Conversion of agricultural biomass to fuels and value-added products: Thermochemical approach

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Background

Conversion of plant lignocellulosic biomass is a key process on recycling of organic carbon in the global biogeochemical cycle.

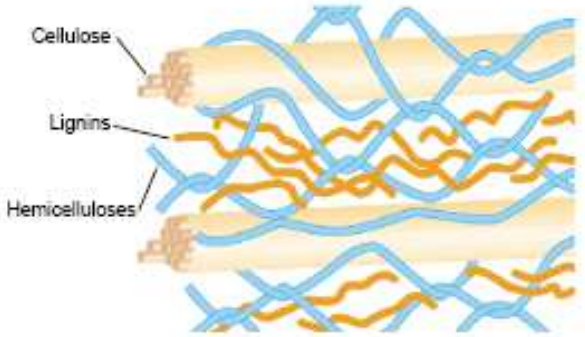
R&D aim to convert lignocellulosic biomass to useful and/or high value-added products (i.e. fuels, chemicals, biomaterials).

The concept that integrates the lignocellulosic biomass conversion to fuels, materials, chemicals is called Biorefinery.

Lignocellulosic biomass

Biomass consists of three polymeric components:

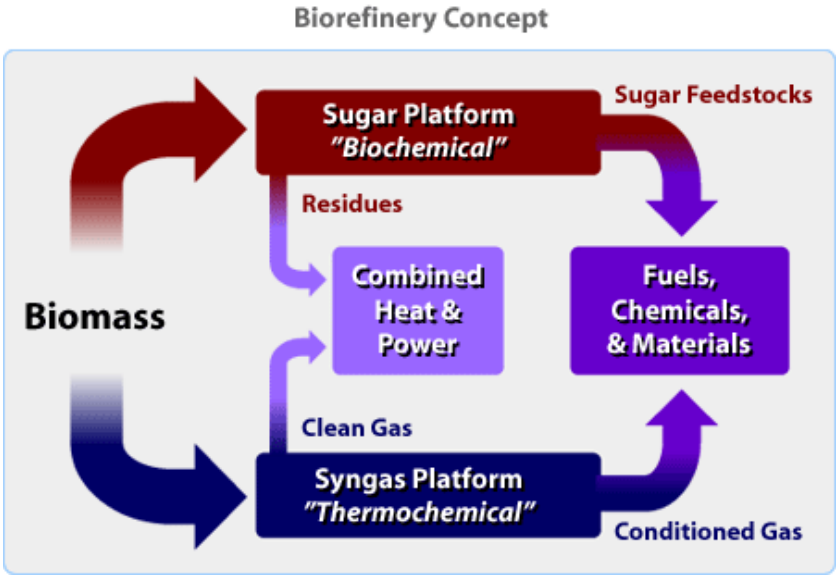
- Cellulose
- Hemicellulose
- lignin

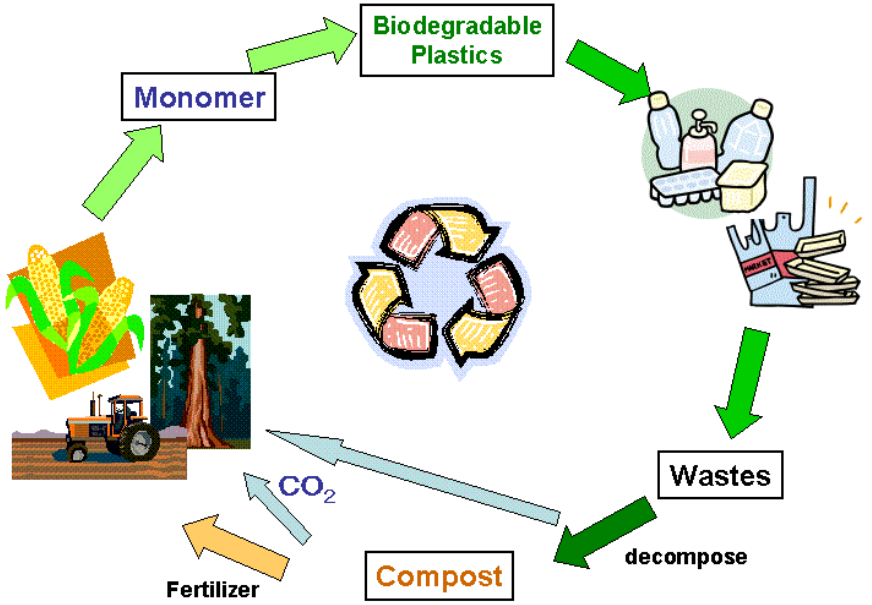


Lignocellulosic	Composition (%dry basis)		
	Cellulose	**Hemicellulose**	**Lignin**
Rice straw	35	25	12
Corn cop	45	35	15
Corn stover	40	25	17
Bagasse	40	24	25
Switchgrass	45	30	12
Wheat straw	30	50	20

Biorefinery

A biorefinery is the technology that integrates biomass conversion process to produce fuels, power and chemicals.





