1. What is the current state of technology in large-scale production of sustainable fuels and chemicals?

a. How can we best combine chemical technologies of different scales to maximize impact?

b. How can we identify ways in which technologies of different practical scales can complement each other?

- Large scale ≥ 500 tons/day; plants at this scale are under construction but not yet operational
- Gasification is well known for other feedstocks but is a new area of technology for biomass
- Multiple process options are under examination at the pilot scale (≤ 50 tons/day)
- Long-term cheap natural gas makes it difficult for petrochemical companies to consider biomass feedstock
  - Using natural gas as a bridge to biomass feedstock
- Are opportunities in both pyrolysis and gasification for combining scales of operation (e.g., small pyrolysis on large fluid-bed combustion system)
- DOE needs to support integrated bench-scale studies, technoeconomic analysis, LCAs.
2. What are the technological and commercial barriers to scaling-up sustainable technologies?

- Improved technologies to handle biomass solids – fibrous, hydrophilic structure, feeding the material at reactors at pressure
- Separation of lignocellulose components
- Need better coupling of fundamental/translational research with applied research. DOE could help fill that gap
- Access to capital
- Catalysts need to be:
  - More tolerant of poisons present in biomass
  - Tolerant to water and steam
3. What skills will chemists and chemical engineers need to enable a growing biomass economy that are not widely held and/or taught today?

- Petroleum, not biomass, is a focus of ChemE curricula
- Cross-training between ChemE, mech eng, biology and chemistry
- More interdisciplinary collaboration among science and engineering in both biochemical and thermochemical processing
- Need to teach a systems approach (cf. forestry, agriculture, energy systems, petroleum)
4. Where can we exploit existing transportation infrastructure to meet the new needs, and where must we build new infrastructure?

- Resources should be devoted to investigating answers to this questions
- Using existing infrastructure as much as possible and market pull – focus on conversion of biomass to existing fuels and chemicals. Work back from the existing need and infrastructure.
- Try to leverage existing pulp and paper processing infrastructure