Integrative Biorefinery research@IBL

Conversion of renewable plant biomass to fuels and chemicals: Bio-process

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National Center for Genetic Engineering and Biotechnology

IBL
JGSEE-NSTDA
Integrative
Biorefinery
Laboratory

Bio-based economy & Biorefineries

Biotechnology plays an increasing importance on key industrial sectors in production of commodity and specialty products for everyday life.

Bioresources are explored as alternative feedstocks and for finding novel microbes and enzymes for development of greener production processes and establishment of the prospective biorefinery industry.

http://www.wallcoo.net/human/SZ_206_Entironment_03_city_Photo_manipulation/html/wallpaper29.html

Fuels:
ethanol , biodiesels & BTL

Feed:
feed supplement, prebiotic

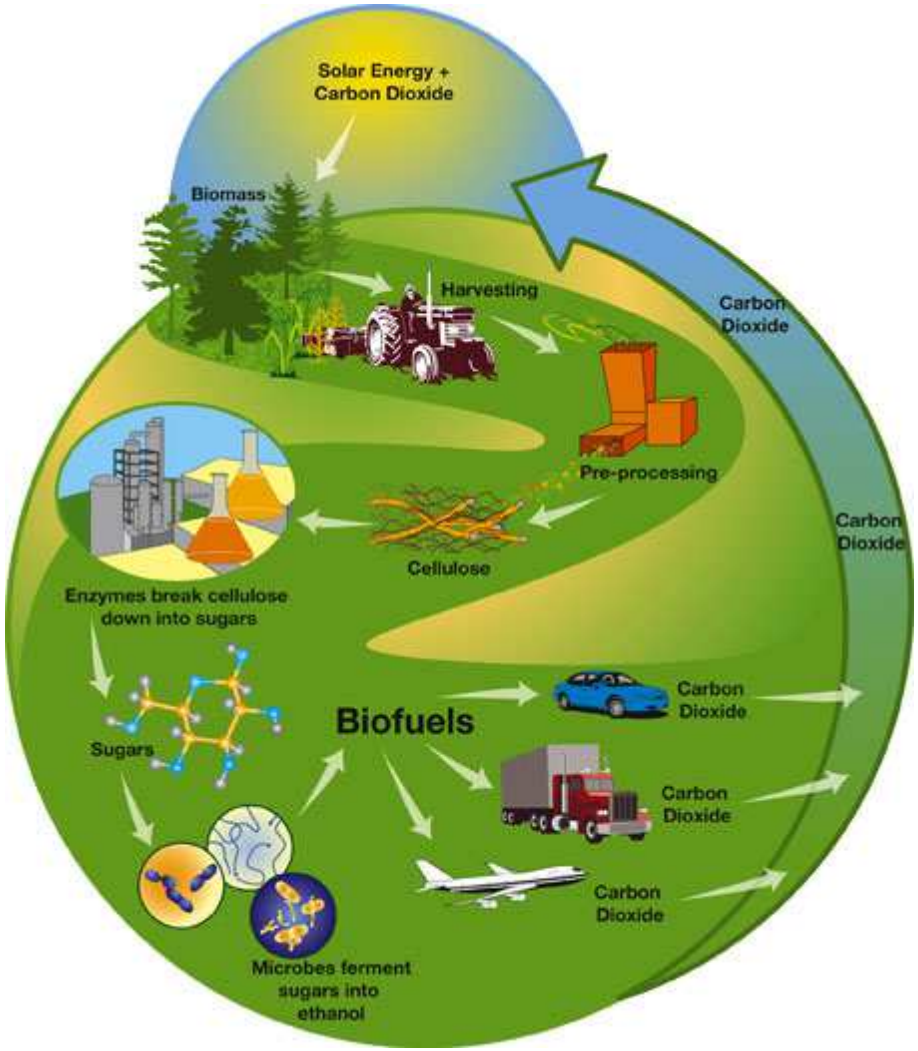
Chemicals:
commodity & specialty

Materials:
bioplastics & biomaterials

Biorefinery industry

Biorefinery is a promising industry related to the production of **biofuels, biomaterials, and chemicals** from renewable or renewable bio-resources.