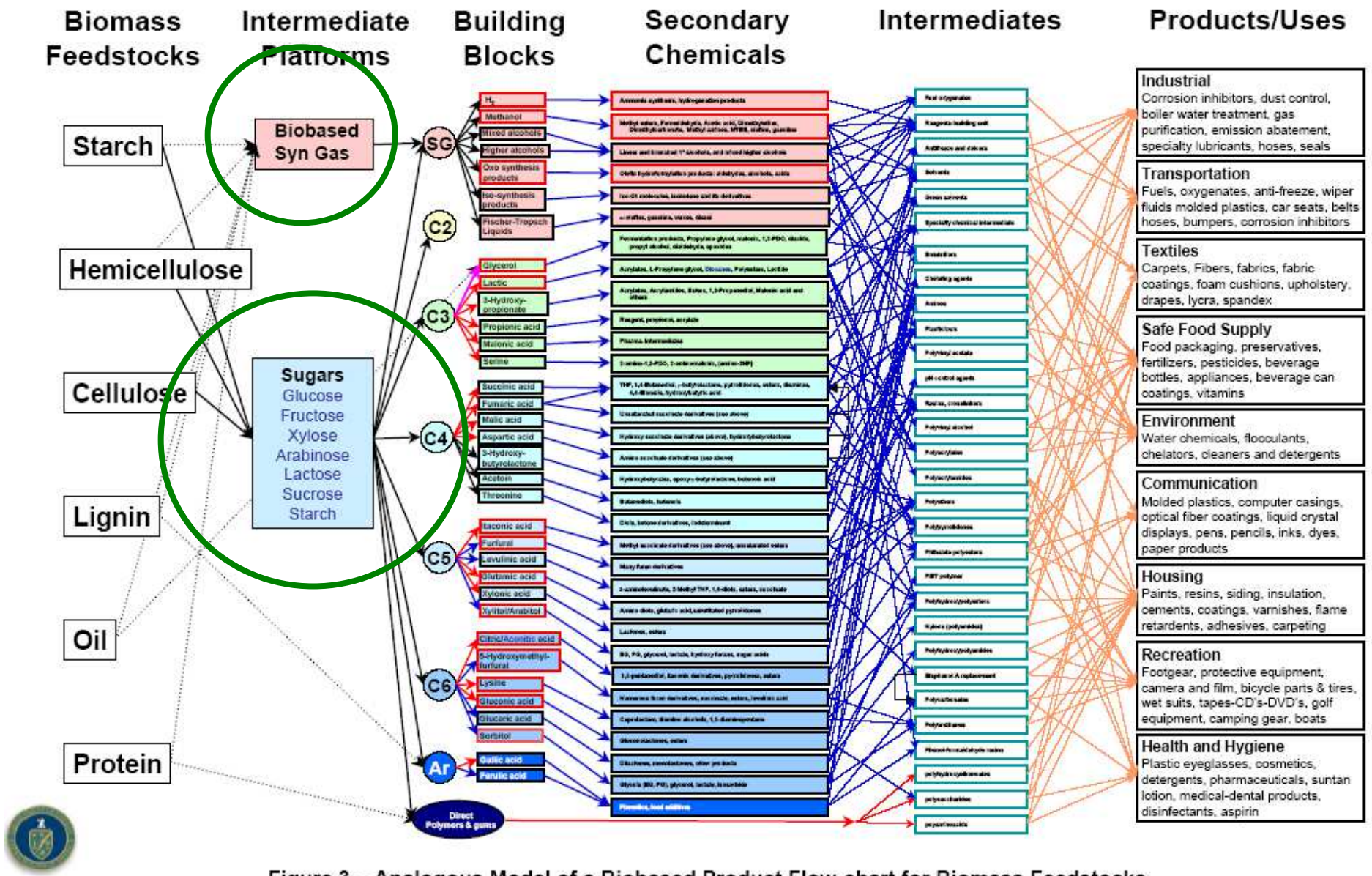


Figure 3 – Analogous Model of a Biobased Product Flow-chart for Biomass Feedstocks

I. Syngas conversion pathway

Biomass

Syngas

Gas purification

Pure hydrogen

Electricity generation by fuel cells or gas turbine

Ammonia

Methanol

Olefins

Alkane fuel

DME

Syngas conversion: Dimethyl Ether (DME)

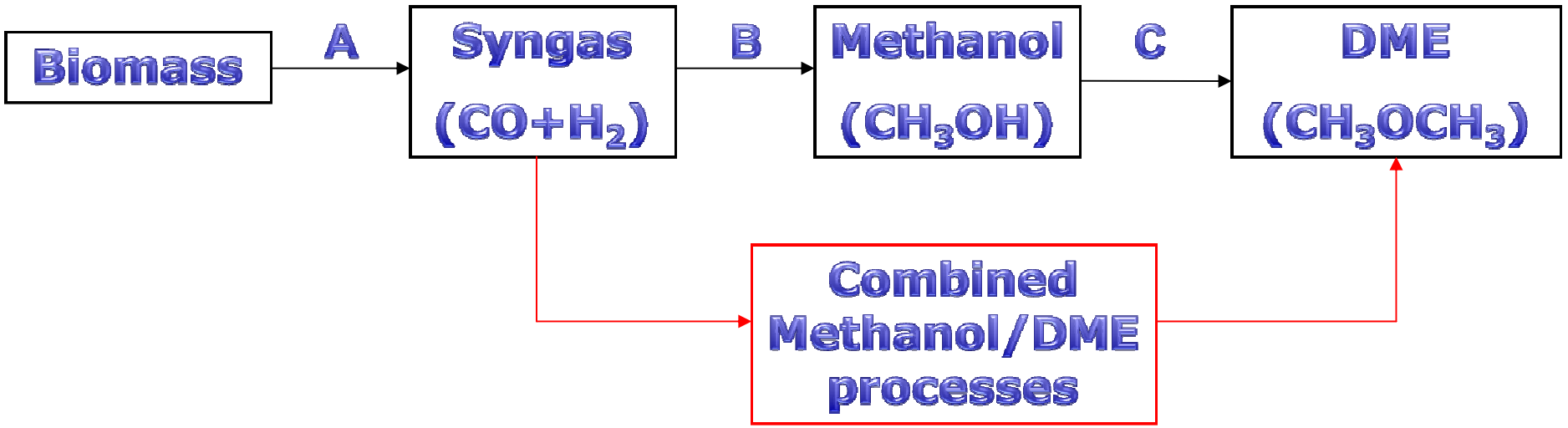
What is Dimethyl Ether ?

- DME (CH_3OCH_3) , the simplest ether , colorless and odorless, contains no sulfurs or aromatics.
- Alternative fuel for diesel or liquefied petroleum gas (LPG)
- high cetane number (55-60)
- no SO_x , low NO_x emission and low pollution for environmental after combustion.

Syngas conversion: Dimethyl Ether (DME)

- Expect to become a fundamental chemical feedstock in the near future.
- Easily liquefied and can be used as a transportation fuel.
- Can be produced in large quantity through natural gas or coal.

Syngas conversion: Dimethyl Ether (DME)



A) Gasification

C_xH_y + oxidants → CO + H_2

B) Methanol Synthesis (Syngas to Methanol)

CO + $2H_2$ → CH_3OH

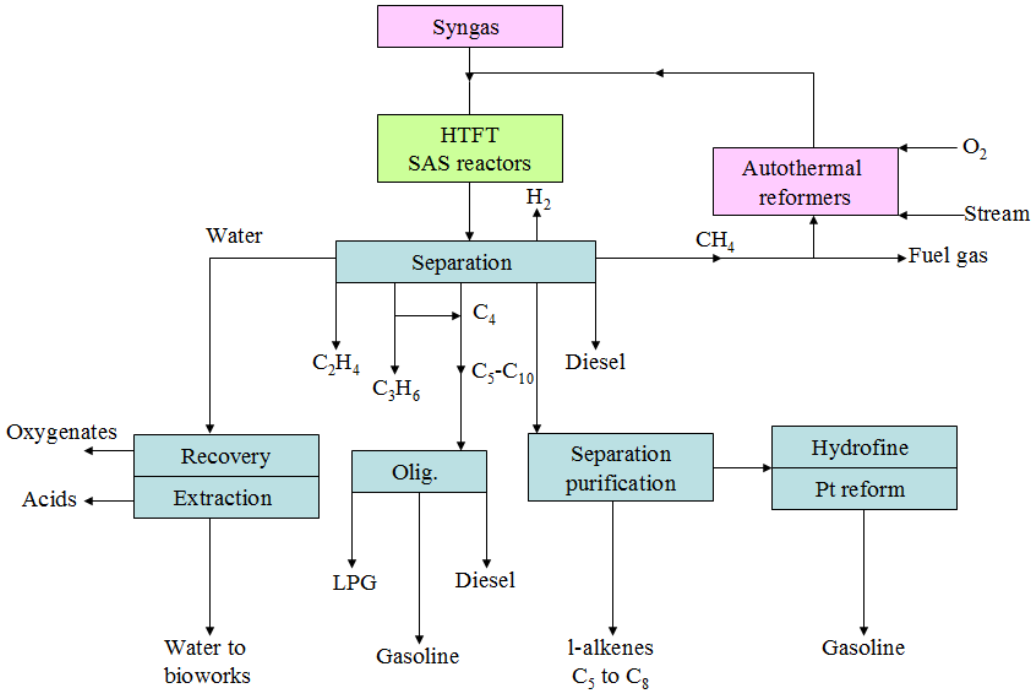
C) Methanol Dehydration (Methanol to DME)

