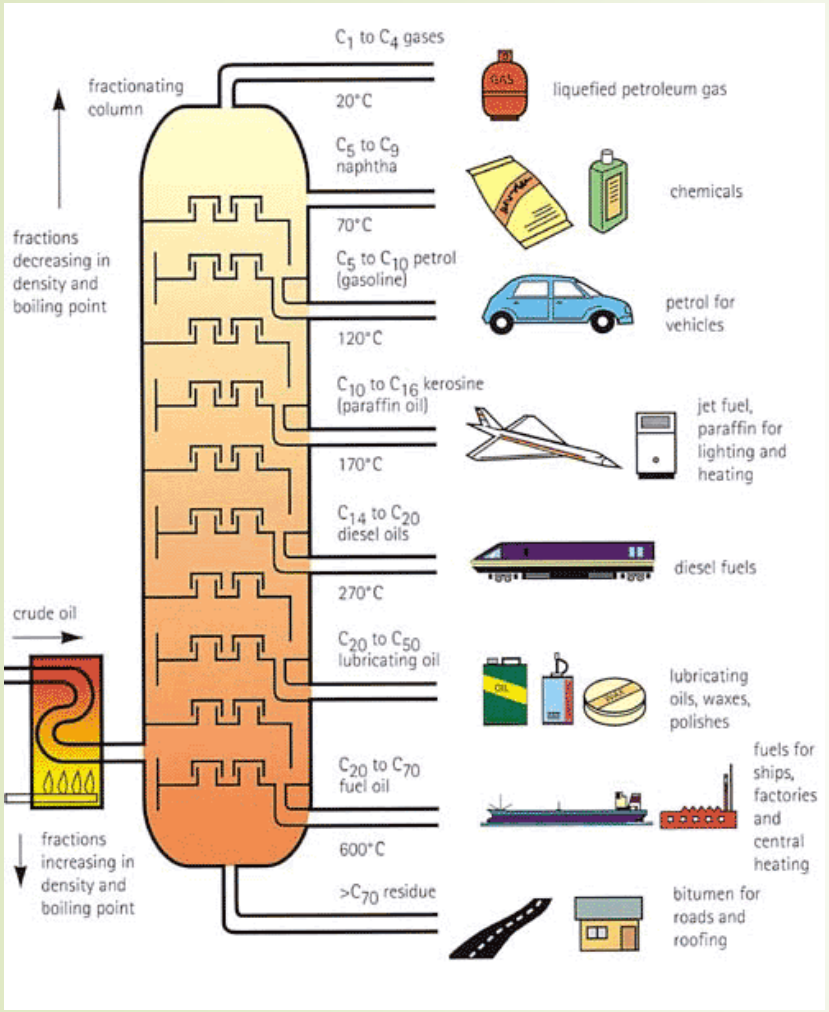
LIGNOCELLULOSIC BIOREFINERIES AS REPLACEMENT OF FOSSILS

Himadri Roy Ghatak

Sant Longowal Institute of Engineering & Technology



Fossils: not just energy source

- Basic major petrochemicals
  - Synthetic fibers (Acrylic, polyester, nylon…)
  - Polymers (PE, PS, PP, PVC……..)
  - Synthetic rubber (SBR, PBR, NBR……)
  - Detergents (LAB, EO)
  - Performance plastics (PMMA, PTFE, PET….)
- Intermediates
  - Fiber intermediates (caprolactum, acrylonitrile….)
  - Building blocks (aromatics, olefins)
- Others (diethylene glycol, epichlohydrin, methyl methacrylate, phthalic anhydride……)

