Converting Cellulose to Biofuels

Introduction

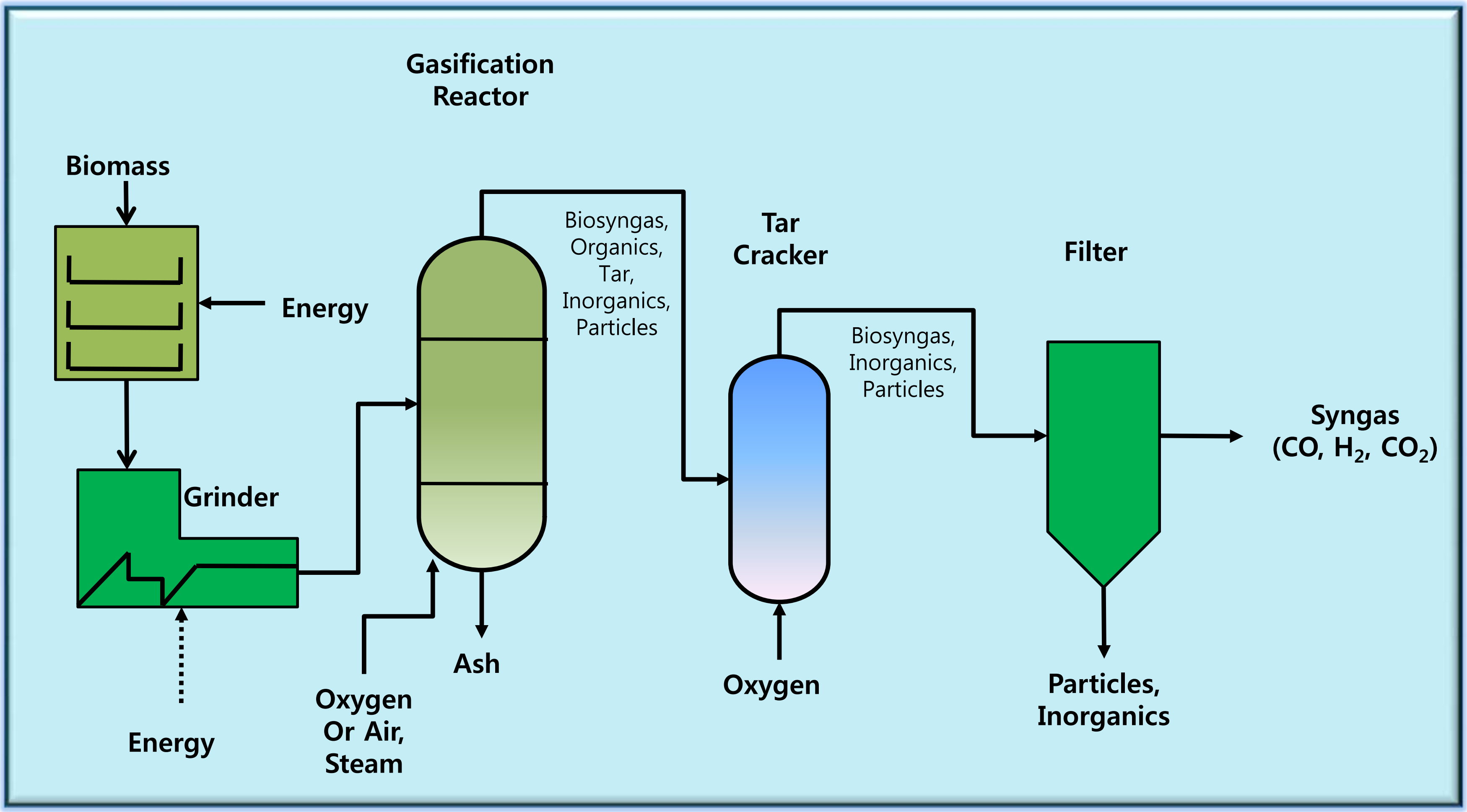
- Renewable Cellulosic Biomass's Potential
  - Reduce dependence on imported oil
  - Enhance energy security
  - Reduce greenhouse gas emissions

Energy Future

- Two major conversion approaches
  - Biochemical Processing
  - Thermochemical Processing

