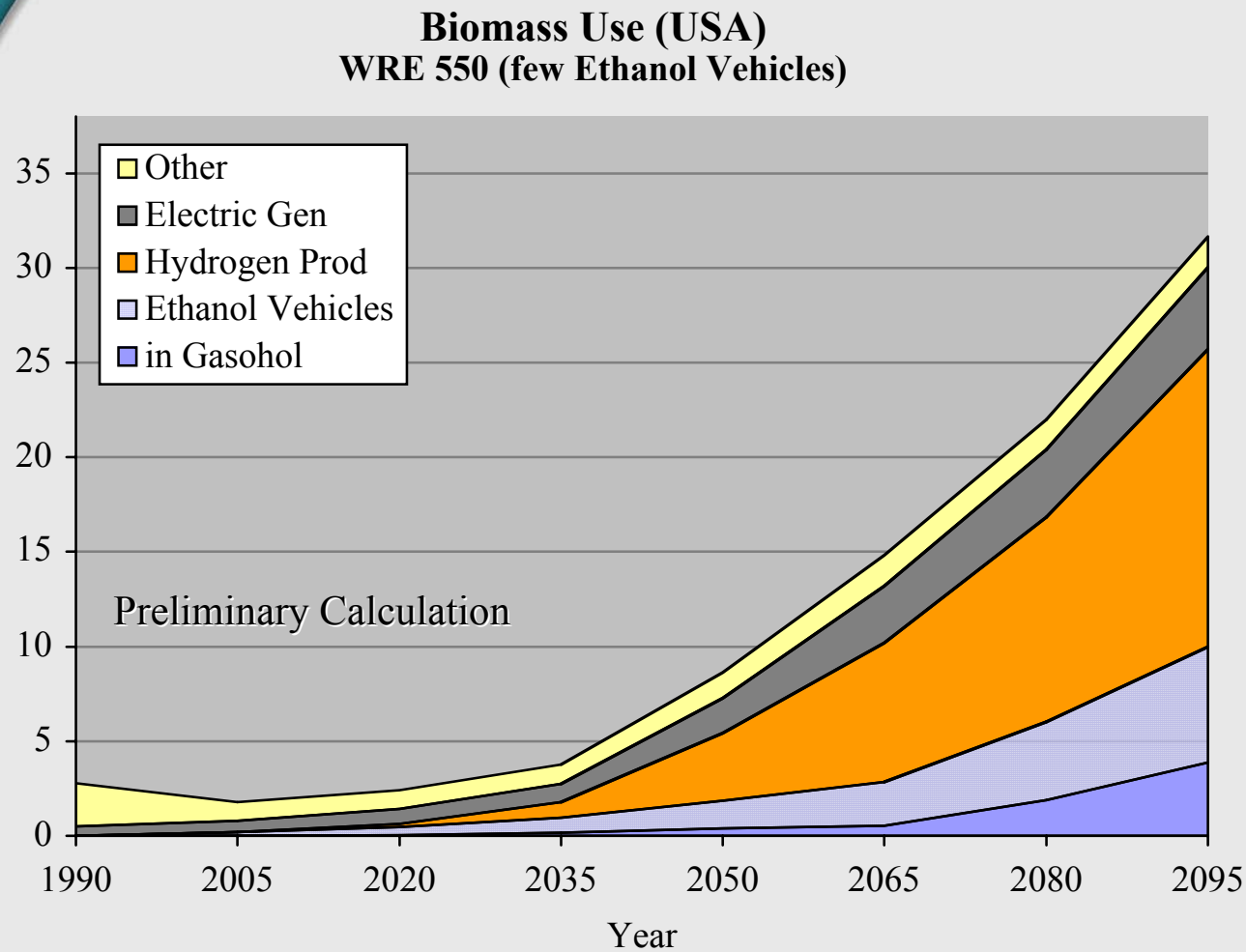
Key questions:

- 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.*

# Biomass
# Energy Supply — Ethanol Pathways

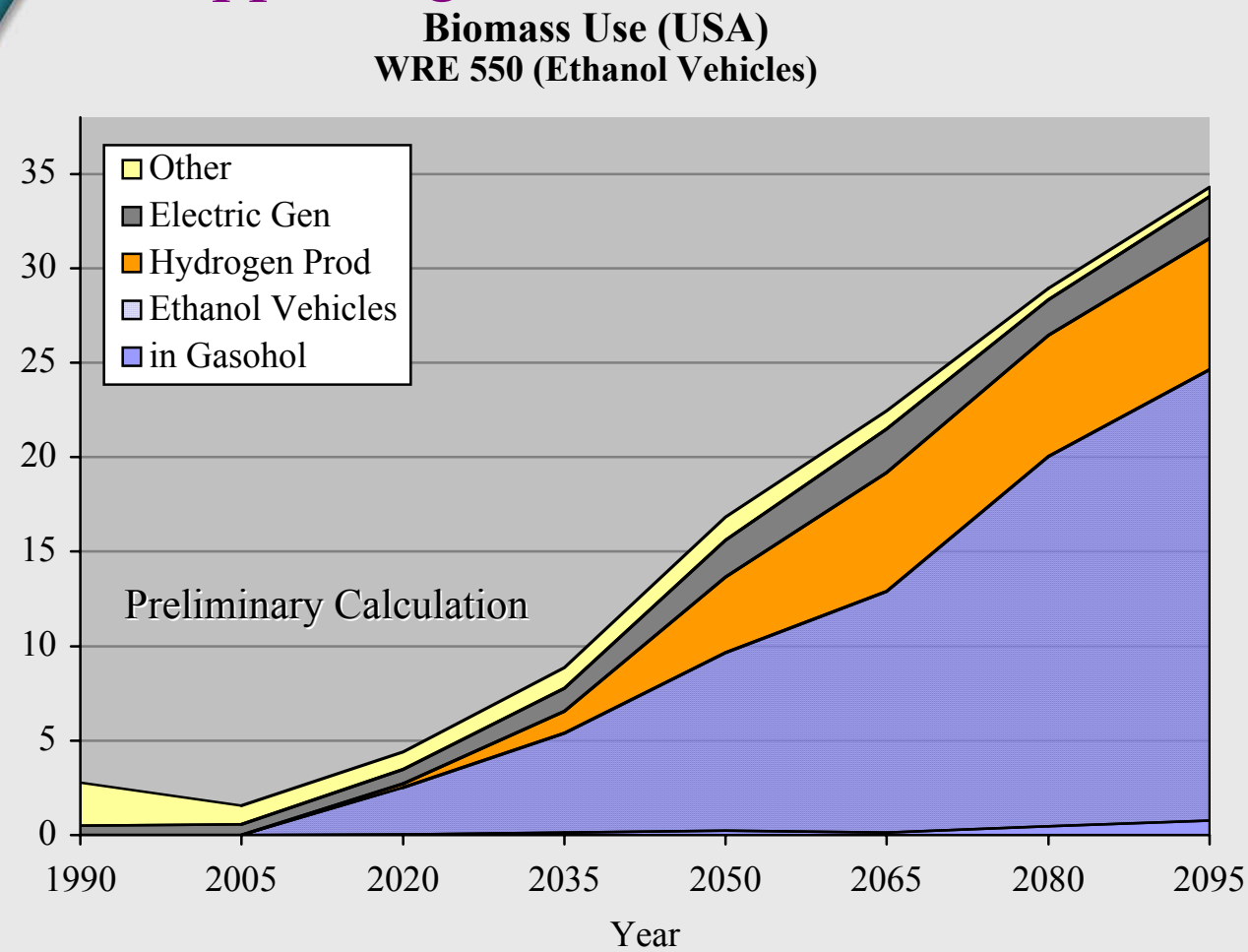
## With few ethanol cars or supporting infrastructure:




Most biomass is either combusted or used as a hydrogen feedstock (assuming H2 demand exists).