Renewable energy choices

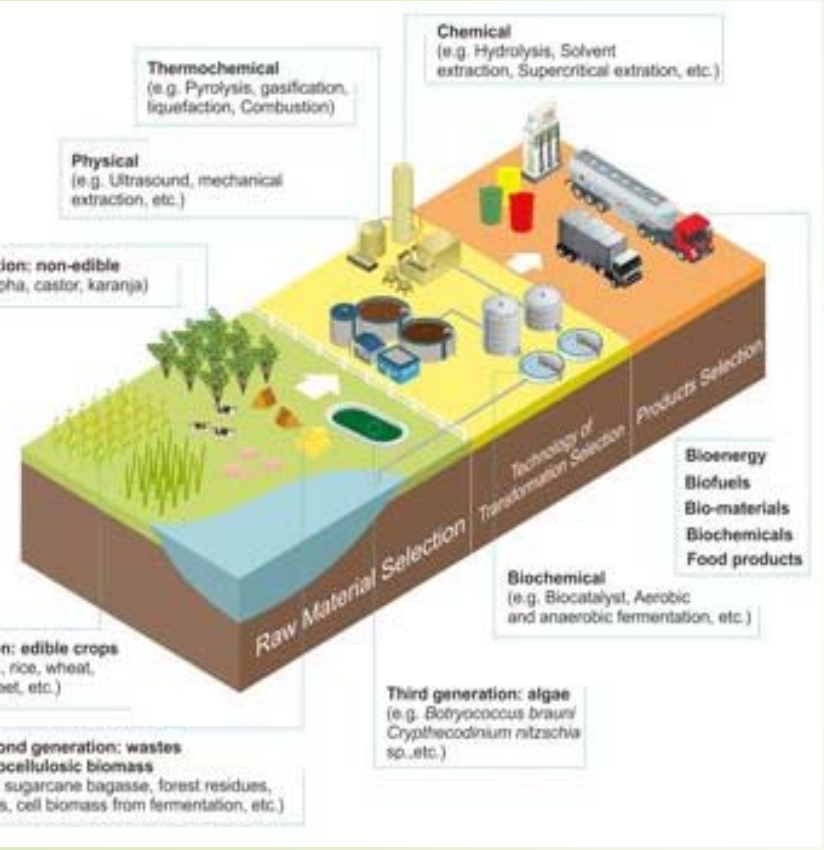
Only energy

Only energy

Only energy

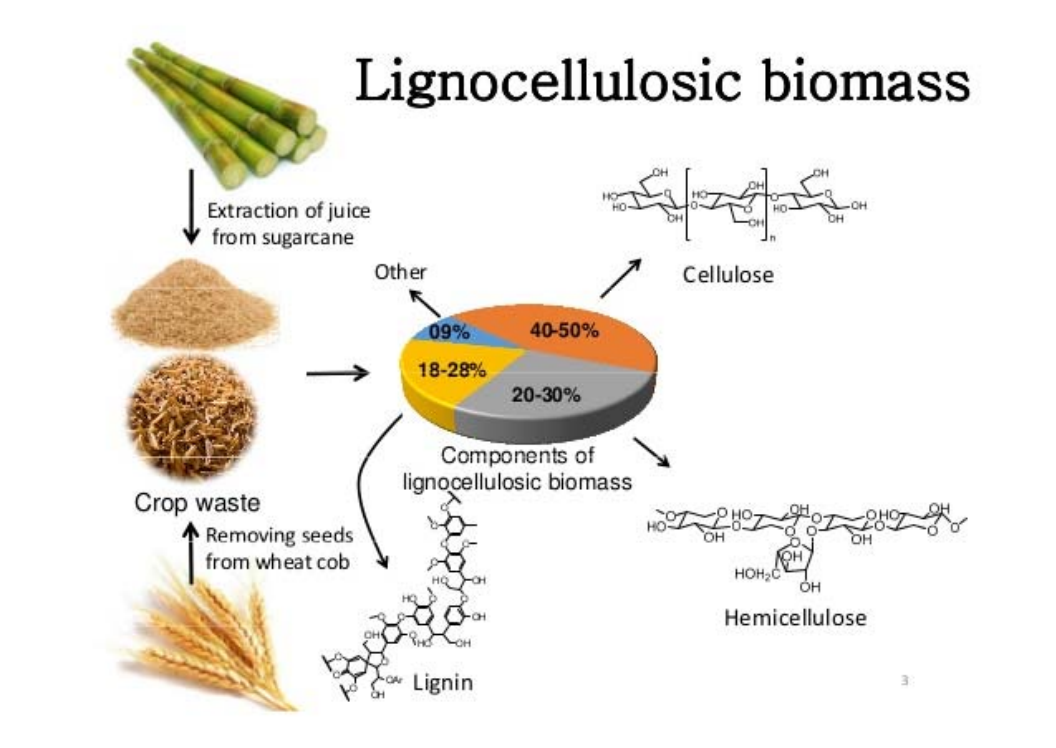
Only energy

Energy plus Organics



Biorefinery is the sustainable processing of biomass into a spectrum of marketable products and energy.