- sustainable production of biofuels, bio-materials and chemicals
- carbon-neutral process
- Food V.S. Feed
- efficient waste utilisation and management
- improved local economics

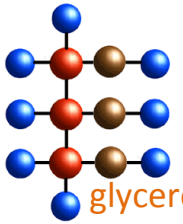


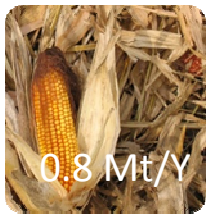
Sustainable alternative production platform to the current petroleum resource

Thailand as a regional hub for biorefinerires

Agricultural platform:

Diverse conventional 1° feedstock & 2° lignocellulosic agricultural residues





Industry platform:

- Strong upstream agro-industry and downstream petrochemical platform
- Asia's leader in biofuel and bioplastic industries

Technology platform:

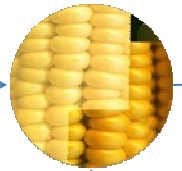
Wide-ranging R&D activities in governmental and industrial sectors on biorefinery industry

Integrative biorefinery: Global & Thailand progress

More cellulosic feedstocks
- local
- seasonal
- logistics

More product portfolio
- fuel
- chemicals
- materials

1978 

1990 

2000 pilot

2010 demo

Commercial cellulosic biofuel plants
DuPont: 30 M G/Y (2014)
Integrative biorefinery **F**eedstock & Product variety

Brazil cane ethanol fuel

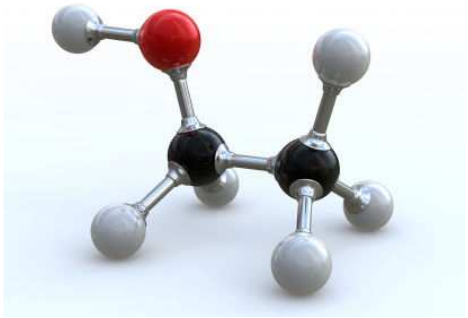
US corn ethanol

Start of Thai ethanol industry

Thailand's 1st Demo-scale acid hydrolysis of bagasse for ethanol production (NEDO, Japan)

Demo-scale cellulosic ethanol plant sugar platform: 10,000 L (2014)

