Biomass to Biofuels: Tailoring Plant Cell Wall Composition and Structure for More Efficient Biofuel Production

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May-14-2015

BROOKHAVEN NATIONAL LABORATORY
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U.S. DEPARTMENT OF ENERGY | Office of Science

Outline

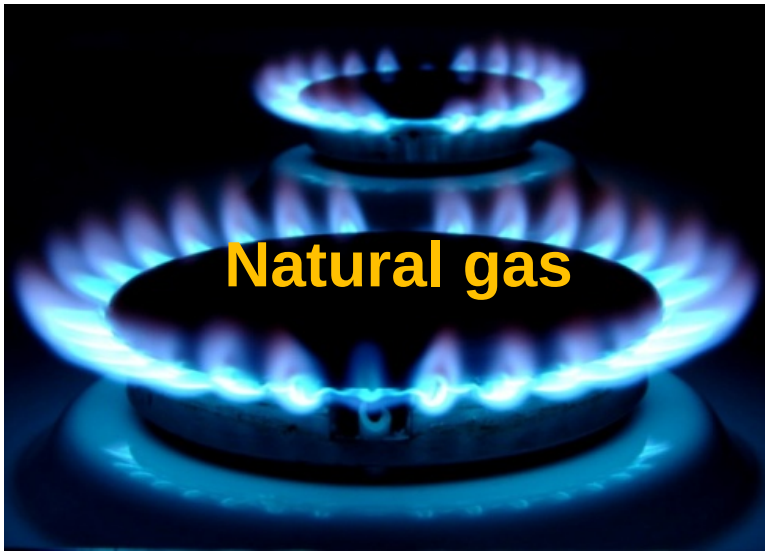
- What are the benefits of cellulosic biofuels?
- Challenges of converting cellulosic biomass to biofuels
- Research activity at BNL to tailor cellulosic biomass for efficient conversion to fuel

Carbon Based Fossil Fuels

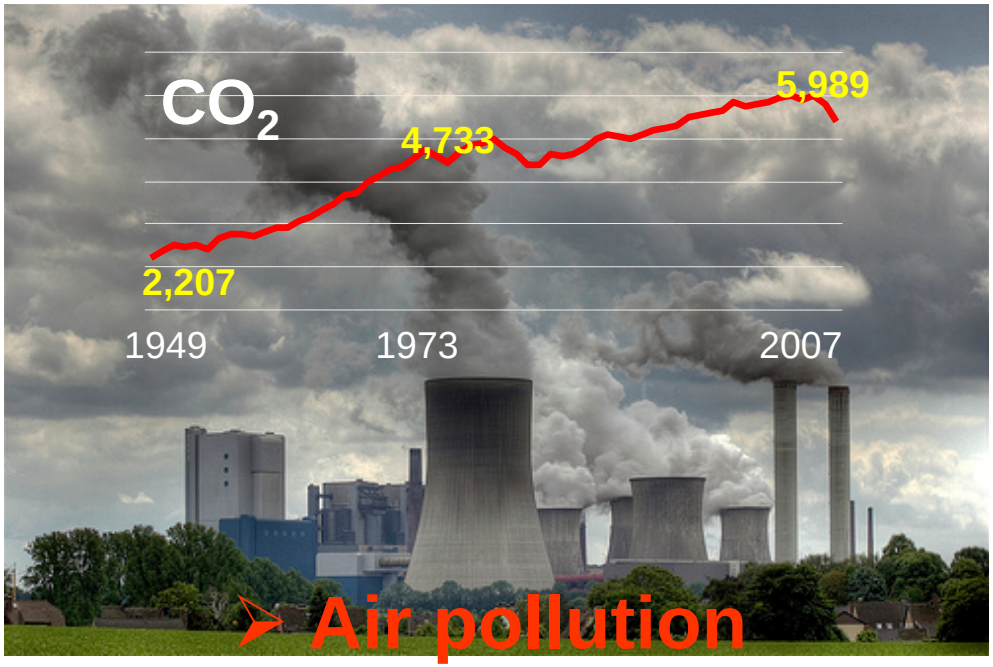
Generated via 300-450 million years' decomposition and conversion from plant and animal debris