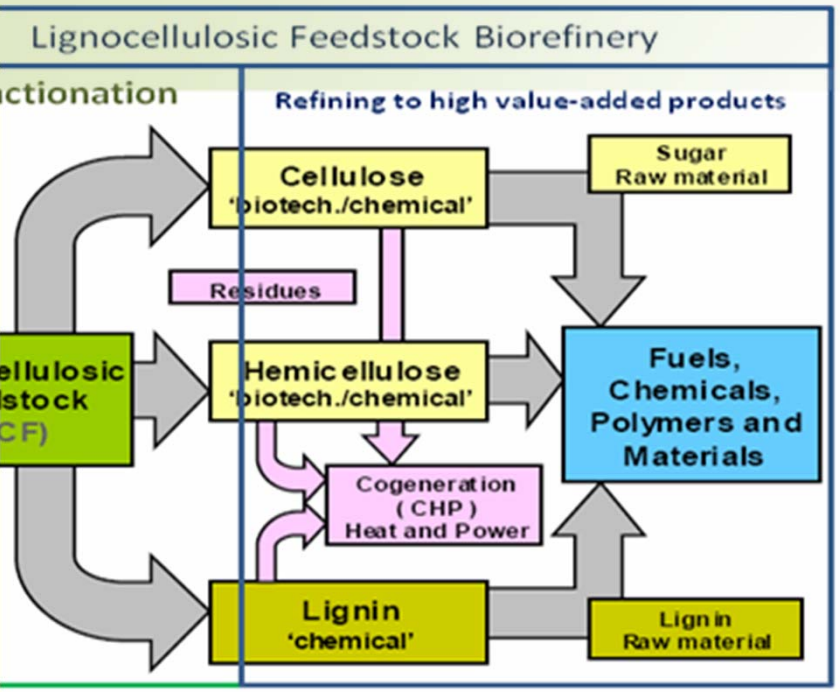
(IEA definition)



Highlights

- No food security issues
- Abundant; typical worldwide availability in million tons (*Saini et al., 2015)
  - Wheat straw 354
  - Rice straw 731
  - Corn straw 128
  - Bagasse 180
- Often available as waste

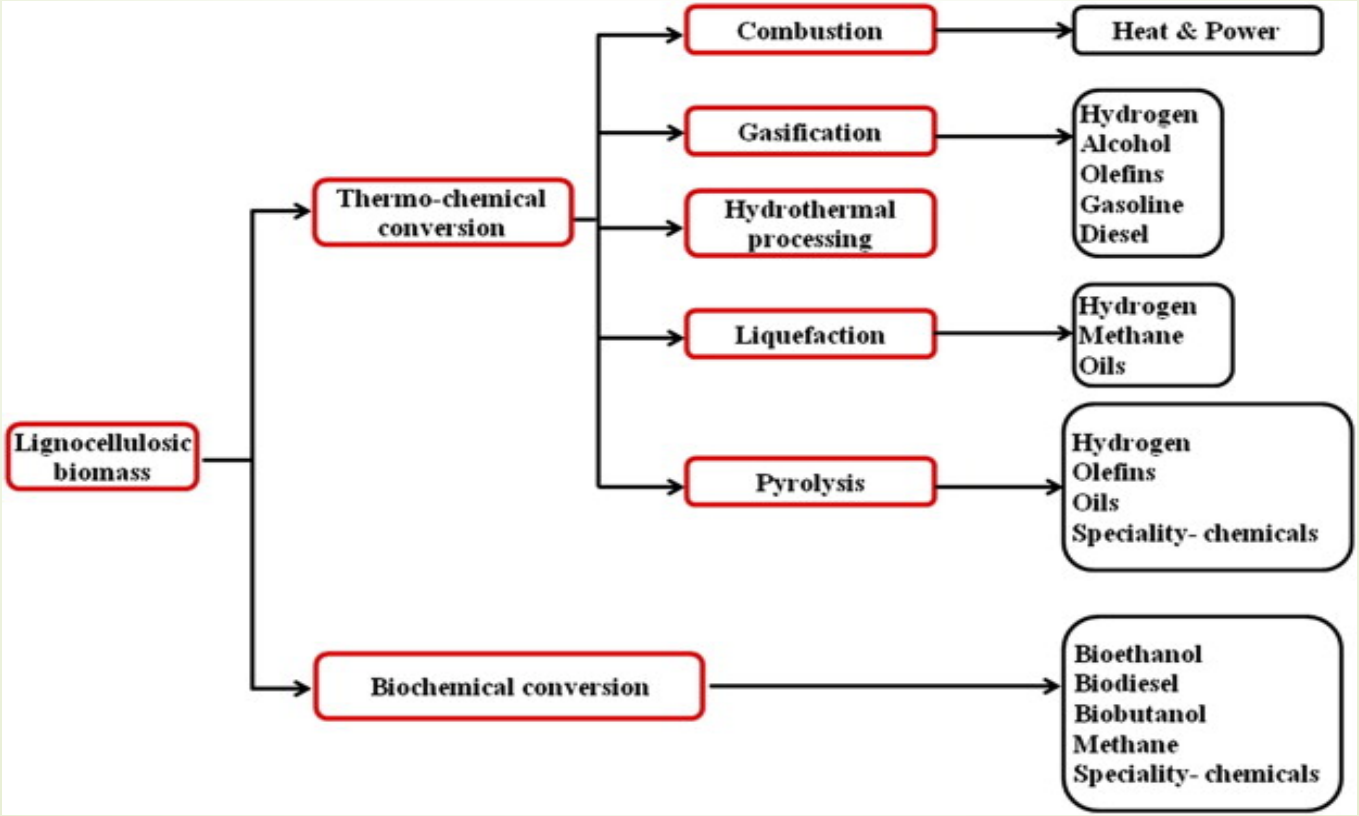
*Saini, J.K., Saini, R., Tewari, L. (2015) ***3 Biotech*** 5:337-353