# Biomass
# Energy Supply — Ethanol Pathways

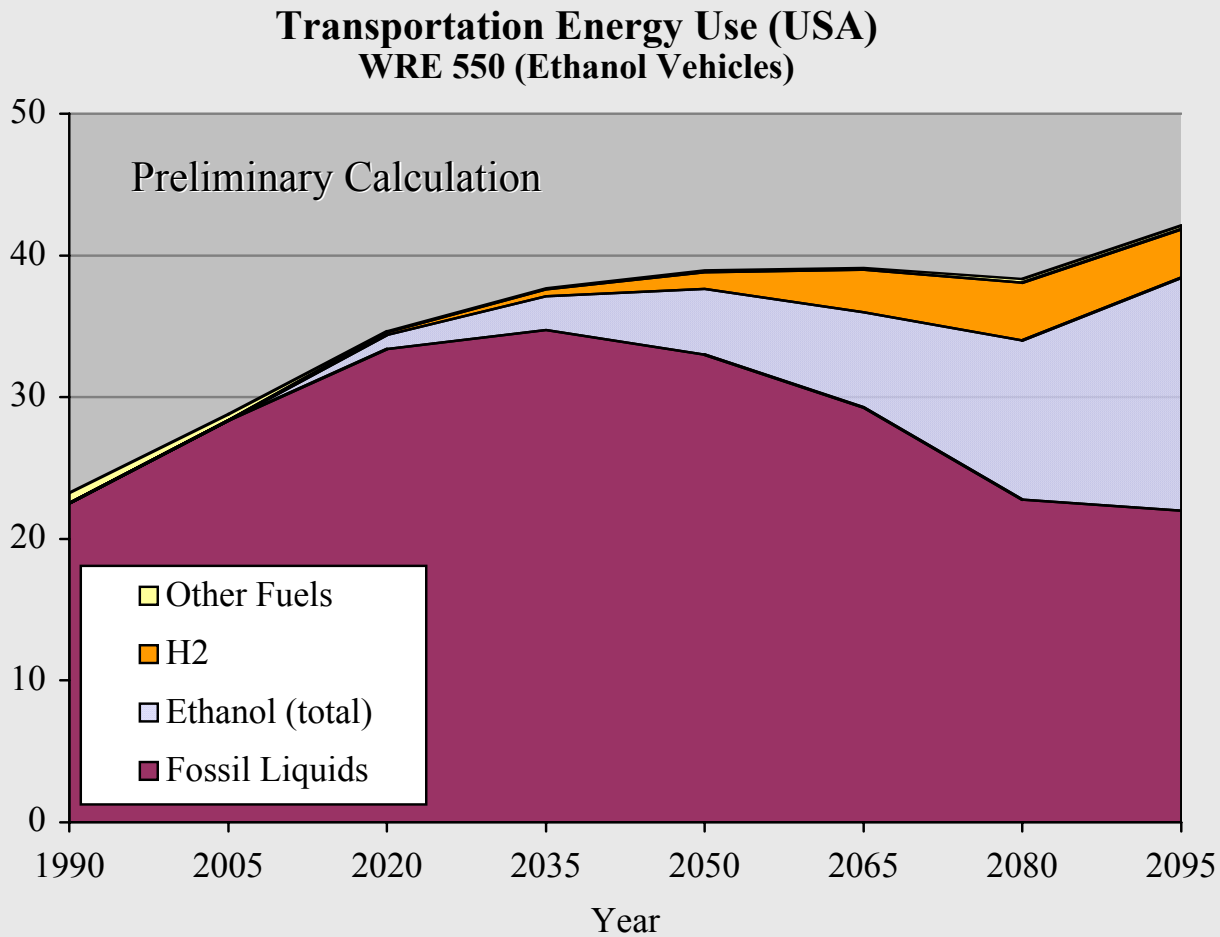
Use of a fuel depends on demand technologies and supporting infrastructure:




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

This is a fairly (overly?) optimistic case for near-term Ethanol use

# Biomass
# Energy Supply — Ethanol Pathways




Most transportation is still powered by fossil fuels – even in a carbon policy case. Is such a system feasible or desirable? Is $H_2$ a better option? Or some other use?

# Biomass Energy Supply — Reexamine Combustion

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.

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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 $CO_2$ flue gas separation
- Integrated biomass gasification, combined-cycle $CO_2$ 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.

