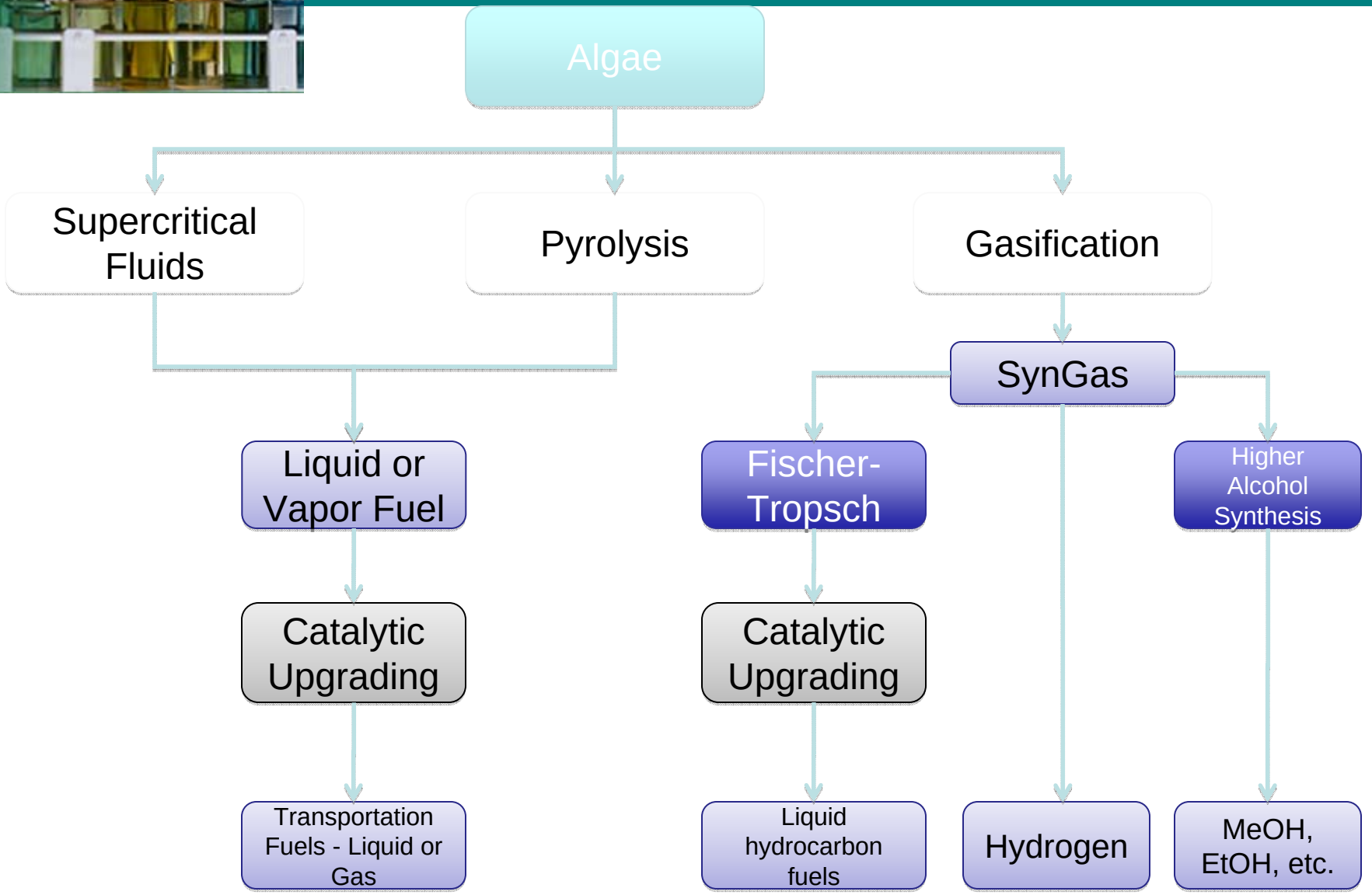
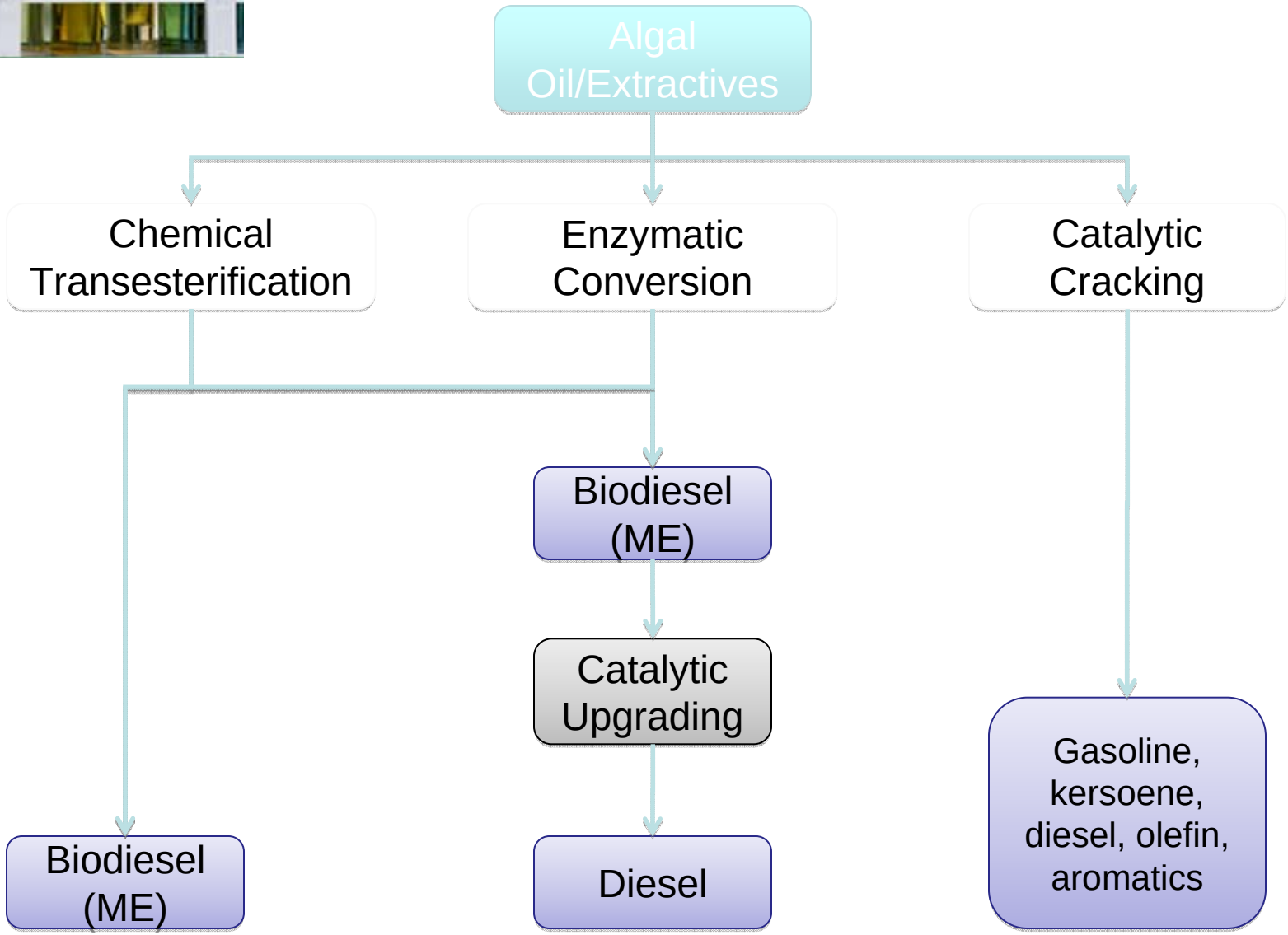
Breakout Session
Fuel Conversion
Session 1-5