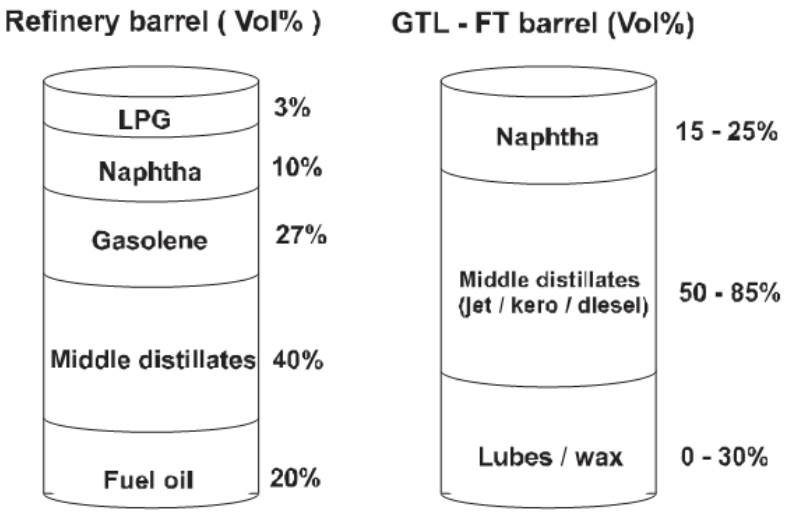
$2CH_3OH$ → $CH_3OCH_3 + H_2O$

Syngas conversion: liquid alkanes

Fischer–Tropsch (F–T) is regarded as technological schemes for converting synthesis gas to transportation liquid fuels.

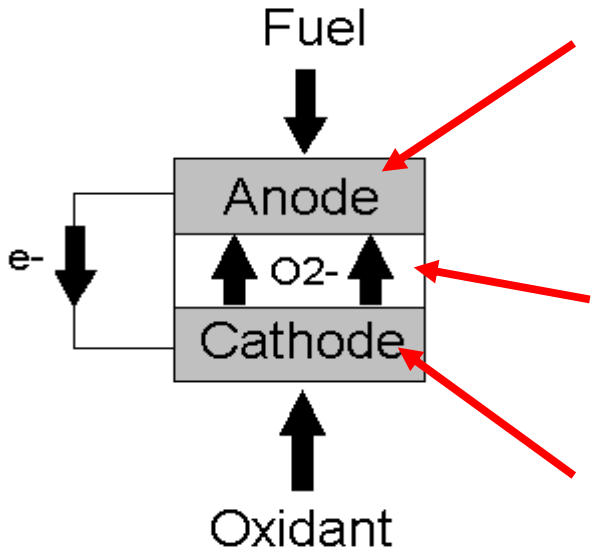
The proposed and future facilities will be substantially less costly than their very expensive predecessors. Cost reductions will be attributable to improvements in catalyst/reactor design.





Syngas conversion: Fuel Cells

A fuel cell is an electrochemical device that produces electricity and heat directly from a gaseous fuel by electrochemical combination of the fuel with an oxidant.



Anode Reaction :

$H_2 + O^{2-} \rightarrow H_2O + 2e^-$ (Oxidation)

$CO + O^{2-} \rightarrow CO_2 + 2e^-$ (Oxidation)

Electrolyte

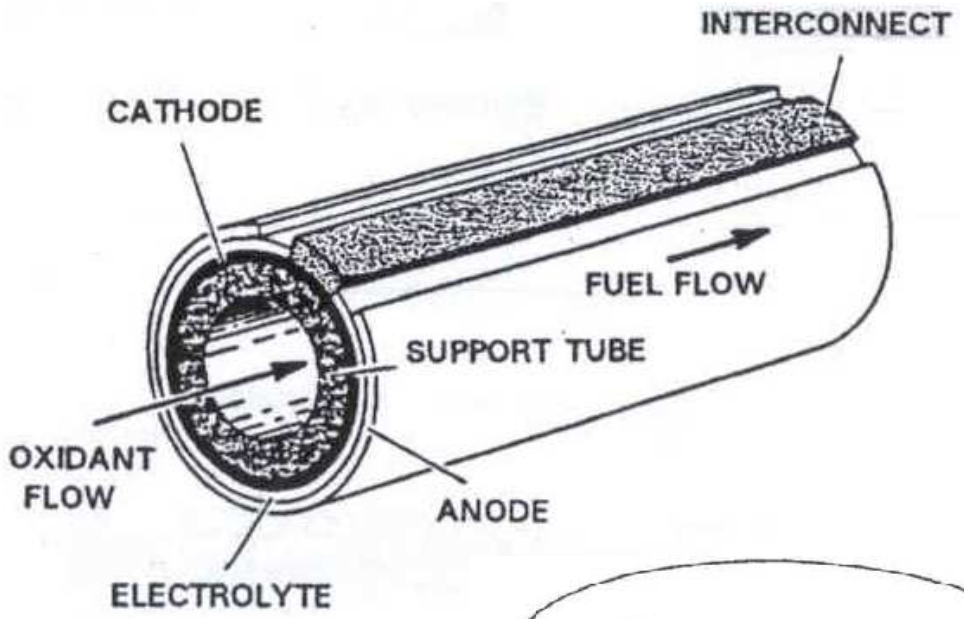
Cathode Reaction :

$O_2 + 4e^- \rightarrow O^{2-} + O^{2-}$ (Reduction)