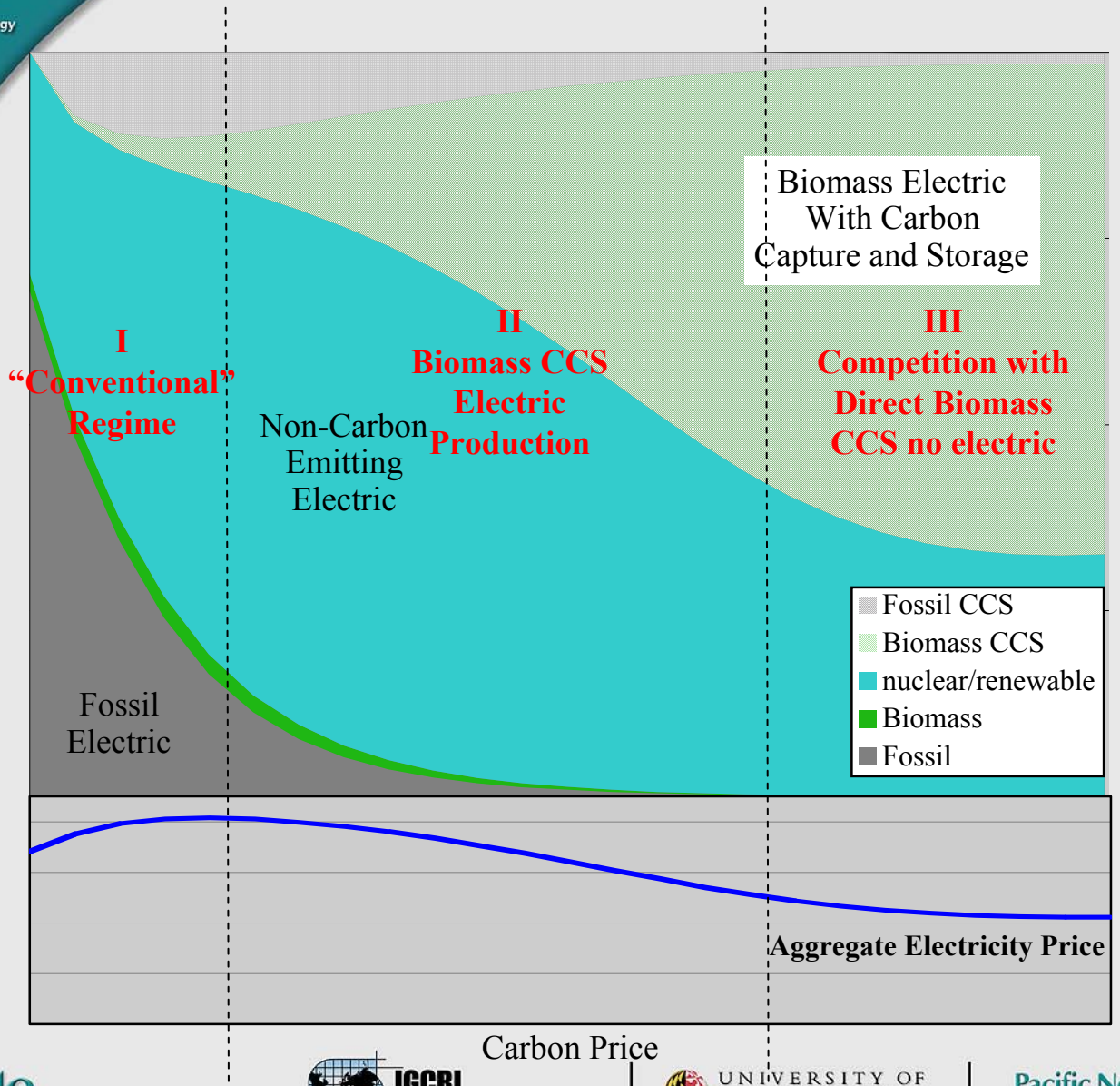
As the carbon price increases the aggregate electricity price can decrease.

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

This option acts to stabilizes electricity prices.

# Biomass CCS

*Results from a "toy" model without full energy system feedbacks*




## Regime I

Carbon venting technologies decrease.