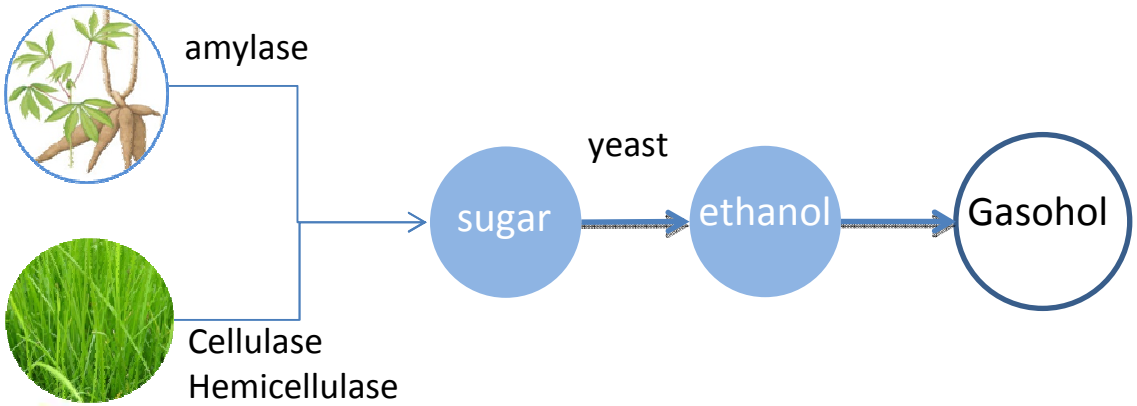

Bio-plastics
Bioethanol
Biorefinery
Chemicals
Biodiesel

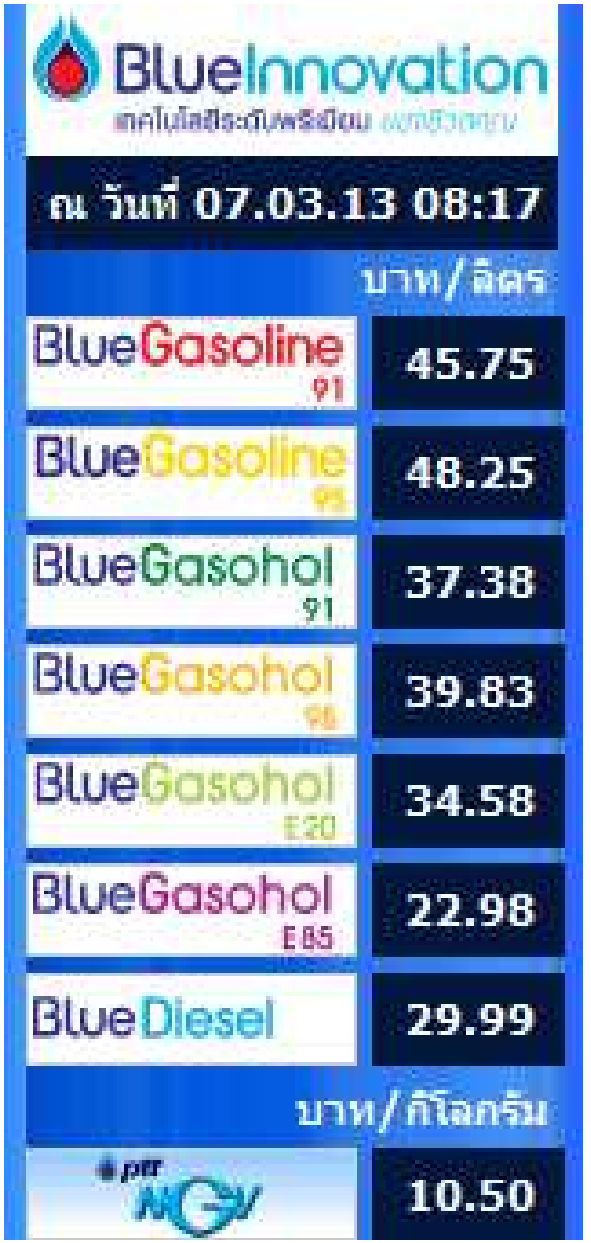


Bioethanol

Renewable energy from fermentation of sugars to ethanol

- Currently, there are 18 major ethanol plants across the country with total production capacity of 2.75 M liters/day (2010)
- Feedstock from molasses/cassava/sugarcane juice
- Available as E10, E20, E85

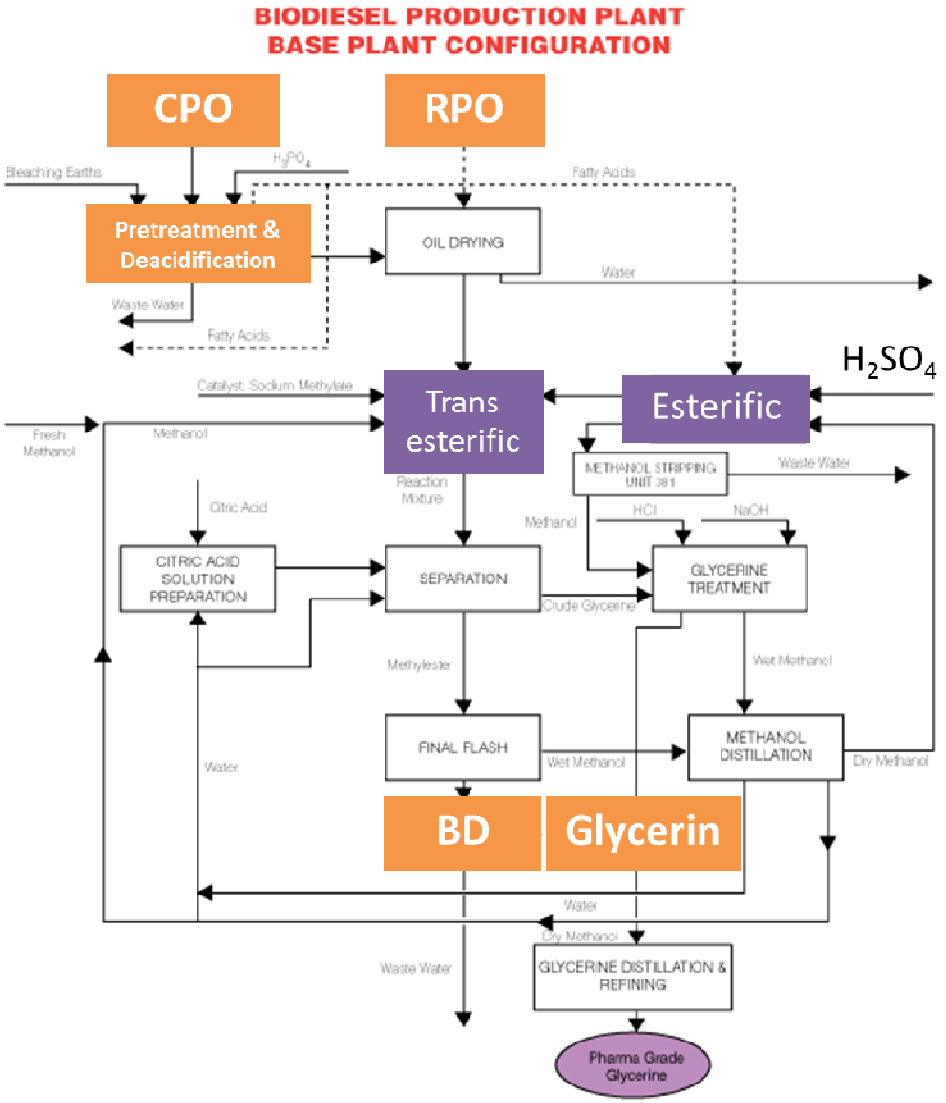




Biodiesel

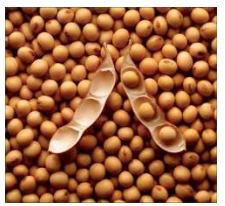
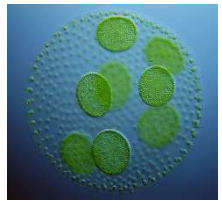
Renewable biofuel from chemical modification of vegetable/waste oils