Overall Reaction : $1/2O_2 + H_2 \rightarrow H_2O$

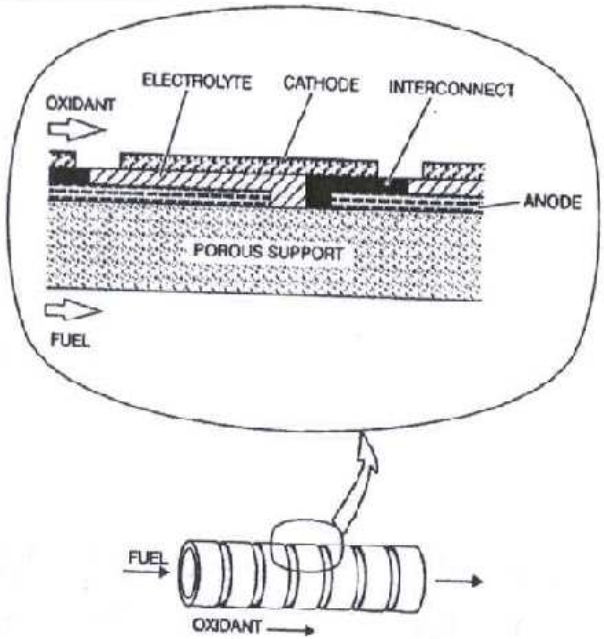
$1/2O_2 + CO \rightarrow CO_2$

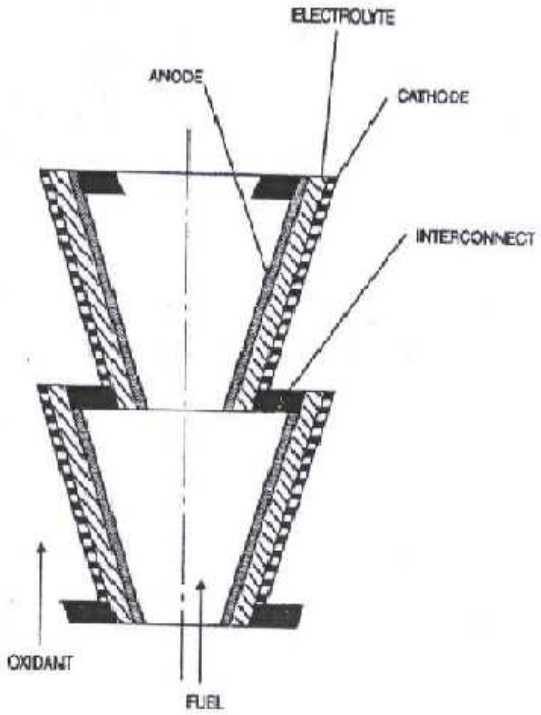
Syngas conversion: Fuel Cells



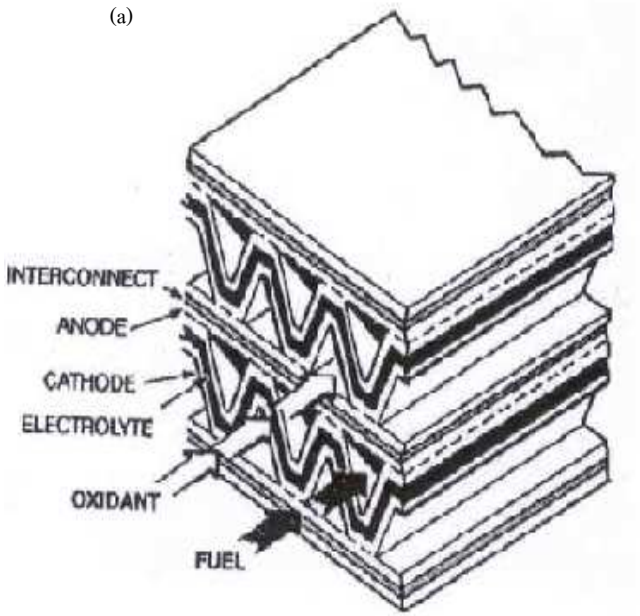
Seal-less tubular

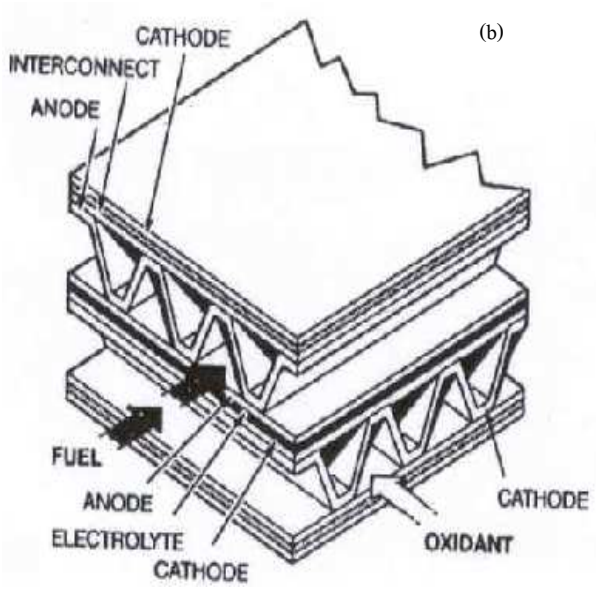
Segmented cell in series design





Syngas conversion: Fuel Cells

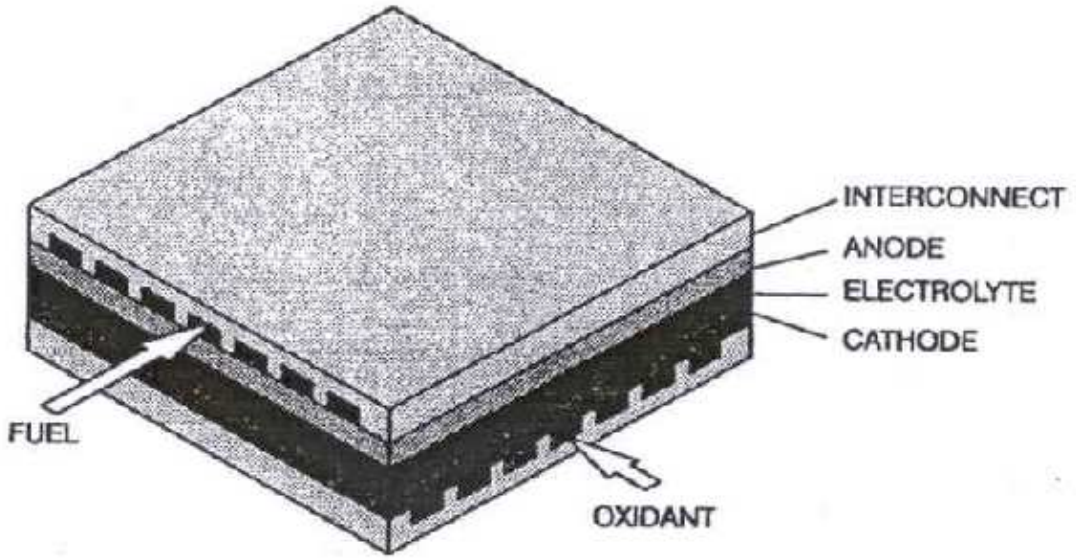




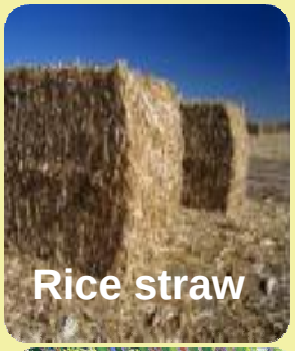
Monolithic

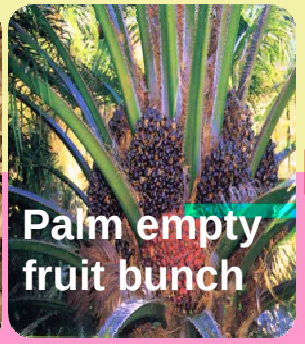
- Co-flow
- Cross-flow

Flat plate



II. Sugar conversion pathway





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MTEC a member of NSTDA

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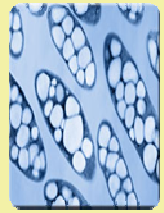
Pretreatment

Fractionation

Hydrolysis

Fermentation

Purification → Ethanol, Chemicals



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Dehydration → Furans & Acids