Lignocellulosic Biorefineries

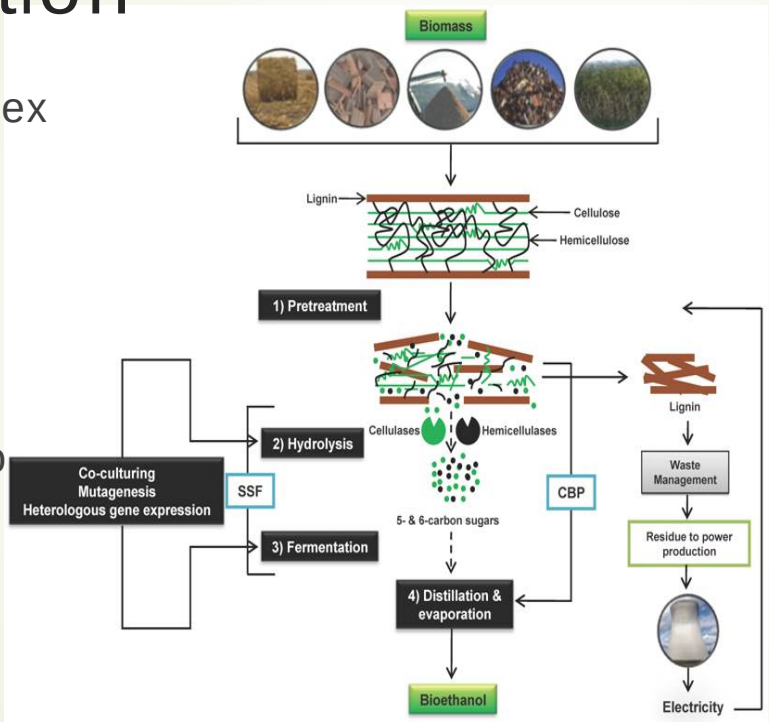
- Cellulose
  - Polymers and composites (Paper, Rayon, Cellophane, Cellulose nitrate…….)
  - Bioethanol
- Hemicellulose
  - Bioethanol
  - Chemicals (furfural, xylitol, lactic acid….)
- Lignin
  - Heat & electricity
  - Chemicals (vanillin, syringaldehyde…..)
  - Polymers and composites