- Currently, there are 13 biodiesel plants in the country with total actual production of 1.3 M L/d mainly from palm oil feedstock.
- Industrial-grade (B5)/ Community biodiesel production
- Fatty acid methyl ester (FAME)



TAG + MtOH $\xrightarrow[\text{Lipase}]{\text{NaOH}\ \text{or}\ H_2SO_4\ \text{or}\ \text{Thermal}}$ FAME + Glycerol



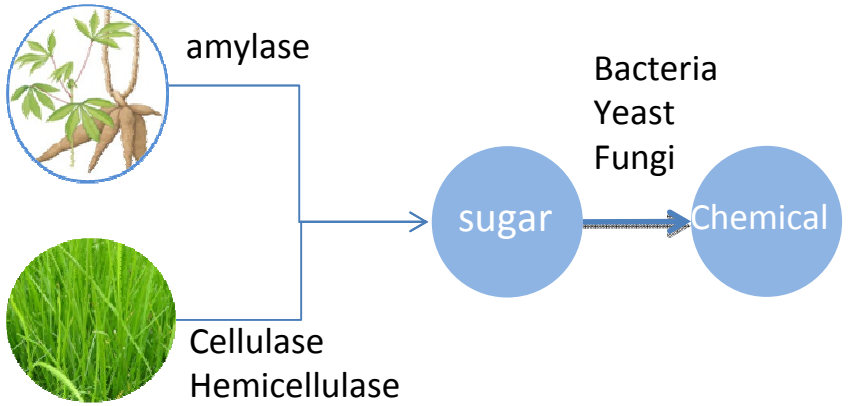



Bio-chemicals

Commodity and specialty chemicals from fermentation

Acetic acid:	14,000 tons/year
Citric acid:	24,000 tons/year
Glutamic acid:	90,000 tons/year
MSG:	270,000 tons/year
Lysine:	50,000 tons/year
Bio-succinic (PTT)	

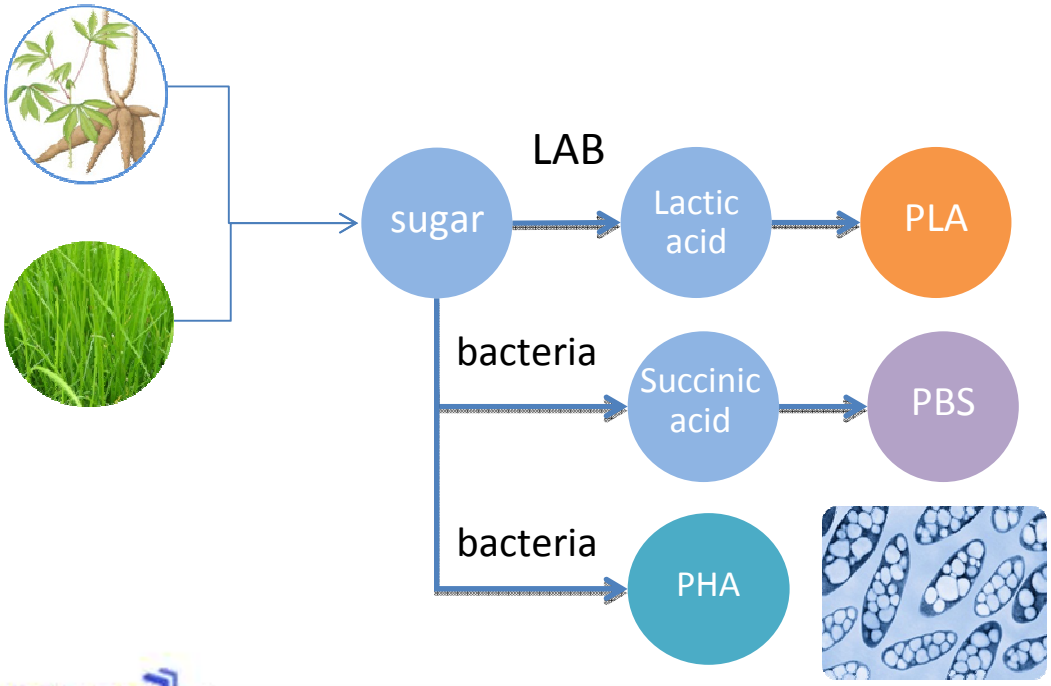
Food
Animal feed
Polymer
Chemical
Pharmaceutical