Aldol-condensation / Hydrogenation → Liquid alkane

Pretreatment of lignocellulosic biomass

Agricultural by-products

Cutting mill

Alkaline

- %NaOH, T @fixed t, %S

Area ↑
Hemicel –
Lignin ↓
Inhibitor –

Alkaline/Oxidation

- %NaOH, T
- %PAA, T @fixed t, %S

Area ↑
Hemicel –
Lignin ↓
Inhibitor –

Diluted acid/Alkaline

- %H_2SO_4, T
- %NaOH, T @fixed t, %S

Area ↑
Hemicel ↓
Lignin ↓
Inhibitor ↑

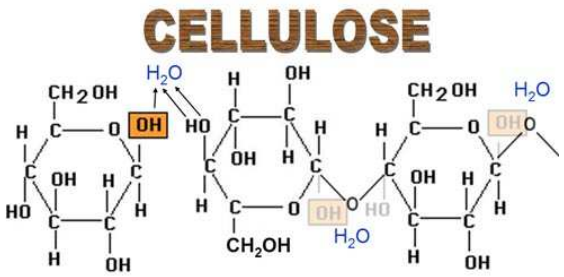
Hot compressed water

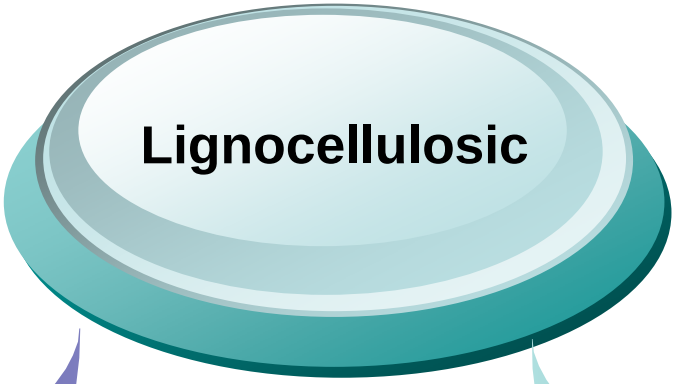
- T, t @fixed %S
- Noncatalytic/catalytic

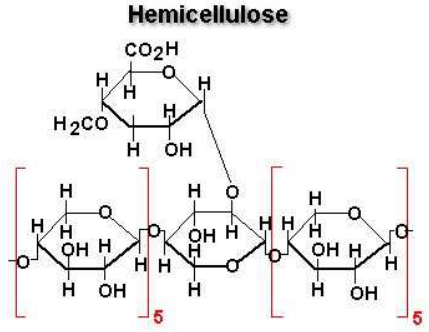
Area ↑
Hemicel ↓
Lignin ↓
Inhibitor –

Fractionation of lignocellulosic biomass

General Concept of Fractionation







Cellulose

- Bio ethanol
- Paper
- Cellophane
- Carboxymethyl Cellulose
- Etc.

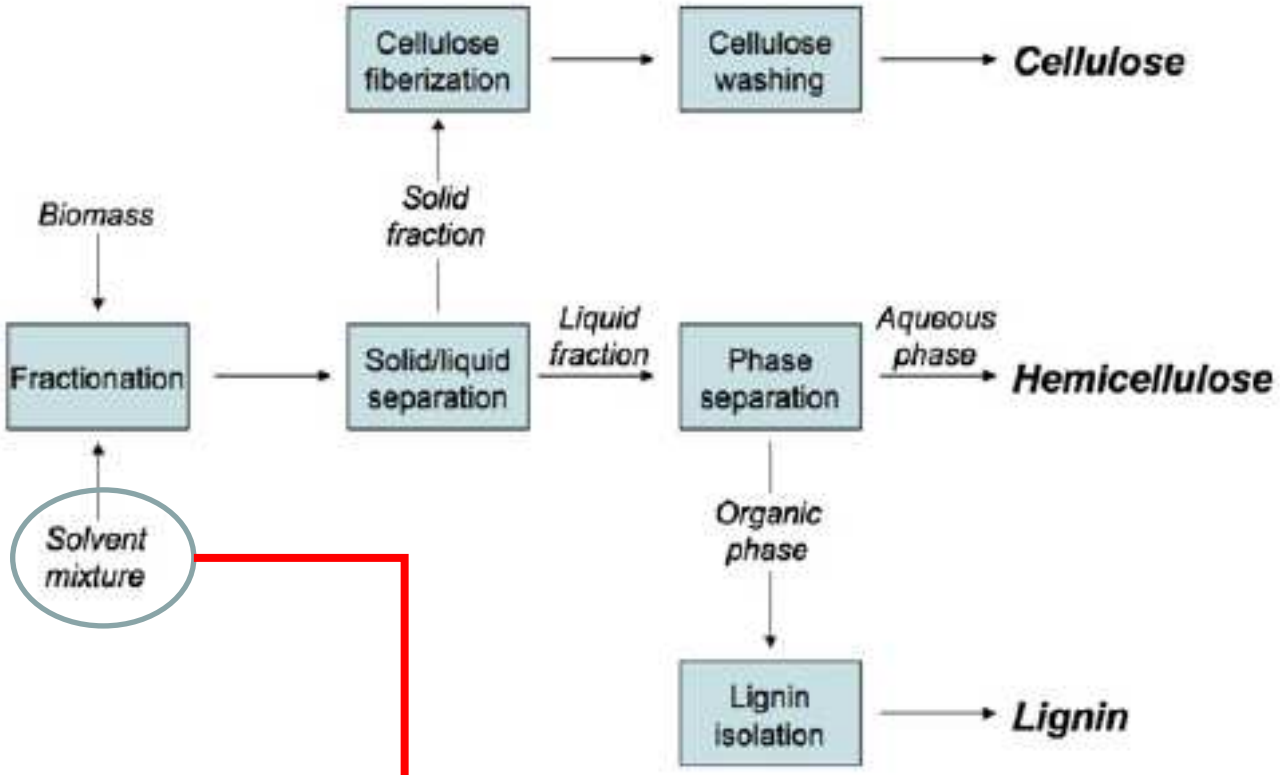
Hemicellulose

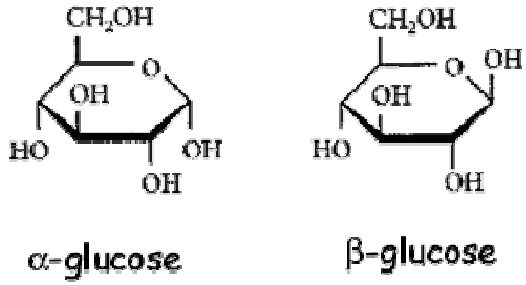
- Xylitol
- 2,3 butanediol
- Lactic acid
- Ferulic acid
- Hydrogel
- Etc.

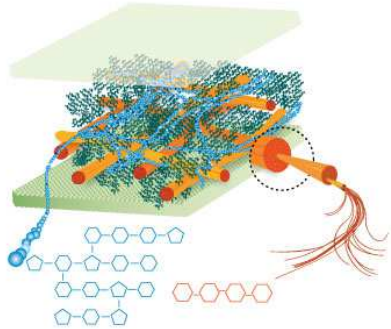
Lignin

- Epoxy
- Phenol
- Carbon fiber
- Binders
- Activated carbon
- Dispersants
- Etc.

