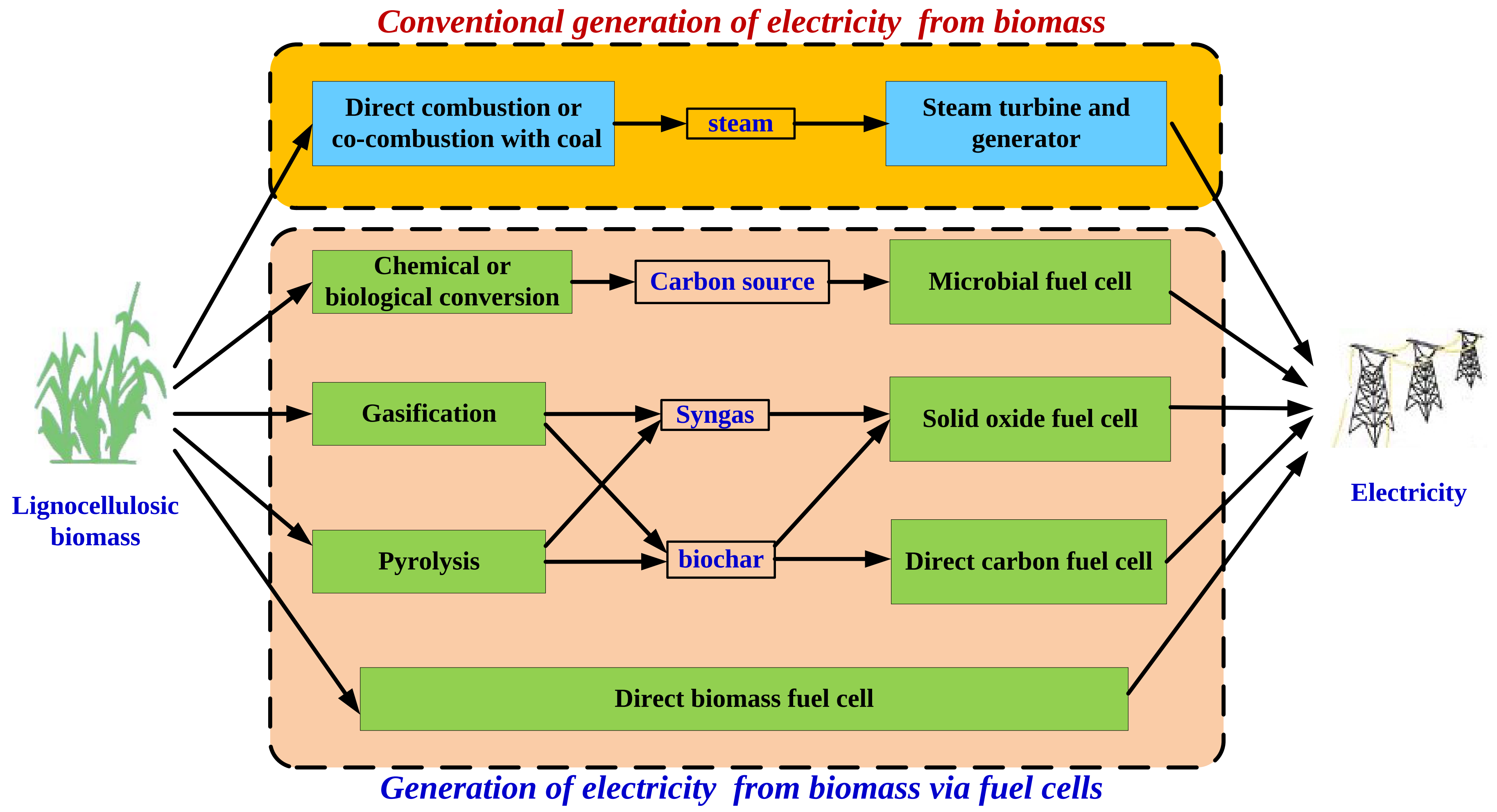
# Introduction and Challenges of Sustainable Biomass Engineering

Yulin Deng, Professor
School of Chemical and Biomolecular engineering
Georgia Institute of Technology