A non-sustainable resource with negative environmental consequences

Reserves: only last for ~50 yrs



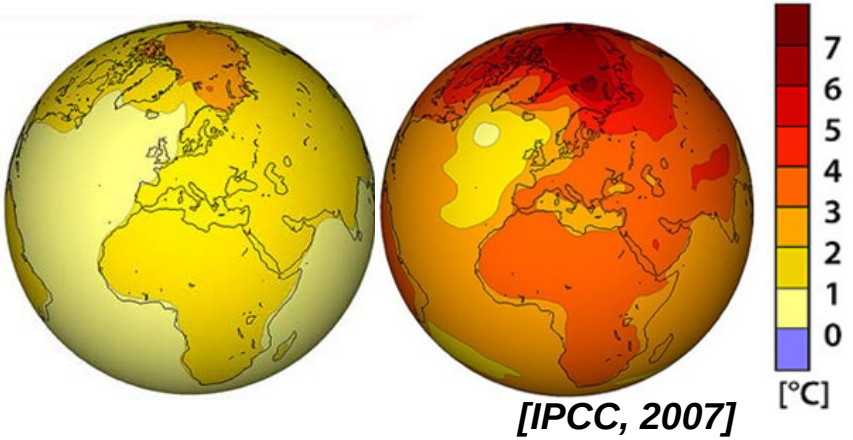
Carbon Based Fossil Fuels



➢ Air pollution

2030
A1B:2020-2029

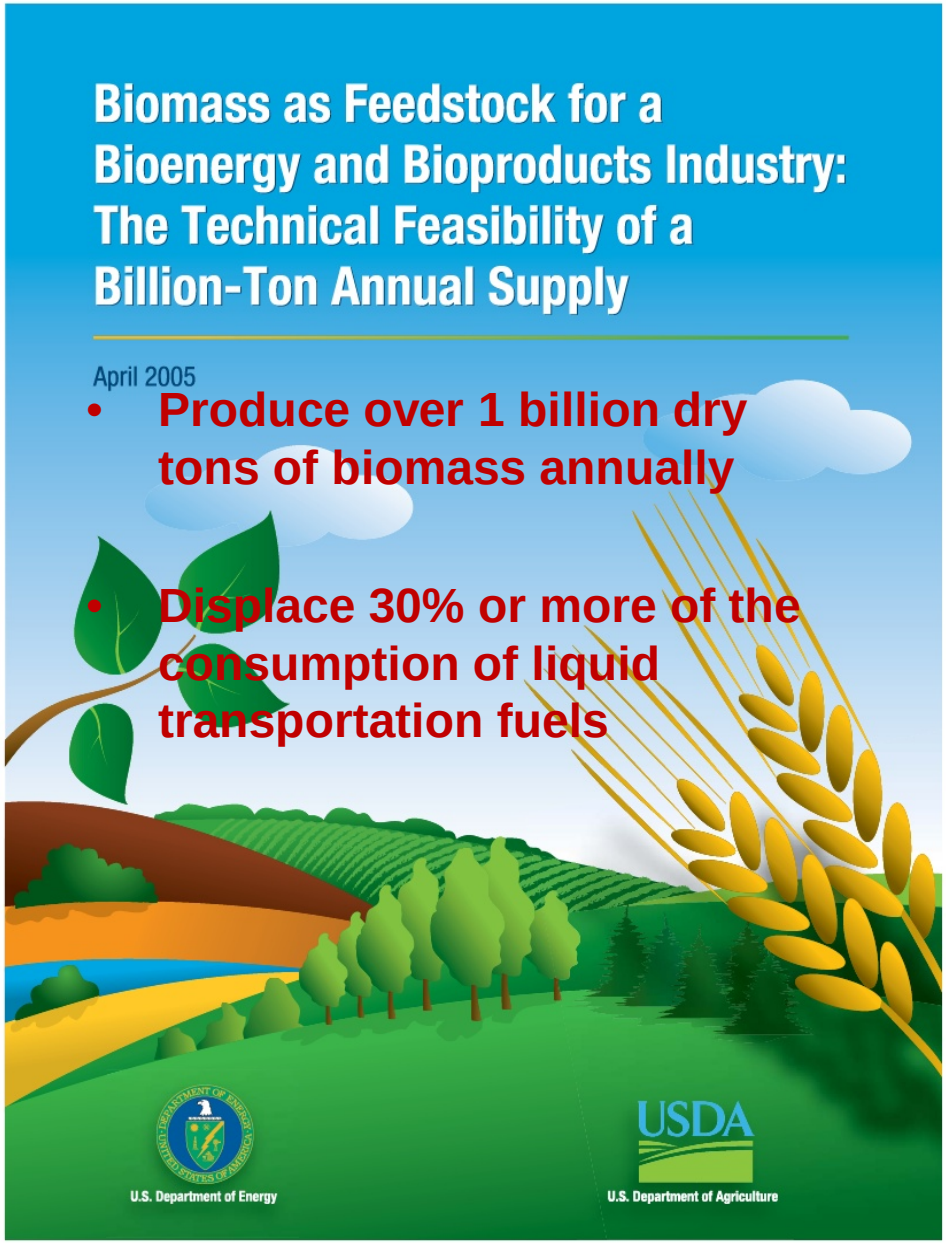
2100
2090-2099



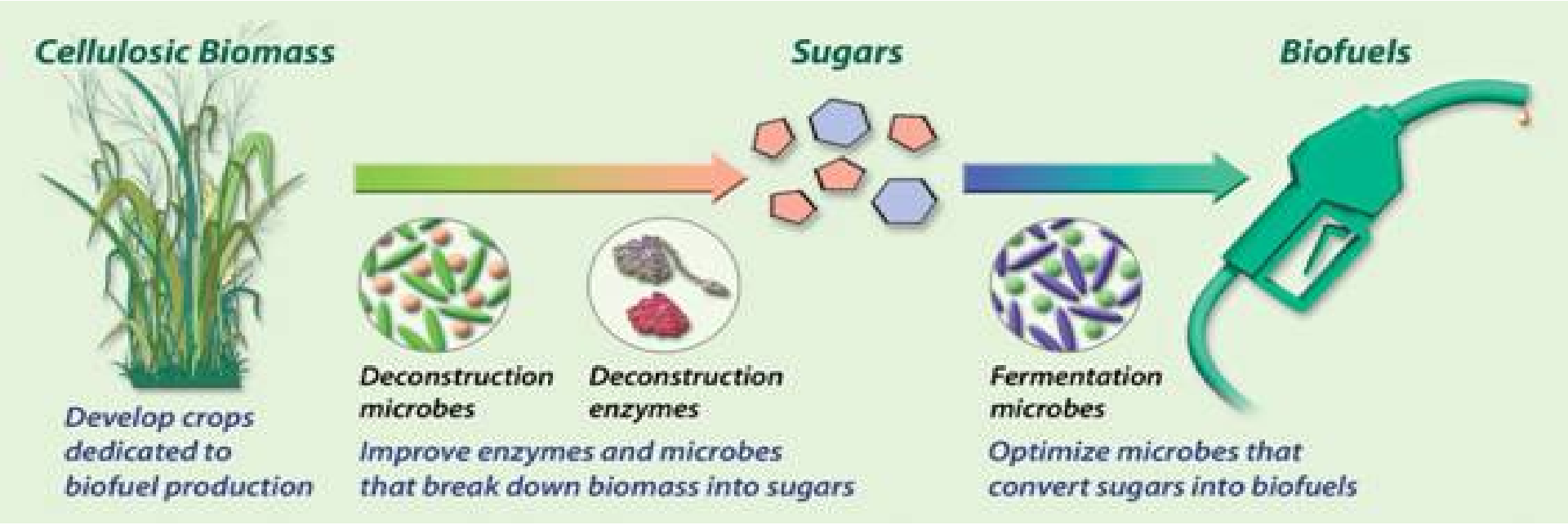
[IPCC, 2007]