20% Reduction in oil used for light-duty transportation

Thermochemical process



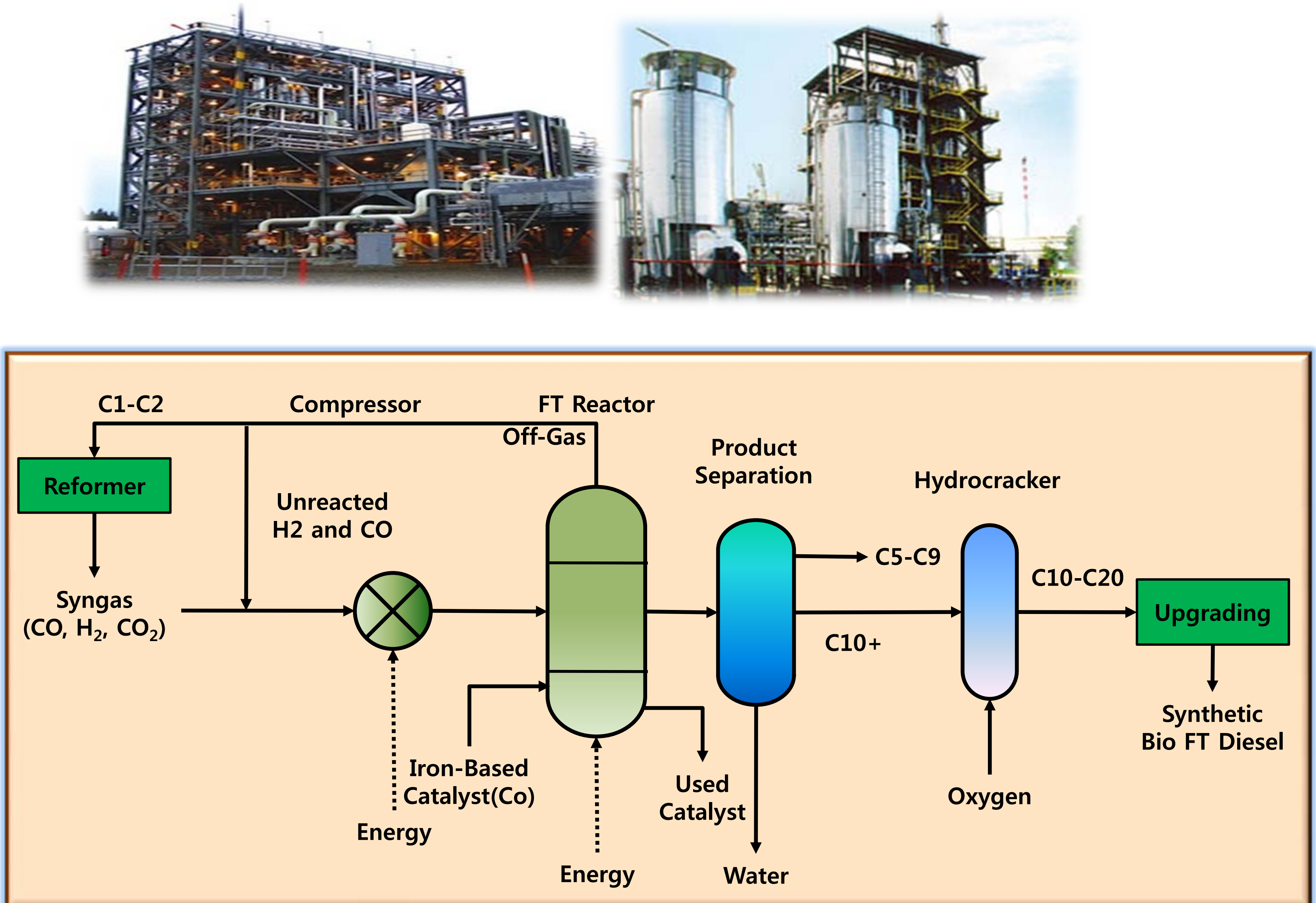


Figure 1. A typical thermochemical route to biofuel involves gasification of biomass to syngas Followed by catalytic Fischer-Tropsch(FT) conversion to biodiesel. Source☹17)