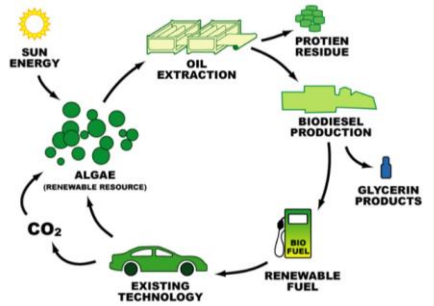
# Biomass Engineering

- Biomass for heat and electricity
- Biomass for fuel
- Biomass for materials
- Biomass for chemicals
- Biomass for foods

# Biomass for energy (electricity)

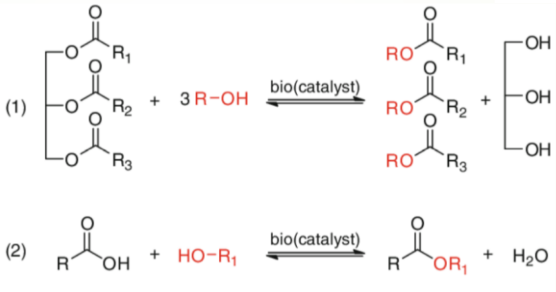


# biomass for fuels

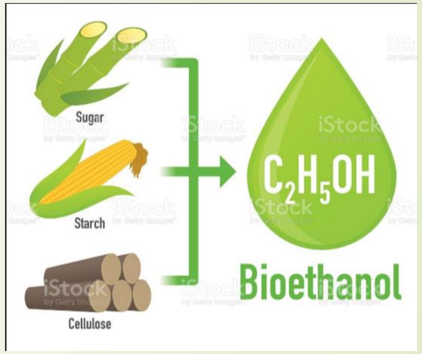



- Algal biofuel

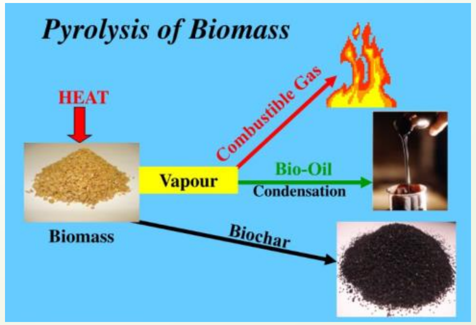
- Fats esterification




- Ethanol from crops and lignocellulosic materials



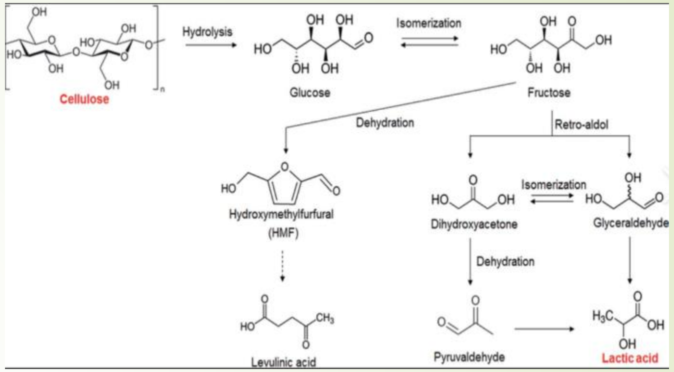

- Pyrolysis of lignocellulose



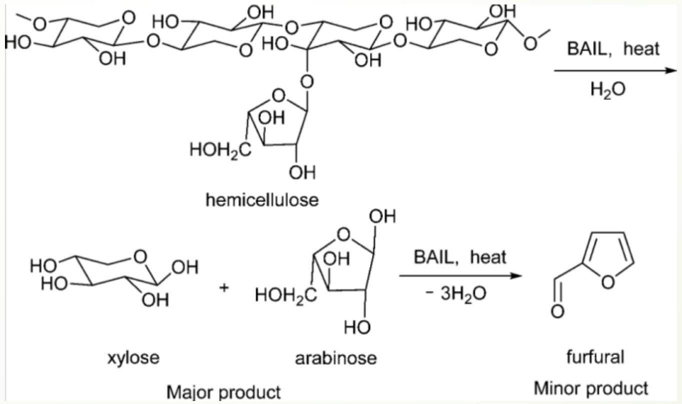

**Biggest challenges: improve yield, selectivity, upgrading, and separation**

# Biomass for chemicals

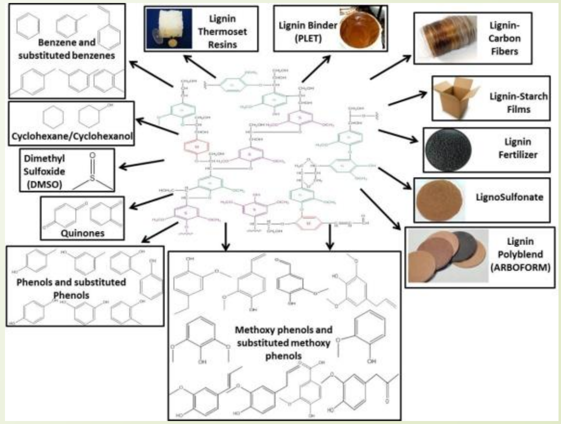
Convert cellulose to chemicals




Convert hemicellulose to chemicals



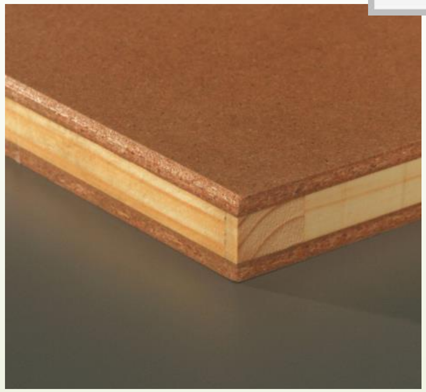

Convert lignin to chemicals




**Biggest challenges: depolymerization, selectivity, and separation**

# Biomass materials

- Building materials
- Paper packages
- Laminate materials such as floor
- Composites
- Plastics
- Fibers and carbon fibers
- Foams
- Activated carbons
- Nanomaterials
- Absorbents

# Biomass materials

- Paper packages
  - The **paper packaging** market was valued at USD 69.91 billion in 2019, and is anticipated to reach USD 88.73 billion by 2025
  - Problems:
    - Strengths at high humility
    - Moisture and liquid barrier
    - Recycling of polymer coated packages
    - Drying energy during papermaking
- Laminate materials
  - Glob market: USD 2.06 billion by the end of 2027
  - Flooring, windows, doors and other building materials
  - Problems: Still use large amount of petroleum binders

# Biomass materials

- Composites:  Biomass fibers, particles and chars for reinforcement:
  - Compatibility: the best performance can be achieved by surface modification
  - Increasing biomass contents: high biomass fillers reduces physical strengths, elastic and thermosetting properties of the polymers