➢ Climate change

Lignocellulose can be made into biofuels



Making biofuels from lignocellulose



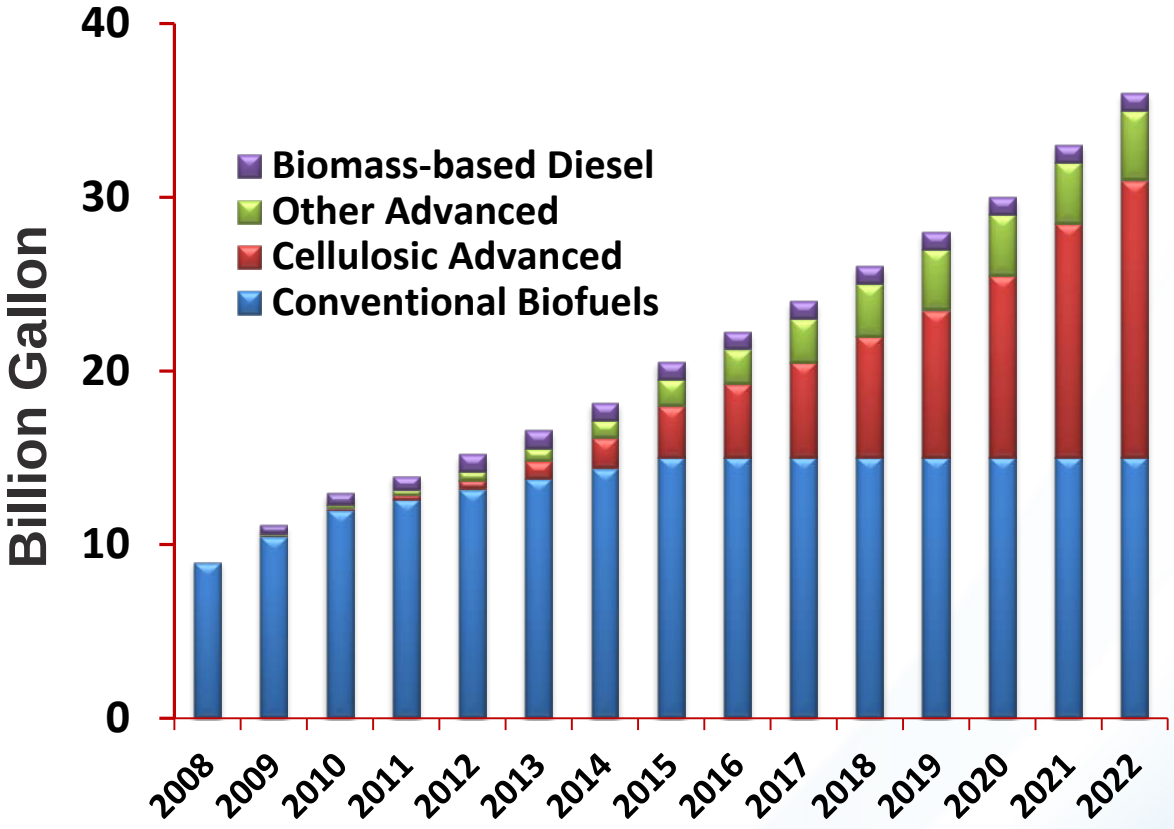
Food *versus* Fuels

Advantages of Cellulosic Ethanol

- Grown on marginal lands
- Abundant and diverse (10 tons/acre)
- Water footprint: low
- Greenhouse gas savings: high