Biochemical Process

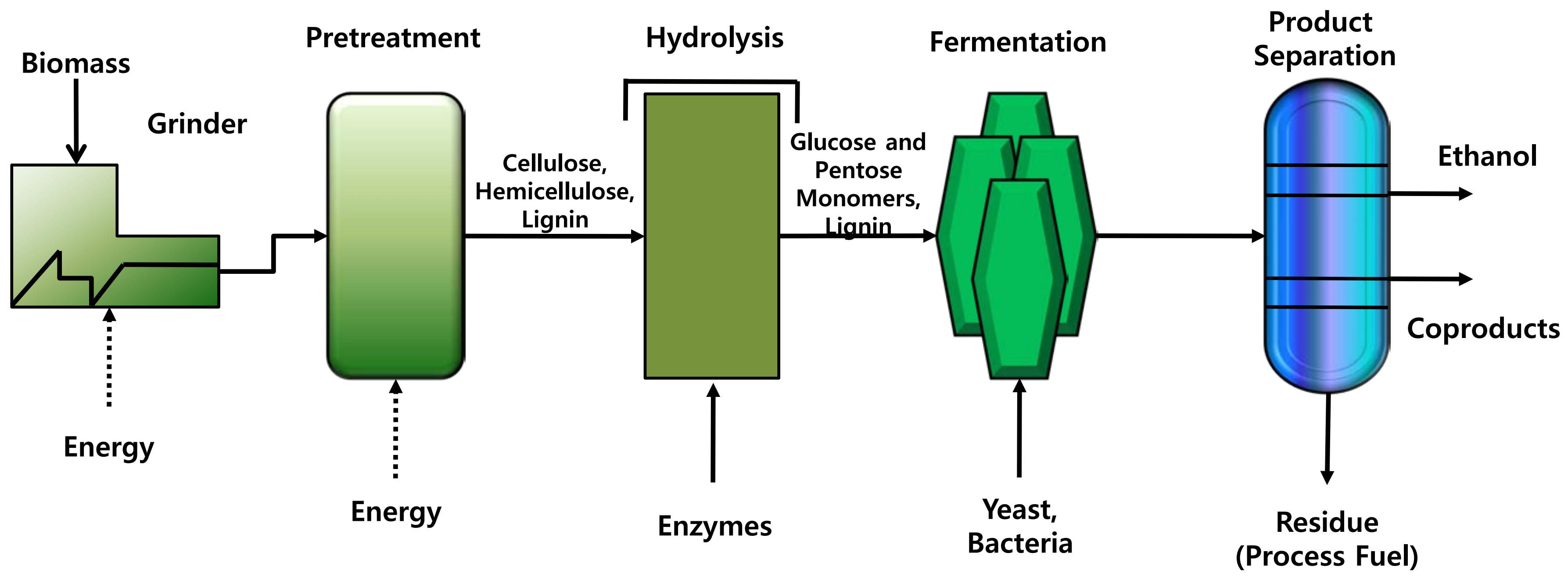


Figure 2. Bioprocessing of lignocellulose to ethanol involves pretreatment, hydrolysis, fermentation and separation. Source; (17).