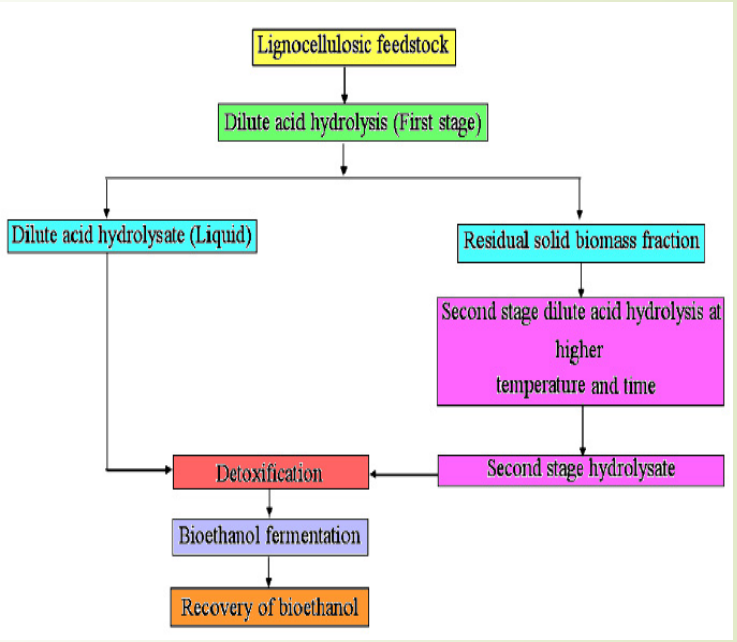
Lignocellulosic Biorefineries: Thermochemical conversion



Hydrolysis & Saccharification

- Breakdown of complex physical structure.
- Breakdown of polysaccharides into oligosaccharides
- Breakdown of oligosaccharides into monosaccharides