[Source: Argonne National Laboratory]

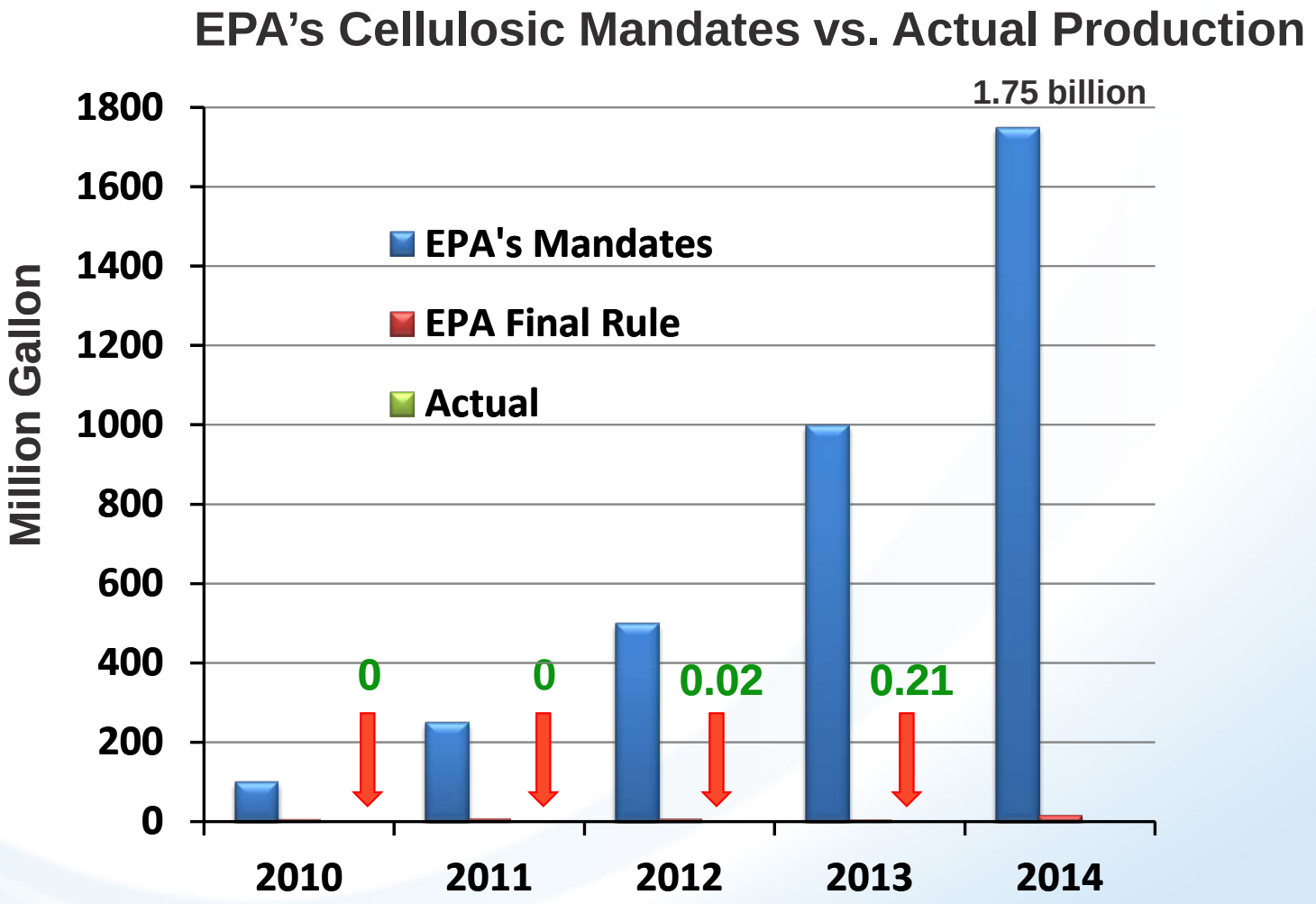
Biofuel use is mandated by the government



The 2007 energy bill requires 36 billion gallons of biofuels by 2022

---SOURCE: US Energy Independence & Security Act of 2007

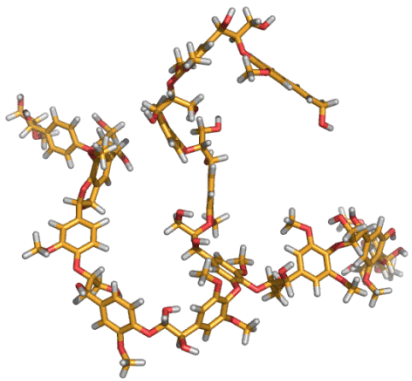
Cellulosic biofuels are not commercially produced…….