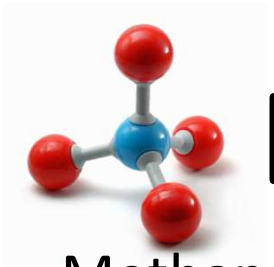


Bio-plastic

Alternative environmentally friendly materials from bio-based feedstock

- NIA has initiated the national strategic plan for bioplastic industry aiming for positioning the country as the “bioplastic hub”
- Primary target: PLA, PHA, and PBS



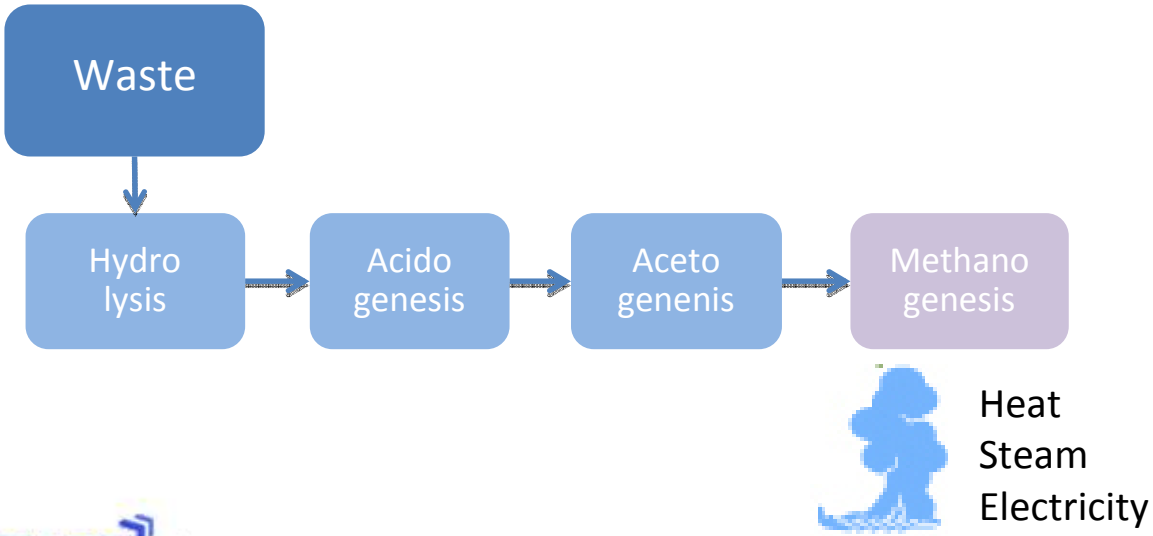


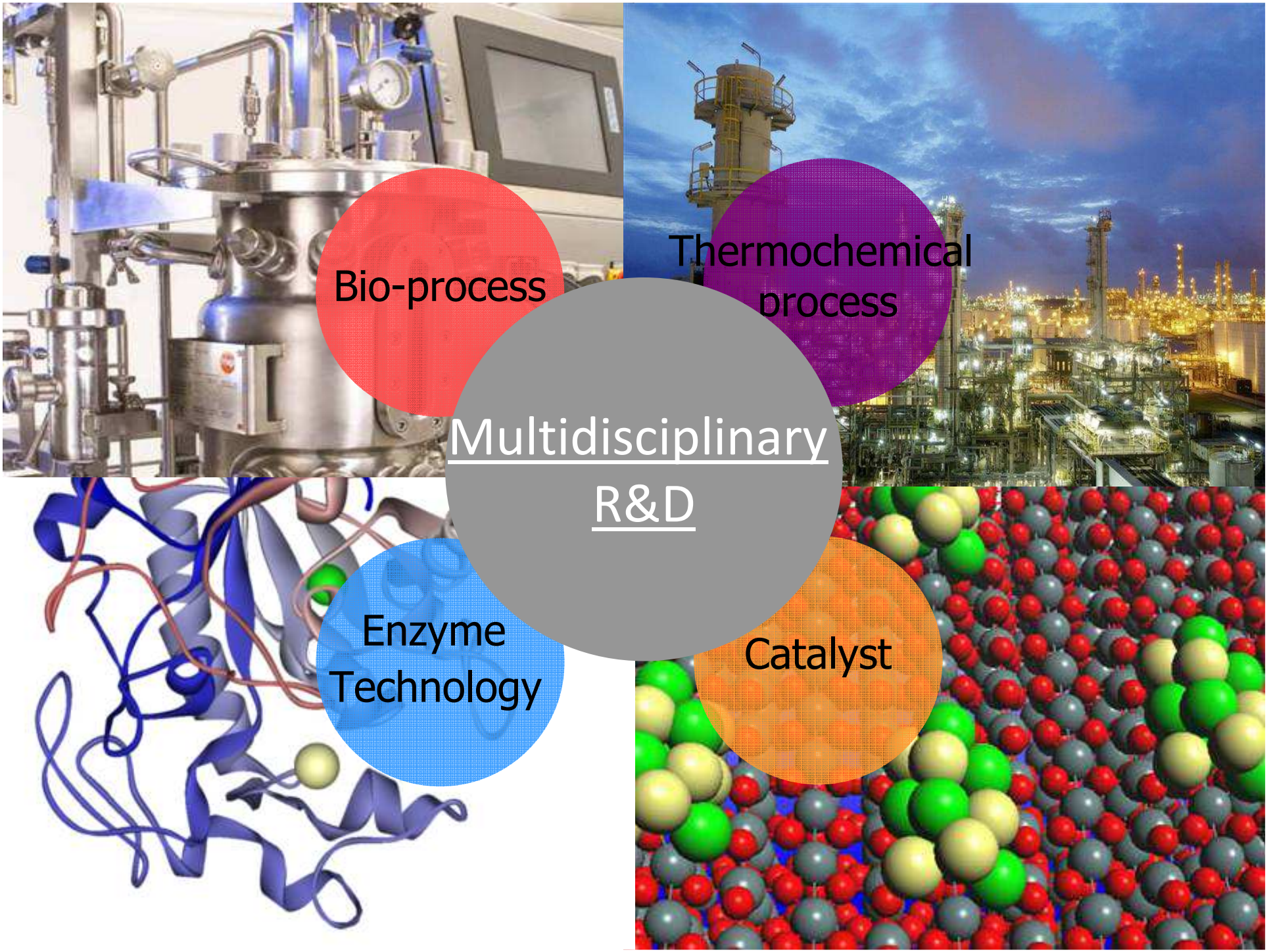
Biogas

Methane and biohydrogen from anaerobic digestion

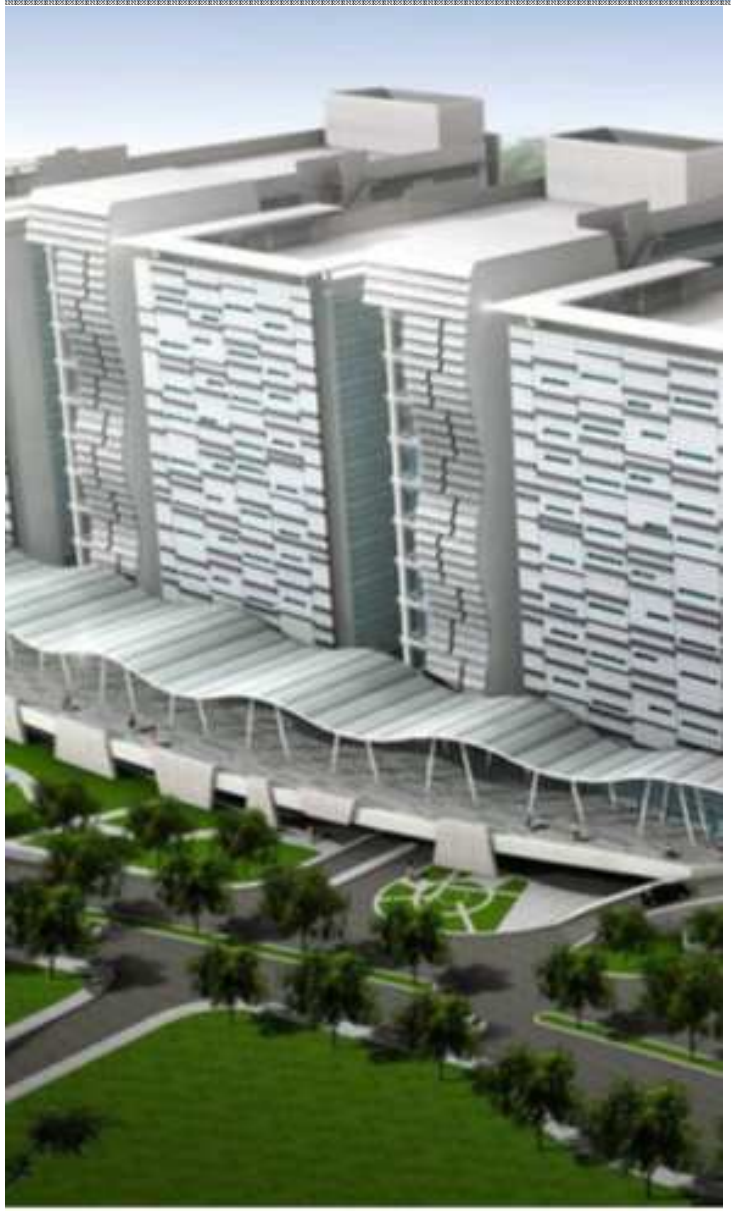
Commercialisation of high rate biogas system in farms and industries