Fractionation process for local lignocellulosic biomass



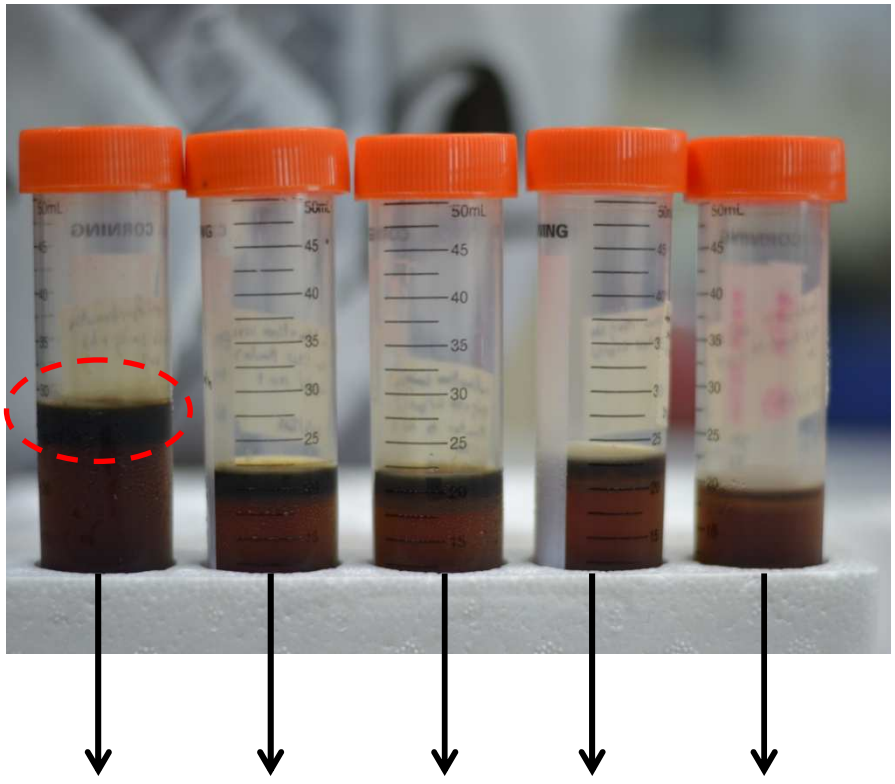




Ternary mixture of methyl isobutyl ketone (MIBK), ethanol and water.

Fractionation process for local lignocellulosic biomass

Phase separation at various temperatures



200°C 190°C 180°C 170°C 160°C

1st phase

2nd phase

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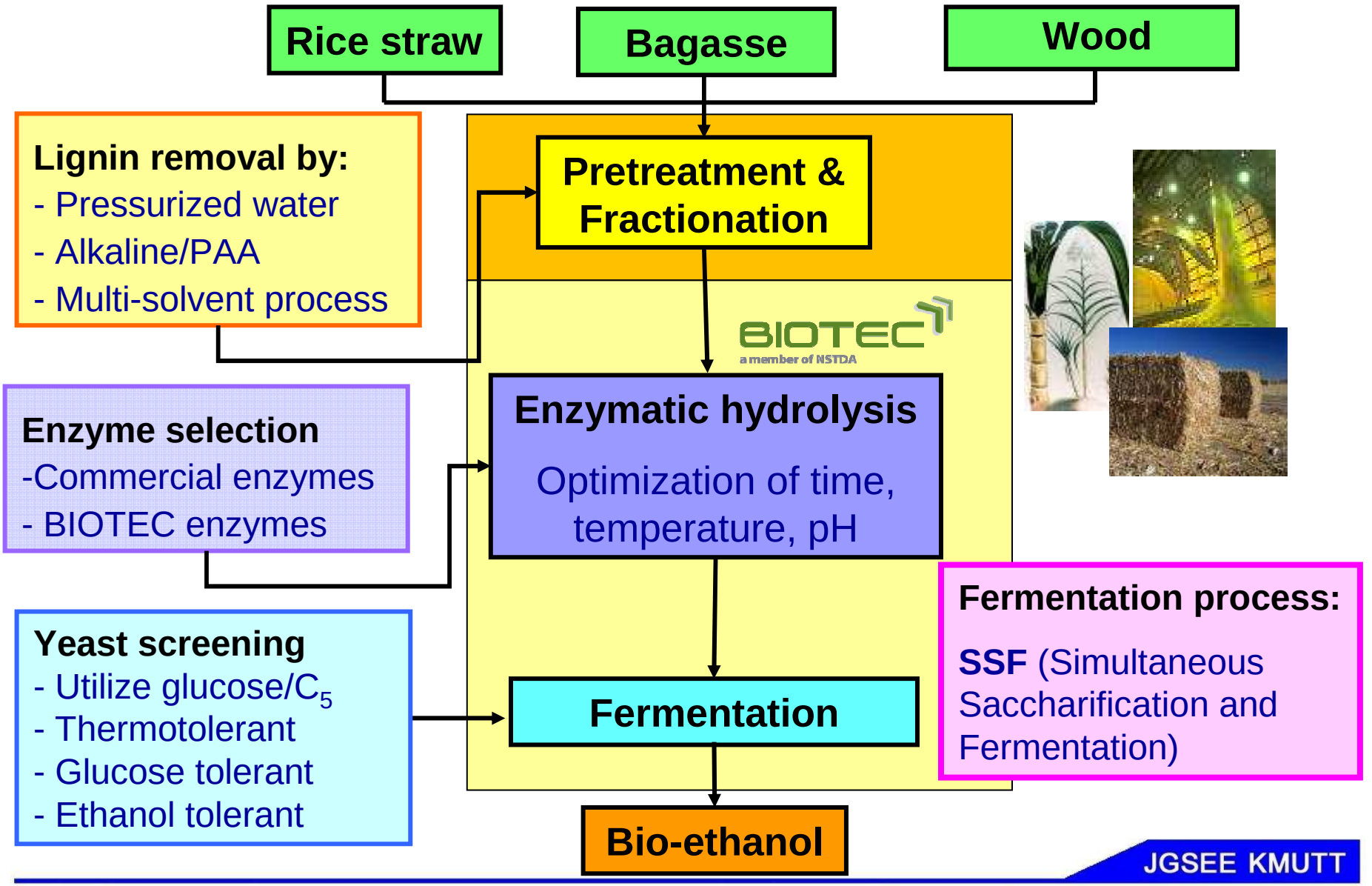
Lignocellulosic-ethanol production