Why have we not produced any cellulosic ethanol?

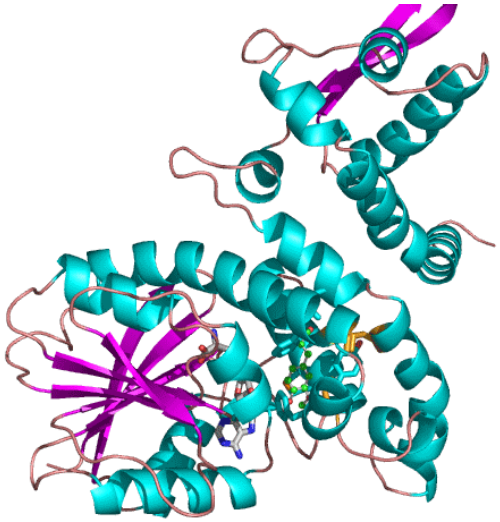
Lignocellulose is hard to break down, because:

- **Lignin is complex and rigid**
- **Cellulose is crystalline**

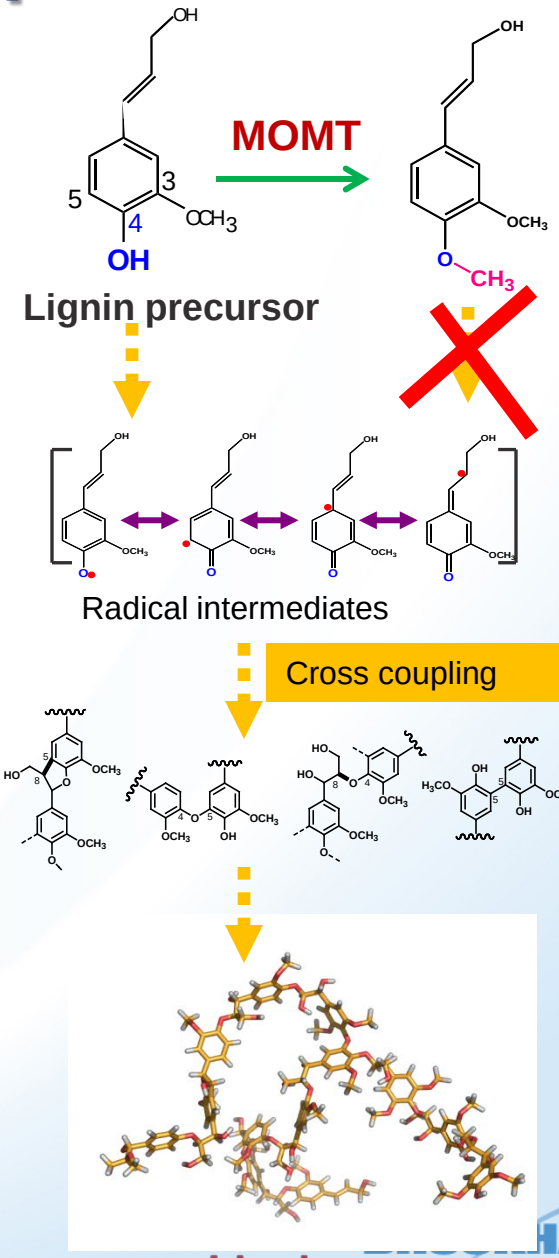


Approach to reducing lignin

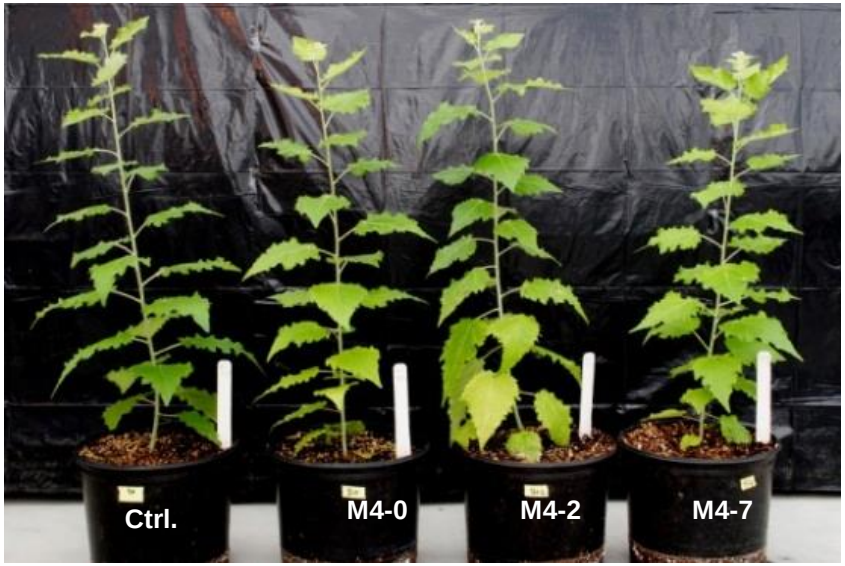
Make novel enzymes to chemically modify lignin precursors to disrupt their polymerization