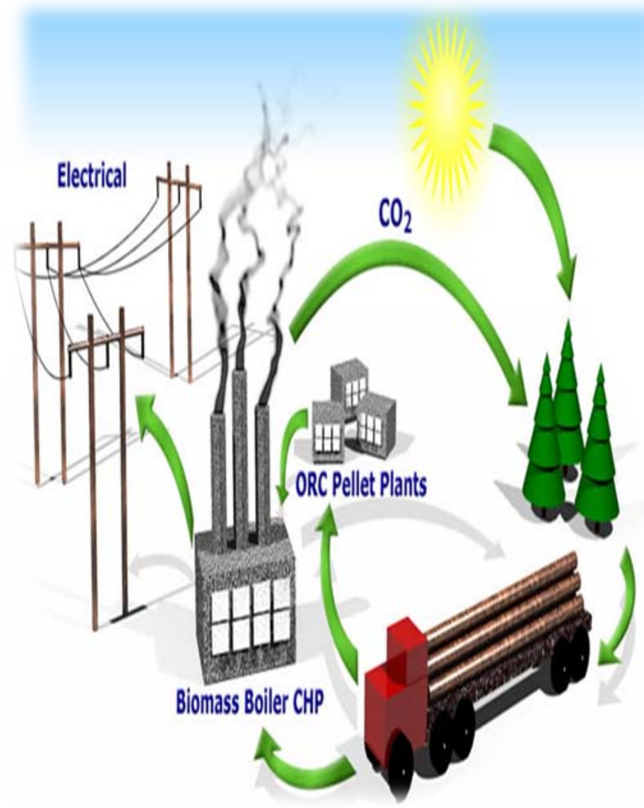
To achieve economical processes,

Key Factors are

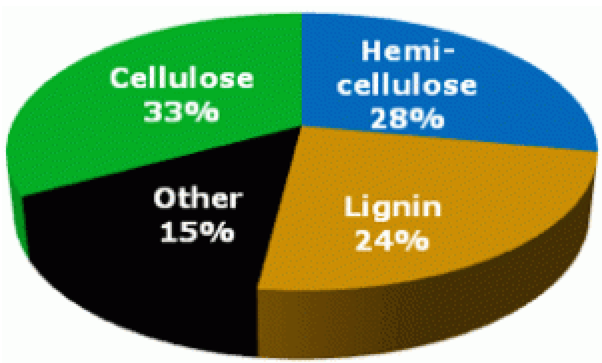
Catalyst Robustness And Costs

Feedstock availability and composition

- Supply of feedstock for use in biorefineries
  - Low density of biomass, transportation costs are high, such that 40-50miles is the maximum distance considered economically feasible for biomass transport



Biomass



Pretreatment
required to maximize ethanol yield:
Various pretreatments(acids, bases, water, steam, heat in some combination).

Table 1. Compositions of different types of cellulosic biomass and the Maximum ethanol yields possible for each of the compositions.

Feedstock Composition	Poplar	Red Maple	Corn Stover	Switchgrass
Cellulose	43.8%	41.0%	34.6%	33.2%
Xylen	14.9%	15.0%	18.3%	21.0%
Arabinan, Mannan, Galactan	5.6%	0.0%	2.5%	3.2%
Acetyl	3.6%	4.7%	Not Availible	2.5%
Extractives	3.6%	3.0%	10.8%	10.2%
Protein	Not Availible	Not Availible	Not Availible	5.7%
Lignin	29.1%	29.1%	17.7%	17.9%
Ash	1.1%	1.0%	10.2%	3.7%
Total	101.7%	93.8%	94.1%	97.4%
Estimated Maximum Ethanol Yield, gal/dry ton biomass	111	97	95	99

Theoretical maximum yield (per short ton), assuming 100% hydrolysis and 100% fermentationData from Laboratory of Renewable Resources Engineering, Perdue Univ.

Biochemical processing

- The **processing of cellulosic biomass** requires **five steps**, as illustrated in Fig 3.
  1. Feedstock preparation
  2. Pretreatment
  3. Hydrolysis
  4. Fermentation
  5. Distillation