## Regime II

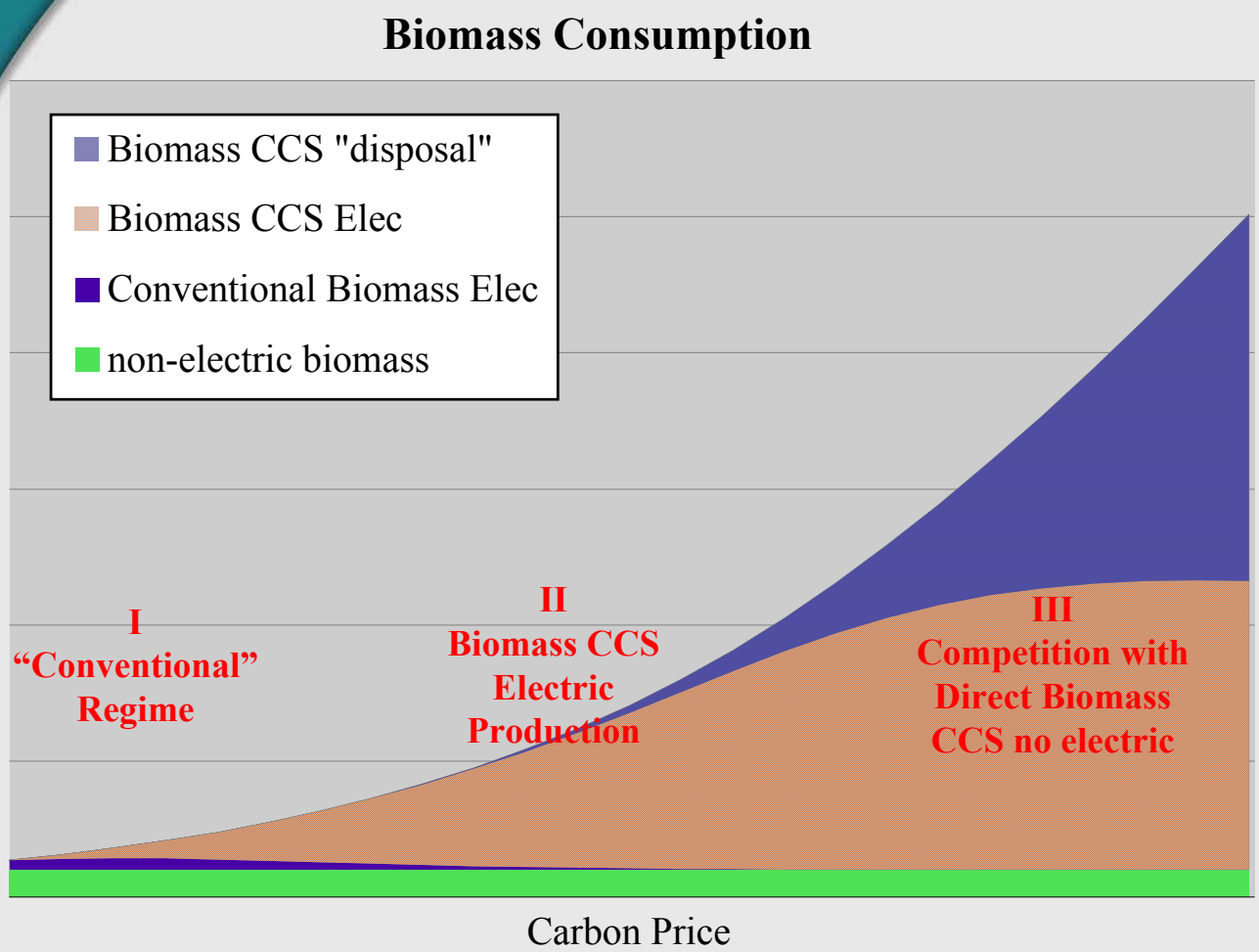
Biomass CCS progressively out competes other low and no carbon technologies.

## Regime IIII

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

# Biomass CCS

*Results from a "toy" model without full energy system feedbacks*




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)

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# 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)

# Summary

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