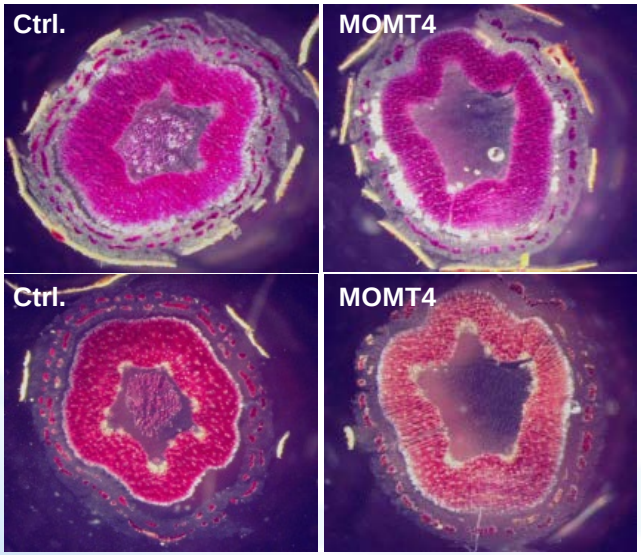
Monolignol 4-*O*-methyltransferase (MOMT)



Transform into Poplar Plants – Grow in Greenhouse



We generated a set of transgenic poplar with monolignol 4-*O*-methyltransferases

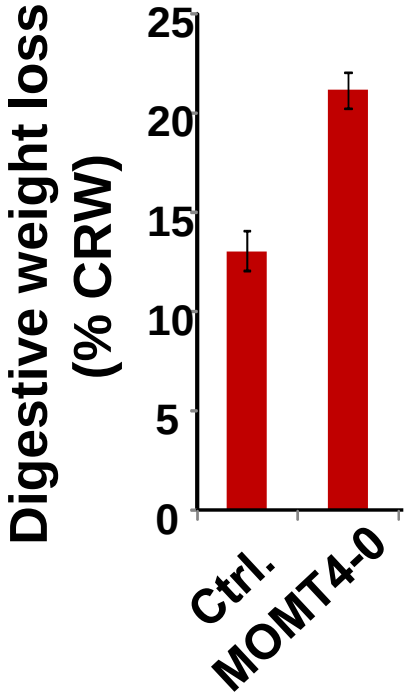


Greenhouse Transgenic Poplar Results

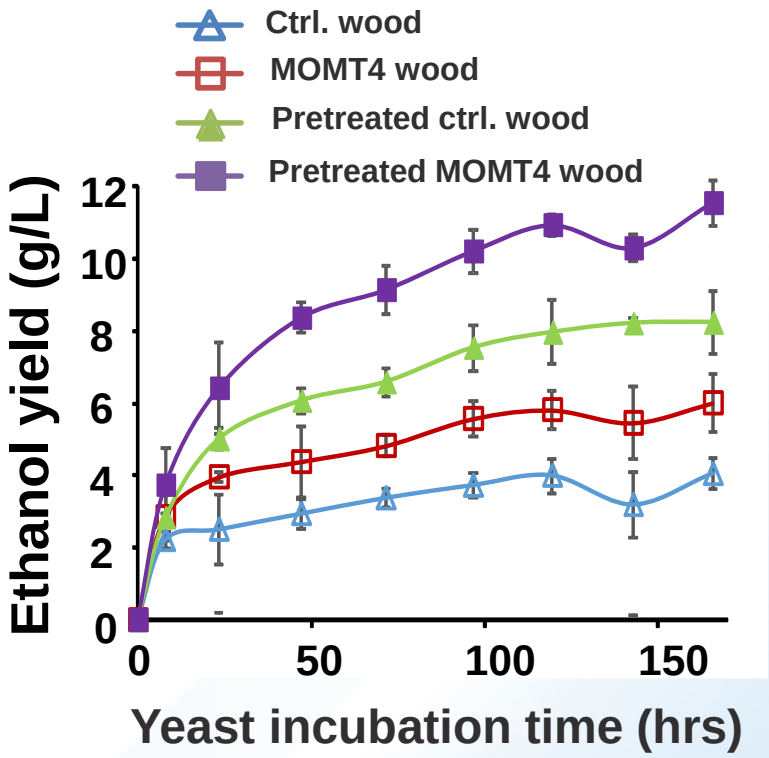
- S-type lignin: >50% reduction
- Cellulose fiber content:
  - Up to 15% increase
- Crystallized celluloses:
  - Up to 53% reduction