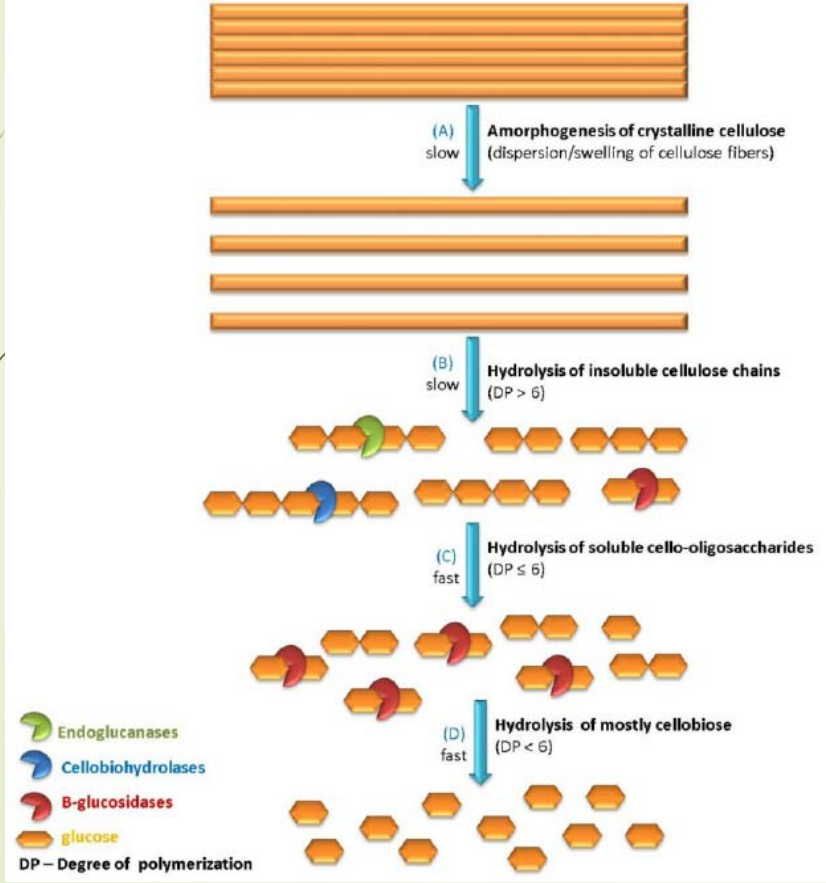




Acid hydrolysis

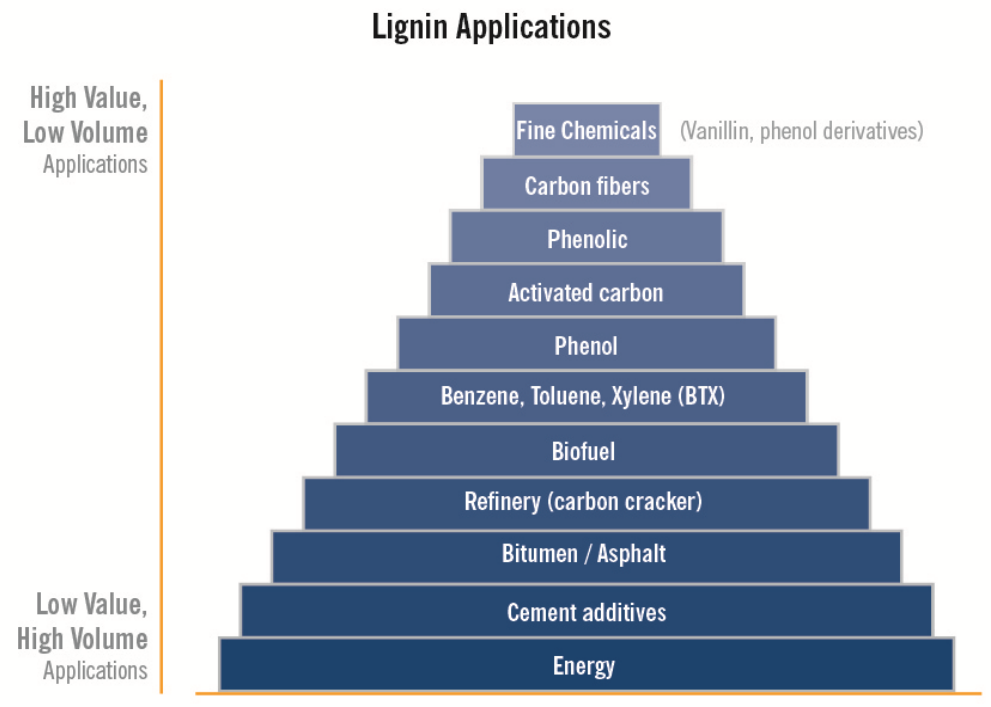
- Dilute acid hydrolysis
  - Target component hemicellulose
  - Hydrolysate contains pentose (xylose) and hexose (mannose, galactose, glucose)
  - High temperature; 160-200 ^{0}C
  - Acid concentration 2-6% (w/v)
  - Sugar yield 70-80%
- Concentrated acid hydrolysis
  - Target component cellulose
  - Hydrolysate mainly contains glucose
  - Moderate temperature; 50-70 ^{0}C
  - Acid concentration 10-30% (w/v)
  - Sugar yield almost 100%

Enzymatic hydrolysis



- Target component cellulose
- Affected by type of biomass and pretreatment
  - DP and crystallinity of cellulose
  - Presence of lignin and hemicellulose
  - Physical structure and accessible area
- Sugar yield up to 80%
- Fungal extracellular enzyme systems most effective (Genus *Trichoderma*, and *Aspergillus*)
- Slow compared to acid hydrolysis

Lignin value addition



- Expected lignin availability from lignicellulosic biorefineries 100000-200000 tons/year (Wyman, 2003)

Possible value added applications

- Polymers
  - Phenol based thermoset resins
  - Blends with LLDPE, LDPE, HDPE, Polystyrene
  - Composites with PP, PET
- Low molecular weight aromatics
  - Aromatic carbonyl compounds (vanillin, syringaldehyde….)
  - BTX
- Carbon products (carbon fiber, activated carbon)

Challenges and opportunities

- Policy incentives for collection, transportation and other logistics issues.
- Development of more efficient and cost effective enzyme systems
  - Genetic engineering
  - Metabolic modifications
- Process engineering optimization
  - Increasing hydrolysis sugar yield and selectivity
  - Increasing gasification efficiencies
  - Development of improved catalysts
- Integrating lignin value addition

Important Indian initiatives

- First demosnstartion plant set up in May 2017, in Pune, Maharashtra
  - To produce one million litres of ethanol per year.
  - Based on straws and other agroresidues.
- First full scale plant to come up in Bathinda, Punjab
  - To produce 100 m^3 of ethanol per day.
  - Byproducts to include 30000 tons per annum biofertilizer, and hundred thousand kg per annum of biomethane.
- In all 12 lignocellulosic biorefineries are planned at estimated investemt of USD 15 billion.

Important world initiatives

- Project Liberty; joint venture between Royal DSM, and POET LLC, Iowa, USA; 25 million gallons ethanol per year.
- Dupont Cellulosic ethanol facility, Iowa, USA; 30 million gallons ethanol per year.
- Abengoa Bioenergy Biomass, Kansas, USA; 25 million gallons ethanol per year.
- Betarenewables (Suppoerted by European Commission), Crescentino, Italy; 40000 tons ethanol per year.


Thank you