### PRESENT SITUATION

- **Cropping area needed to replace 15% of transport fuels in the USA***

<table>
<thead>
<tr>
<th>Crop</th>
<th>Oil Yield (L/ha)</th>
<th>Land needed (million ha)</th>
<th>% Existing US Cropping Area</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maize</td>
<td>172</td>
<td>462</td>
<td>178</td>
</tr>
<tr>
<td>Soybean</td>
<td>446</td>
<td>178</td>
<td>67</td>
</tr>
<tr>
<td>Oilseed rape</td>
<td>1,190</td>
<td>67</td>
<td>42</td>
</tr>
<tr>
<td>Oil Palm</td>
<td>5,950</td>
<td>13</td>
<td>7.2</td>
</tr>
<tr>
<td>Algae/cyanobacteria (70%)</td>
<td>137,000</td>
<td>0.6</td>
<td>0.6</td>
</tr>
</tbody>
</table>

- **Cornell Study – energy needed to produce corn ethanol can be up to 29% greater than resultant energy of biofuel itself**

*Gressel et al, 2007
**Covington, 2011
85% of maize crop in the US currently is genetically modified with traits for herbicide tolerance and/or pest resistance

Perlack, 2005
FEEDSTOCK IMPROVEMENT

- Yield improvement
  - Pest and disease resistance
  - Increased stress tolerance
  - Marker assisted selection of metabolites

- Meeting feedstock demand projections
  - Farmland limitations
  - Agricultural Intensification

- Modification of plant architecture
  - Increased carbon allocation
  - Increased water availability
  - Increased sunlight exposure
Agricultural productivity - a measure of output to input - has increased steadily over the last half century.

Source: USDA-NASS, 2003a

Figure 16: Agricultural productivity, 1948-1996

Perlack, 2005
STRATEGIES FOR AMENABILITY INCREASES

- Enzymatic treatments that make cellulosic ethanol economically feasible
- Reduction in feedstock lignin content
  - Shortening of pre-treatment processes
- Nanotechnology and perforation of seeds to increase germination rates
  - Reduce waste of non-coordinated harvests
- Multiproduct production
  - Creation of high value co-products
  - Viable biorefinery options
  - Decrease in overhead costs
POLICY IMPLICATIONS

- Acceptance and environmental impact
- Stigma of risk - must be openly addressed
- Consumer acceptance and public opinion
  - Star-Link corn case
  - Contamination and inadequate confinement
  - Bt corn
- Development of a coherent policy (federal, state, private market)
- Scrutiny from environmental organizations
  - Expectation as a green technology
  - Increasingly stringent regulations
DEPLOYMENT CHALLENGES

- Economic effects
  - Increases in food prices due to increased pressure on farmlands
  - Costs of regulatory compliance
- The ethics of GMOs
  - The effects on small farmers
  - Patents on genes and lawsuits
- Increased intensification of agriculture, industrialization
  - Incorporation of environmentally sustainable traits to offset impact of production
  - Is intensification unavoidable in bioeconomy?
  - Soil degradation
- Biosafety components
  - Reproductive sterility requirements
  - Food vs. Fuel production
PROSPECTS FOR THE FUTURE

- **Use of non-food crops**
  - Switchgrass and other perennial crops
    - Introduction of corn gene
    - Increase starch content, decrease lignin content
  - Optimum production from highly diverse mixtures

- **Increased usage of forest products and woody residues**
  - Tree plantations
  - Shortening of breeding timeline

- **Increased yield potentials and nitrogen-use efficiencies resulting in projected 16-23 million fewer acres and 0.6-1.4 million fewer metric tons of nitrogen in 2030 as compared to 2009 corn crop.*

*Smyth et al, 2011
POTENTIAL FOREST RESOURCES

Perlack, 2005
SUMMARY AND OPINION

- Genetically Modified vs. Improvement of Pretreatment Processes
- Pretreatment for use of non-food crops
- Currently – not economically viable in United States
- Dependent on country, climate, available feedstock
  - United States vs. Brazil
  - Difference in markets – free market driven vs. controlled pricing