Greenhouse Results are Very Promising

Sugar Yield



Ethanol Fuel Yield



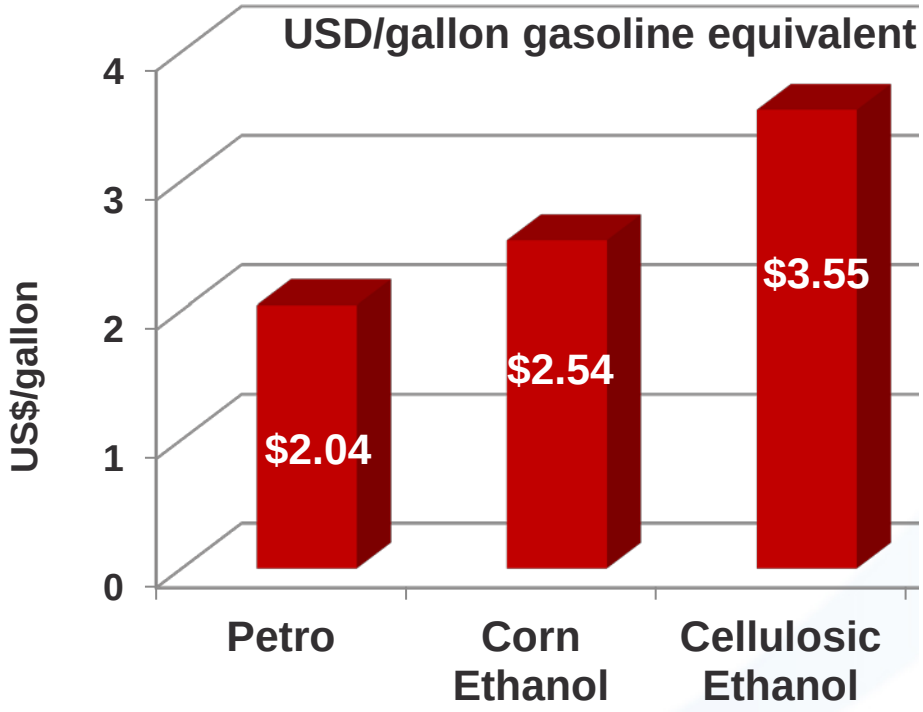
Modified Poplar yields 62% more simple sugars

Ethanol yield is increased 40-48%

The greenhouse results must be confirmed by field studies

Economics*

Calculated with 40% increase in ethanol yield, anticipated saving ~$1.42/gallon



*Survey data from Bloomberg New Energy Finance, 2012

Path to Commercialization…

- ✓ Create novel enzymes (3 yrs)
- ✓ Transform into poplar (0.5 yr)
- Test growth and properties
  - ✓ in growth chambers (1.5 yrs)
  - ✓ in greenhouse (1.5 yrs)
  - in field trials

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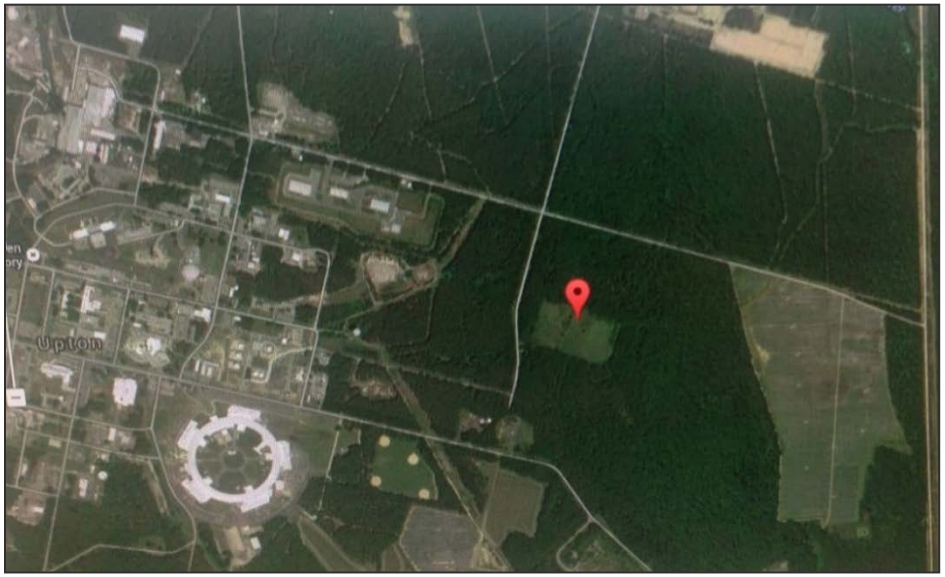
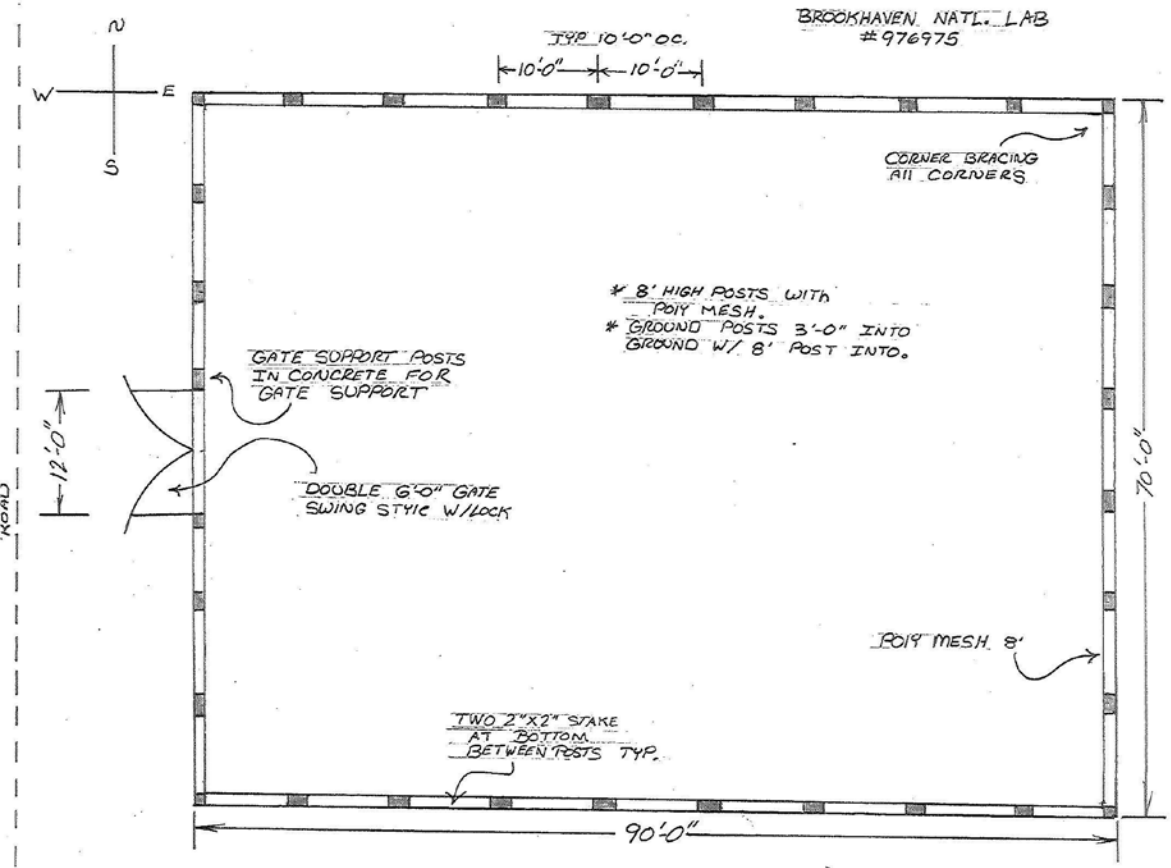
Field Study
Location…..