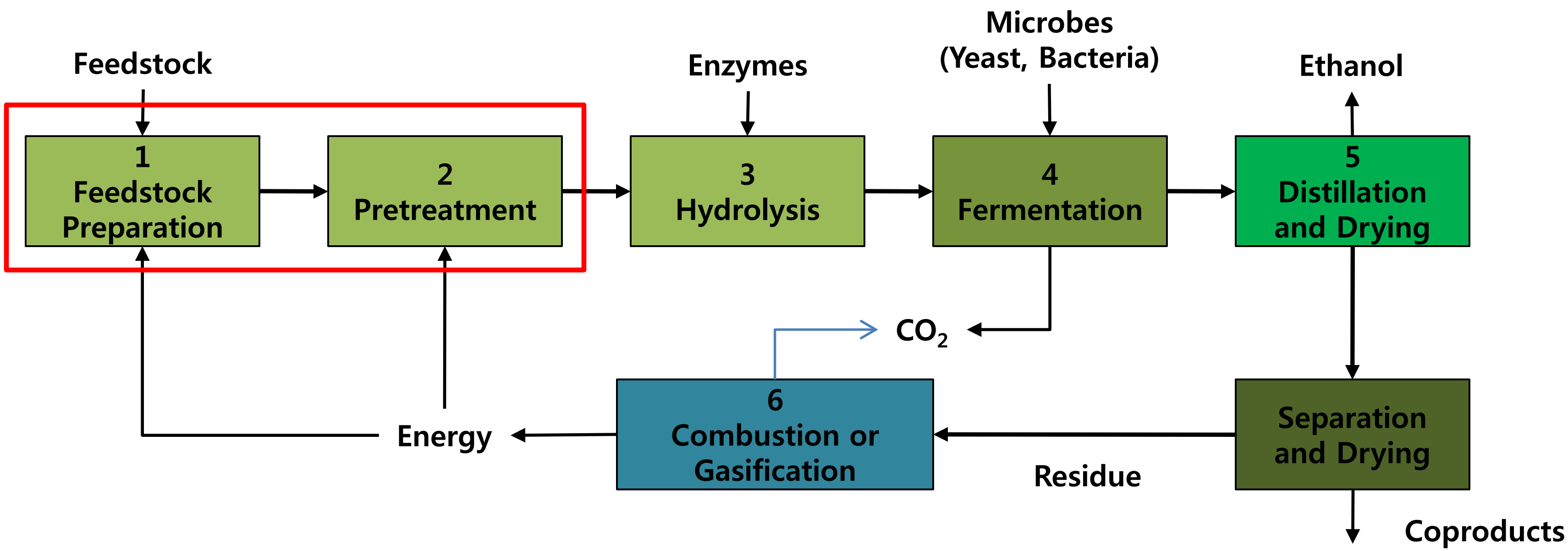


Fig 3. The basic unit operations in a biorefinery.

- Consolidated bioprocessing(CBP)