- 2,300 biogas plants
- 380 million m^3 (equivalent to 188 ktoe)
- Cassava waste water (53%), manure (39%) with potential substrates e.g. municipal wastes, POME, and glycerol




Bio-process
Thermochemical process
Multidisciplinary R&D
Enzyme Technology
Catalyst

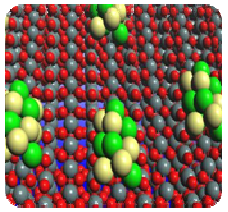
NSTDA-JGSEE Integrative Biorefinery Laboratory (IBL)



IBL is established as a stragetic multi-disciplinary R&D center as a **1st focal point** for biorefinery research aiming to strengthen the country's platform technology and accelerating commercialisation of biorefnery processes in industrial sectors.

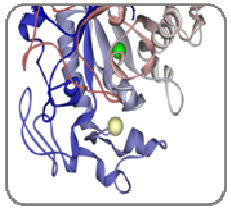
- Allied strength from BIOTEC & JGSEE and their network
- Platform technology & Industrial-directed translational R&D
- Multi-disciplinary integrative R&D

Thermal



Chemical & Catalytic

Bio-process



Enzymes & Biocatalytic

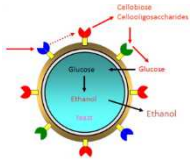
Integrative biorefinery laboratory: **network**

BIOTEC a member of NSTDA

Enzymes

- Fungi
- Metagenomes
- Consortia

BIOTEC a member of NSTDA



microbial cell engineering

users

Biomass

Sugars

Fuel
Ethanol; BTL

Chemicals
Building blocks
Aromatics

Up-scaling

ptt Group

MITR PHOL

JGSEE The Joint Graduate School of Energy and Environment

Hydrothermal & Solvothermal pretreatment/ fractionation

Lignin

Materials

National Institute of Advanced Industrial Science and Technology (AIST) 独立行政法人 産業技術総合研究所

QUT Queensland University of Technology

Enzymes

- Anaerobic/ facultative bacteria

Lignin conversion

QUT

Catalyst design & process optimisation

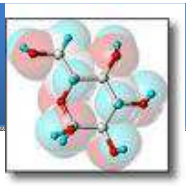
JGSEE The Joint Graduate School of Energy and Environment

NANOTEC a member of NSTDA

Process design and up-scaling

BEC BIOTEC a member of NSTDA

Integrative biorefinery: Sugar platform



- Chemical pretreatment
- Thermal pretreatment
- Reaction design

- Enzyme screening
- Enzyme formulation
- Process optimisation

- Strain selection
- Genetic engineering
- Co-fermentation

pretreatment → hydrolysis → fermentation

- High biomass digestibility
- Low chemicals
- Energy efficient
- Up-scaling capability

- Synergistic enzyme action
- Higher efficiency
- Low cost on-site production

- Lignocellulolytic enzyme expression
- Consolidated process
- C6/C5 ultilisation

BIOTEC a member of NSTDA

JGSEE The Joint Graduate School of Energy and Environment

BTRC

AIST National Institute of Advanced Industrial Science and Technology (AIST)