- Existing “Biology Field” in center of BNL campus
- 70’ x 90’ fenced plot in center of field
- ~150 trees will be grown in the field for one year period

Perimeter Control Fence



- 8’ Tall 12.5 gauge fixed knot fencing
- Class 3 Galvanization Steel Wire
- 4’x4’ CCA Treated Posts and Corner braces
- Stakes between posts to stop small animals
- Life Expectancy: 20-40yrs

Completed Field Trial Approvals

- ✓ Local:
  - ✓ Experimental Safety Review
  - ✓ Institutional Biosafety Committee
  - ✓ BNL Institutional Risk Management Committee
- ✓ Federal:
  - ✓ Environmental Protection Agency
    - ✓ National Environmental Protection Act (NEPA)
  - ✓ United States Department of Agriculture (USDA)
    - ✓ Animal and Plant Health Inspection Service (APHIS)

USDA
United States Department of Agriculture

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

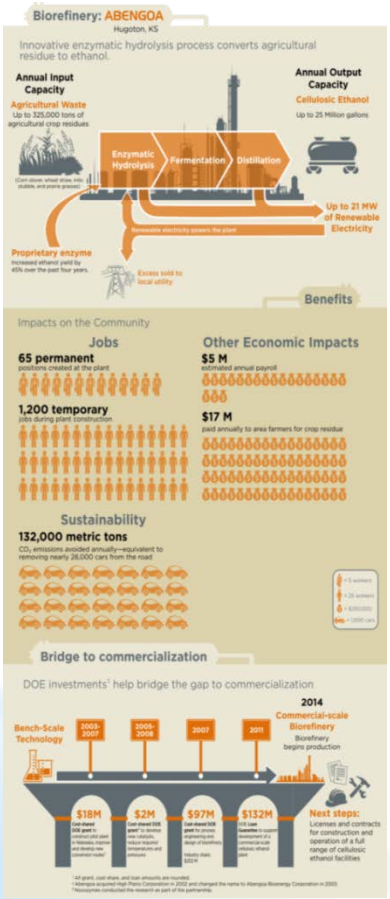
Field Study Controls

- Poplar trees typically do not flower until 8 years old
  - as a precaution, trees will be monitored in every 3 days during flowering season, and any catkins will be destroyed
- The plot will be monitored for broken branches
  - if any are found they will be removed and destroyed
- Fence integrity will be monitored
  - and repaired if needed
- The trial will be terminated by harvesting at end of year 1
  - Any residual plant materials will be removed and destroyed
  - Round-up will be applied after harvesting to prevent any regrowth of roots
  - Site will be monitored in the following year and any regrowth will be destroyed


Catkins

Scaling-up of Cellulosic Biofuel Production

As of Oct 2014, three commercial scale cellulosic ethanol biorefinaries, POET-DSM, INEOS, and Abengoa, were opened in US



Questions ?