Production of furans and organic acids

Lignocellulosic biomass

Pretreatment

Enzymatic hydrolysis

Thermocatalytic hydrolysis: HCW

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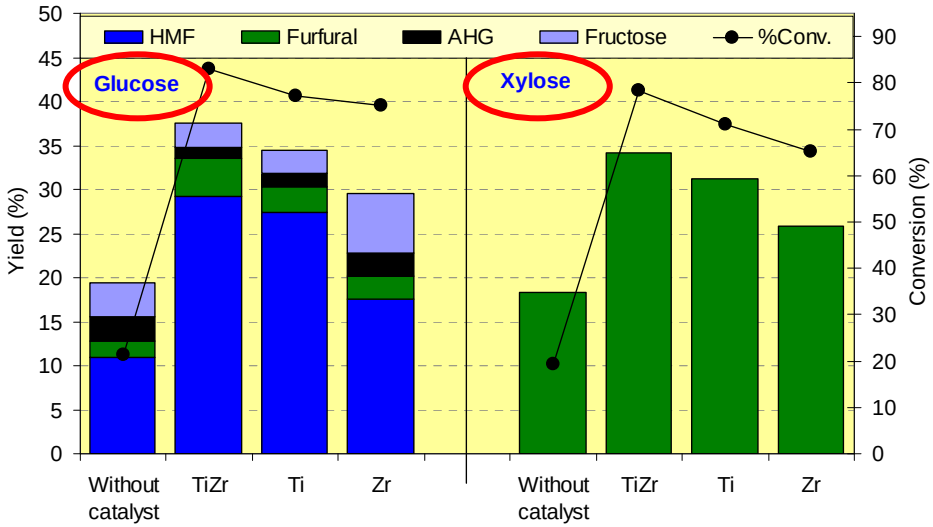
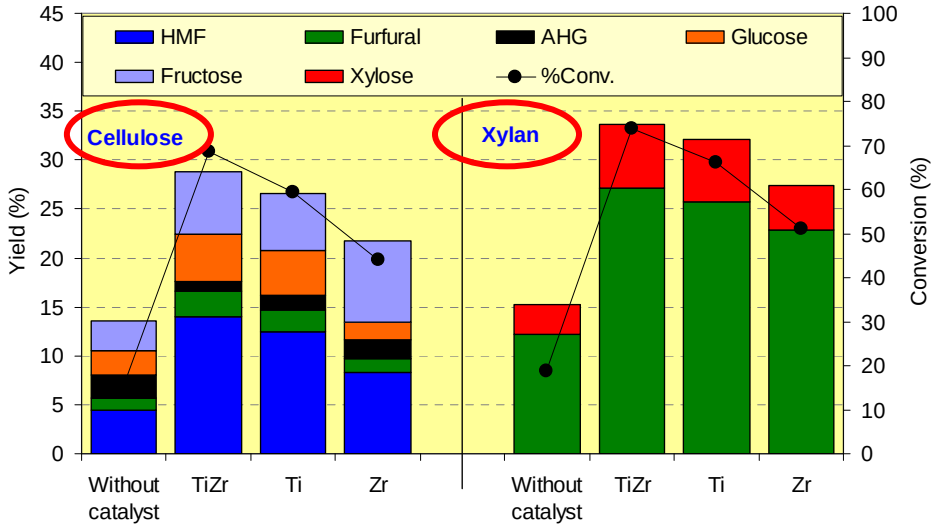
Enable to maximize the sugar yield with rapid production rate without pretreatment required

Sugar: glucose + C_5

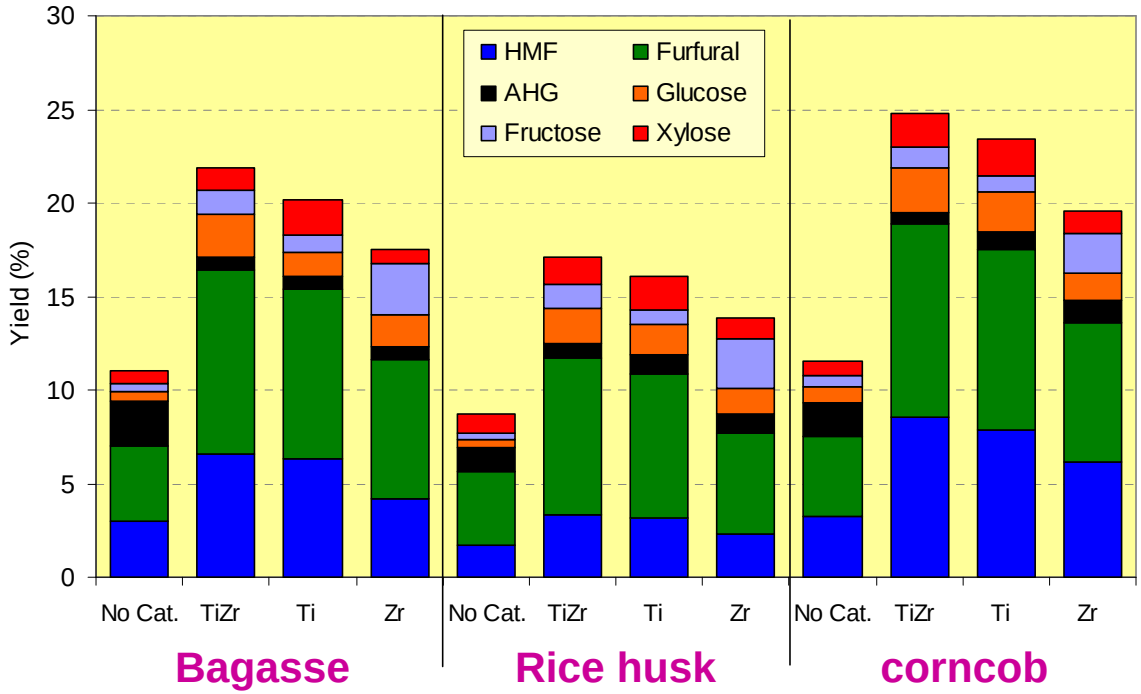
dehydration

Furans and organic acids





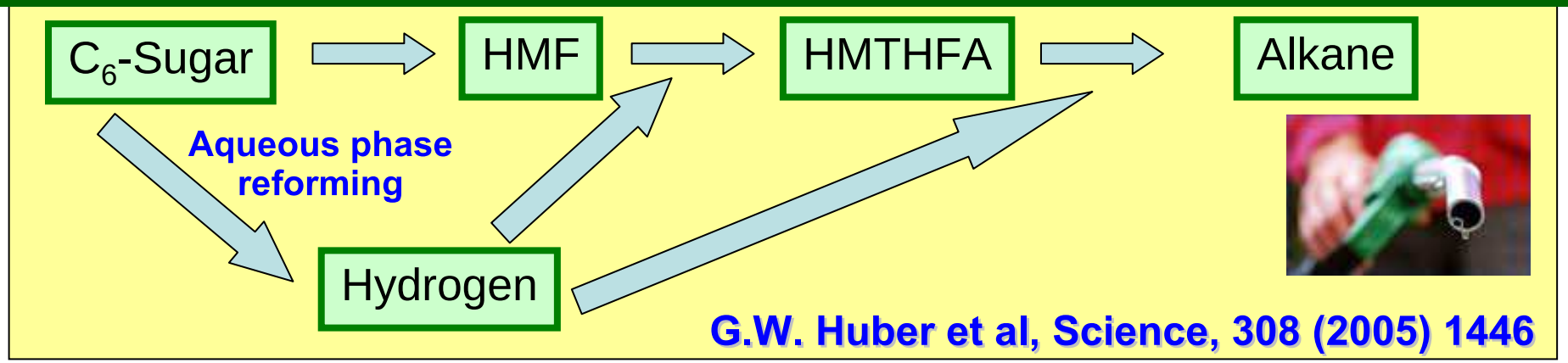
A. Chareonlimkun, V. Champreda, A. Shotipruk, N. Laosiripojana, Fuel 89 (2010) 2873-2880.