  - Biodegradability of biomass is reduced when it is introduced into petroleum polymer composites
- Plastics from biomass materials
  - Poor elastic properties
  - Moisture sensitivity
  - Chemical grafting or modification: harmful organic solvents are used
  - Not processible:  Cellulose and lignin cannot be melted;  There are only limited solvents available so the processability of cellulose and lignin is poor

# Biomass materials

- Cellulose fibers:
  - Regenerated cotton fibers are the only commercially available fibers: environmental problems
  - Wet spun cellulose nanofiberils to make cellulose ropes shows some unique properties, but the cost is very high, and is still not available for large scale production
- Carbon fibers from lignin and cellulose
  - The strength is still lower than that from polymers such as polyacrylonitrile
  - Impurity, broad molecular weight distribution, branched lignin structure, etc. affect the fiber strength significantly

# Biomass materials

- Foams:
  - Lignin reinforced polyurethane (PU) is one of the good approaches to make partially sustainable foams
  - Lignin will reduce PU strength if lignin content is higher that 15%.
  - Lignin addition will change soft PU foam to rigid.
- Nanomaterials
  - Nanocellulose fibrils (CNF) and crystals (CNC) are unique sustainable materials that have been used as polymer reinforcement, barrier films, biosensors, supercapacitors, solar cells, absorbents, coatings, paper additives etc.
  - Nanocellulose is hydrophilic so its compatibility with hydrophobic polymers as well as its sensitivity to moisture are disadvantages: surface modification is commonly needed
  - Lignin nanoparticles have also been reported, but their applications have been reported
  - Starch nanoparticles have been used in paper wet end, food additives, paper package binder and paper coatings

Thanks

Questions??