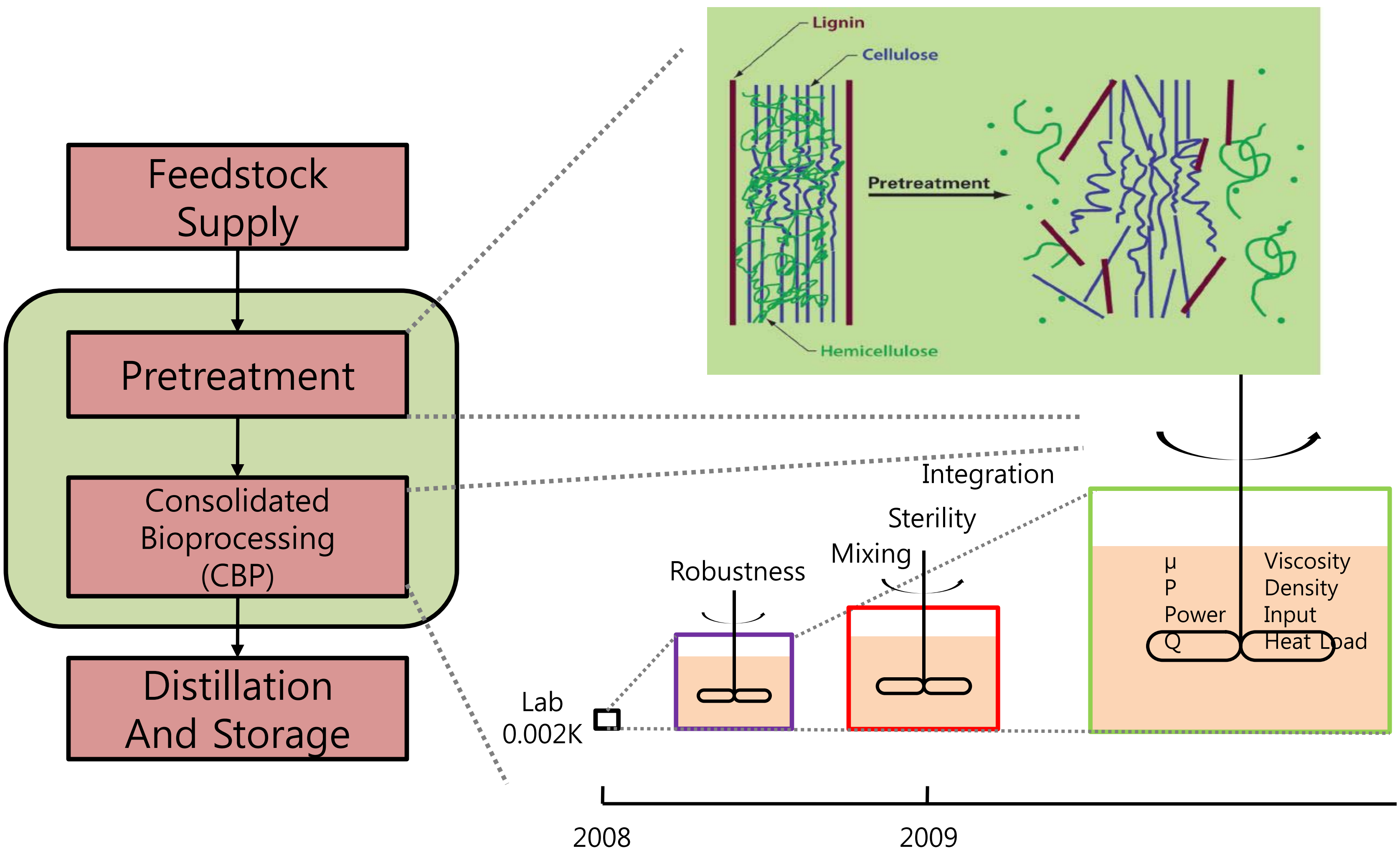


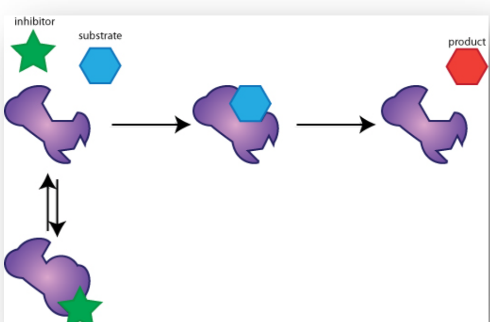
Fig 4. Consolidated bioprocessing combines hydrolysis and fermentation in a single vessel using A microorganism genetically engineered specifically for these dual purposes

Microorganisms for ethanol fermentation

Saccharomyces is a genus in the kingdom of fungi that includes many species of yeast. Many members of this genus are considered very important in food production. One example is *Saccharomyces cerevisiae*, which is used in making wine, bread, and beer. Other members of this genus include *Saccharomyces bayanus*, used in making wine, and *Saccharomyces boulardii*, used in medicine.

Why?

- Produce ethanol at high concentrations
- Perform reliably in commercial starch-to-ethanol facilities
- Glucose into ethanol under anaerobic conditions (Embden-Meyerhof pathway)
- Making CO_2 as a byproduct



Characteristics

- Tolerant of inhavitors and products
- Consume a wide range of substrates (both hexose and pentose sugars)
- High productivity to result in high yield

Fermentation inhibitors

- The major inhibitors present in biomass hydrolysates
  - Weak acids
  - Furan derivatives

  (Furfural and 5-hydroxymethyfurfural)
    - Result from the degradation of the sugars found in the hemicellulose and cellulose fractions during processing
  - Phenolic
- Effects
  - Negatively affect product yield
  - Negatively Voumetric productivity

  (grams of product per liter per hour)

Enzyme inhibitors

- Constitue a major cost in the bioconversion of cellulose to ethanol
  - Nonproductive adsorption of enzyme onto lignocellulosic substrates prior to reaction
  - Intermediate and end - product inhibition
  - Mass-transfer limitations affecting the transport of the enzyme to and from insoluble substrates
  - The distribution of lignin in the cell wall
  - The presence of hemicellulose, phenolic compounds,, proteins and fats
  - Lignocellulose particle size
  - And crystallinity and degree of polymerization of the cellulose substrate

Summary

- Ethanol is produced in large quantities, and an estimate 12 billion gal will be derived from corn in 2010
- Since the cellulosic portion of the corn kernel is a potential source of an advanced biofuels as well Cellulosic ethanol is likely to be the first such fuel on the market
- The technologies to process wood and other lignocellulosic feedstocks currently under development will enable the rapid expansion of cellulosic ethanol production from non-food feedstocks and lead the way for other advanced biofuels over the next ten years.