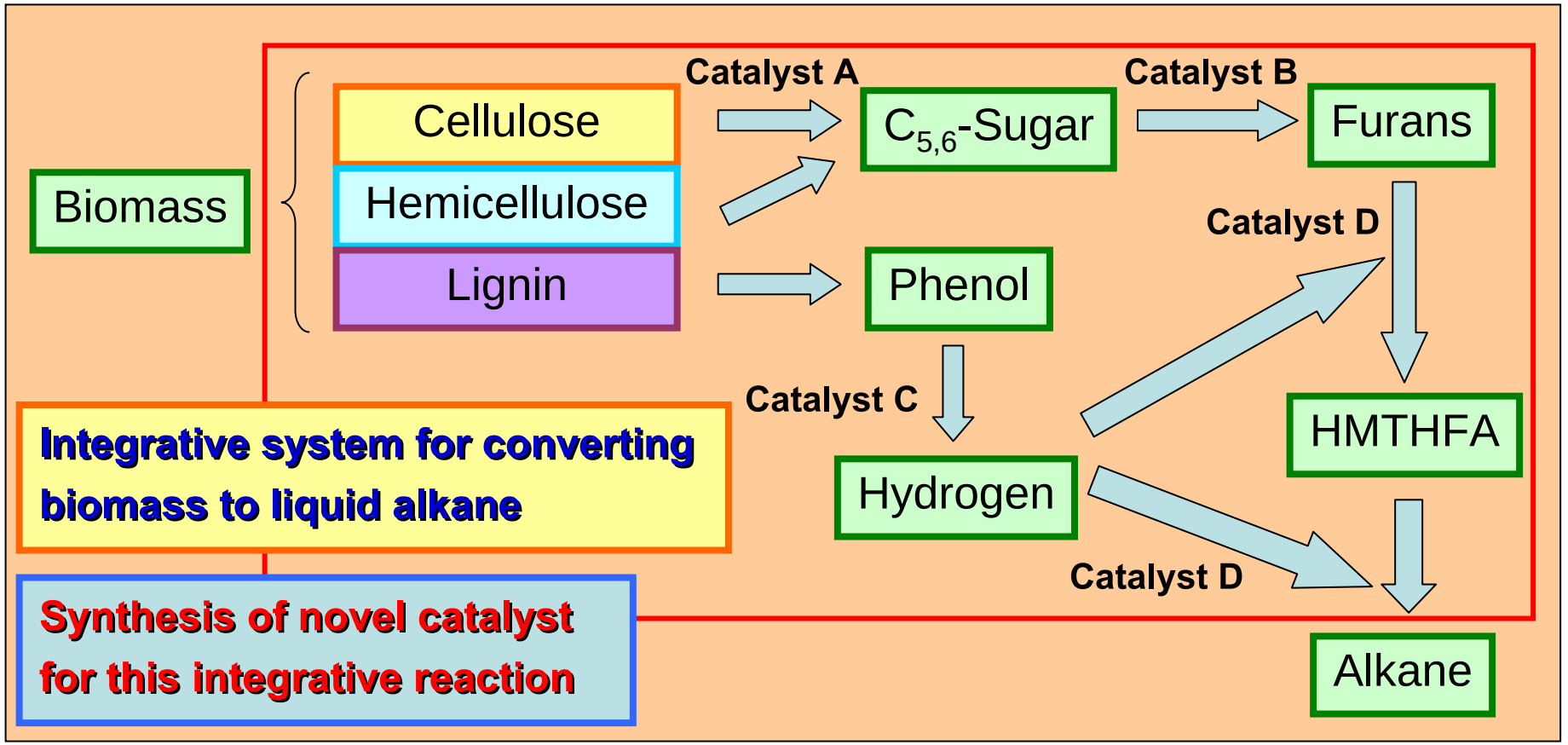


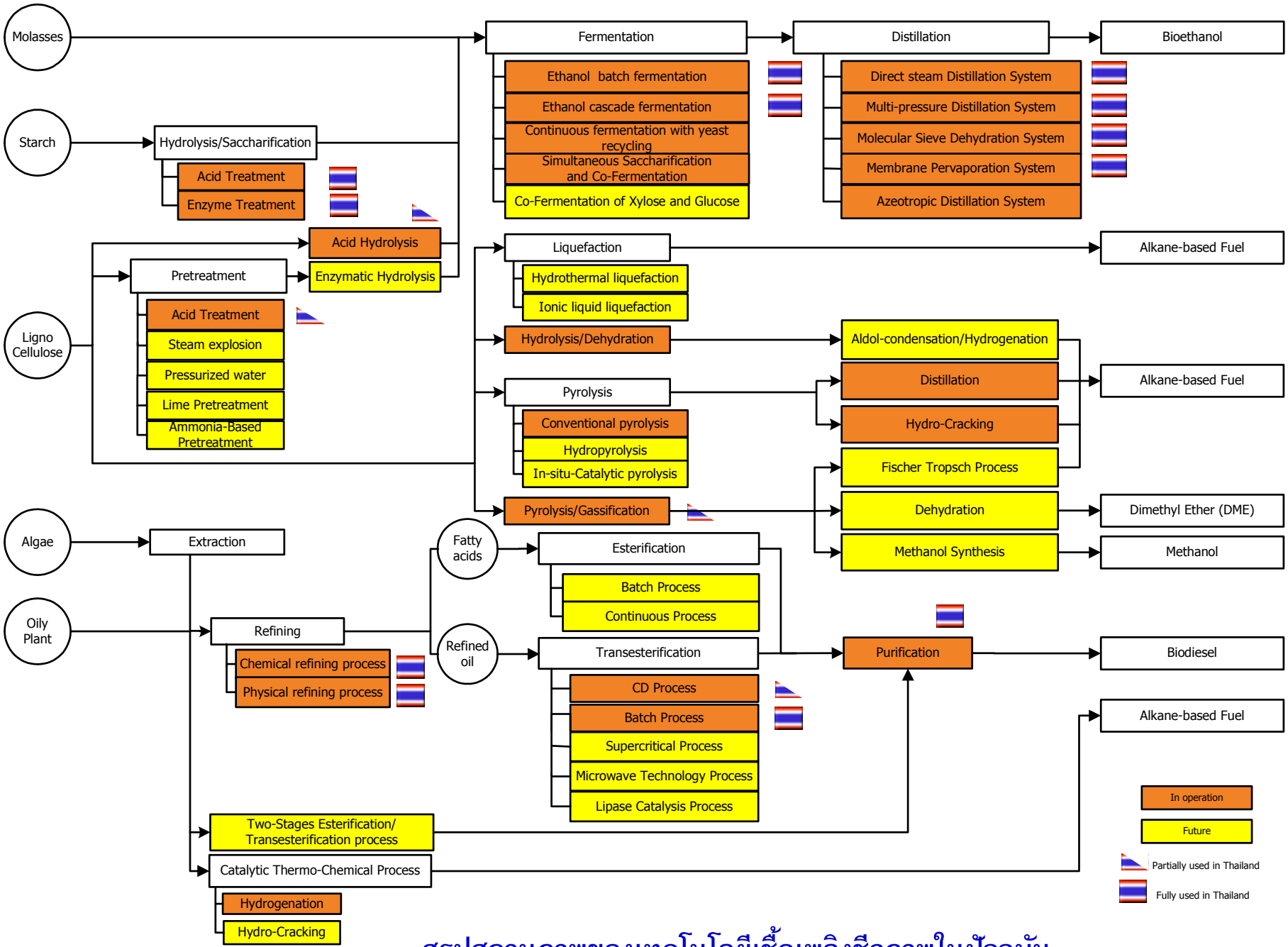
Enhance furan yield of 12-18% from biomass

A. Chareonlimkun, V. Champreda, A. Shotipruk, N. Laosiripojana, Bioresource Technology 101 (2010) 4179-4186

Biomass-to-liquid (BTL) Production







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