December 9, 2008

Fuel Conversion Background Algae



Fuel Conversion Background
Algal Oil and Extractives



Fuel Conversion Goals and Barriers

Goals for Report

- Address critical needs in fuel conversion technologies
- Roadmap development
- Identify interdependencies to upstream and downstream aspects of biofuel conversion

Key Barriers

- Converted fuel must meet current customer requirements
- Multiple perspectives on fuel conversion technologies (e.g. thermochem; fermentation, transesterification, etc)
- Feedstock influences process selection, conversion efficiency ,and end product quality
  - Wet vs. dry, extracted oil, whole algae, etc
- Fuel production targets' influence fuel conversion technologies
  - Production scale, process time, and flexibility influence choices

Fuel Conversion Sub-goals

1) Infrastructure
   - Test algal fuels against relevant specs and for material compatibility
   - Understand emissions and performance characteristics of algal fuels

2) Thermochemical
   - Reactor design improvements to lower cost – capital cost per gallon
   - Pyrolysis
     - Determine optimum conditions for oil yield (time and temperature)
   - Gasification
     - Determine optimum conditions for indirect gasification
     - Evaluate feasibility of using oxygen generated by algae for gasifier – eliminate the need for tar reforming
     - Piggy-back ongoing syngas to ethanol research for cellulosic sources

3) Direct Production
   - Comparison

Fuel Conversion Sub-goals

4) Catalytic Upgrading

- Conversion of oxygenates to fuels
- Development of cost-competitive technologies
- Alternative processing routes

5) Biochemical

- Deconstruct algal cell wall to lyse cells
- Obtain suitable and relatively uniform feedstocks for subsequent enzymatic conversion into desired fuels and/or fuel precursors (e.g., diesel, sugars)
- Optimize specific enzyme activity to function using heterogeneous feedstocks
- Develop consistent feedstock stream (e.g. organism, lipid level, composition).
- Define necessary enzyme reactions (cell wall deconstruction (autolysin), carbohydrate conversion into sugars, nucleic acid hydrolysis, lipid conversion into diesel surrogate.
- Unique enzymology for polar and nonpolar lipid conversion.

Fuel Conversion Sub-goals

6) Transesterification
- Lower cost
- Heterogeneous catalysis
- Product fractionation
- Kinetic optimization

7) Supercritical Fluids
- Demonstrate extractability of triglycerides from algae
- Demonstrate conversion of polar lipids to FFA
- Demonstrate nitrogen reduction strategies for biocrude

Fuel Conversion Strategy

- Leverage technological resources at DOE, National Labs, and private industry to improve conversion efficiency and cost
- Develop crosscutting collaborative projects (similar to DoD)
- Seek co-processing opportunities with other biofuels
- Initiate discussions with regulatory agencies & standards organizations
- Initiate research on feedstock characterization in collaboration with instrument vendors, standards groups, and industry
- Develop process models
- Develop clear understanding of future fuel requirements

Fuel Conversion Milestones

- Develop RFPs and schedule for funded research
- Identify evaluation and QA/QC protocols (ASTM, EN, bench-scale experiments, etc.)
- Fuel evaluations and sampling
- Engine emissions and performance testing
- Feedback to algal fuel production community to improve product

Fuel Conversion Roles and Investment

- Production development is primarily by private sector
- Technology demonstrations driven by industry
  - Pilot studies should be funded through private/public partnerships
  - Loan guarantees an option
- National labs, academia, and industry collaborate together on development projects
- Numerous venture capital opportunities

Fuel Conversion Interfaces

- Development of optimized/robust algal/extract composition streams will enable robust fuel conversion
- Direct production of fuels using algae as chemical refineries – tie to algal biology
- Impact of co-products on fuel conversion price points: is there a breaking/tipping point?
- Policy and site selection will determine intermediates, and therefore fuel conversion
- Regulatory/policy
    - Level playing field for all biofuels processes
        - Timing of the bureaucratic process
- CO_2 sourcing, siting, land
- Water – inputs and discharges

Fuel Conversion Controversial Topics

- Definition of fuel conversion
- Price estimates
- What constitutes algal “fermentation?”
- Feedstock to consider
  - Wet vs. dry
  - Whole algae, extracted oil, or remnants

Fuel Conversion Recommendations

- Insufficient input on use of algal carbohydrates for bio and thermo conversion to fuel intermediates
- Follow up with a specific sub group on non-lipid algal biomass conversion to fuels
- Development of robust data sets on feedstock intermediates and fuel conversion efficiencies; coupled with fuel types
- Parametric studies are essential for success
- Need demonstration projects to establish link between algae → extracts → intermediates → conversion → fuel products