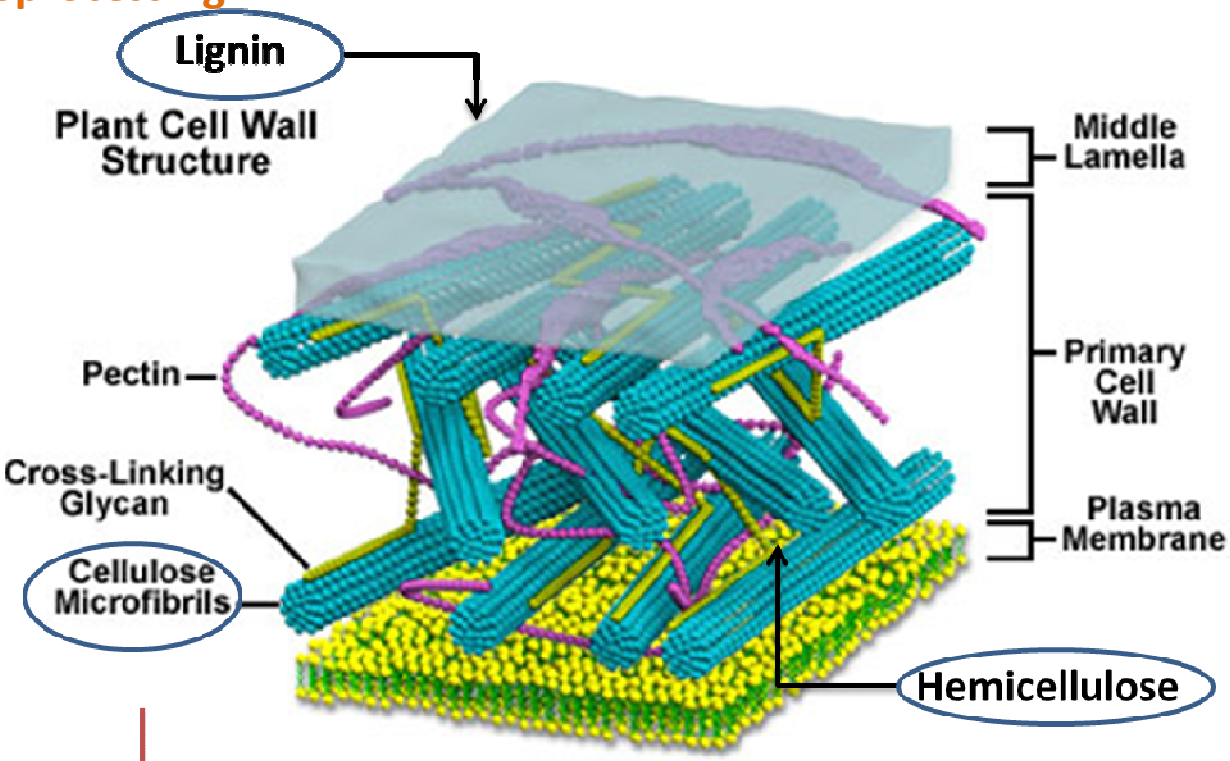
Lignocellulosic biomass

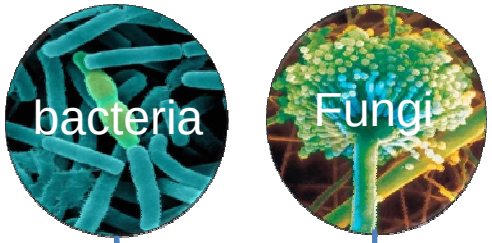
Degradation of plant lignocellulosic biomass is a key process on recycling of organic carbon in the global biogeochemical cycle.

R&D aim to understand the basis on lignocellulose degradation by means of complex microbial and enzymatic processes. This can be achieved through exploring the basis of lignocellulose degradation in nature, which will provide the platform for our further application of potent microbes and enzymes on sustainable bio-industries.

Lignocellulose composition & decomposition

Due to its complex structure, degradation of lignocelluloses involved various biomass degrading microbes, forming microcosms producing various enzymes working specifically and synergistically. Sugars are then subsequently converted to various products providing the concept of **consolidated bioprocessing**





Cellulase
- Endoglucanase
- Exoglucanase
- B-glucosidase

synergy ← EXP

+?

Hemicellulase
- Xylanase
- B-xylosidase
- Mannanase
- Etc...

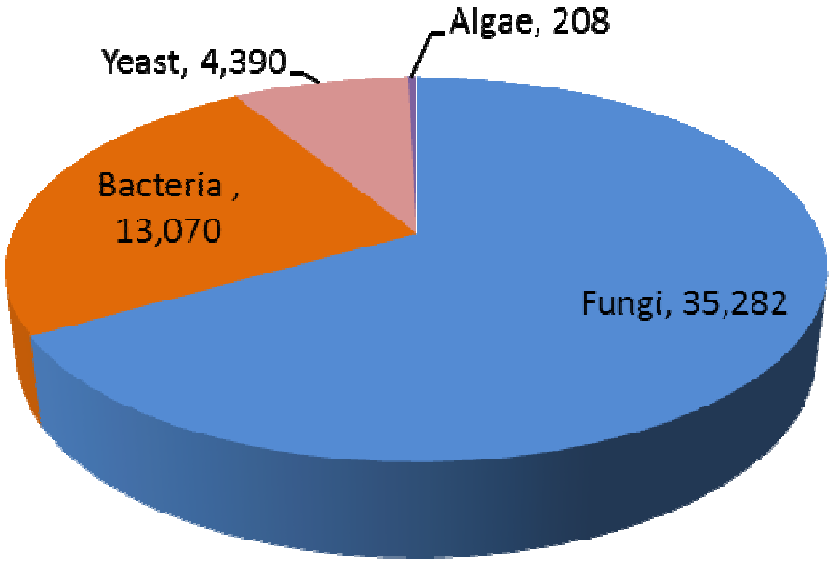
Ligninase

sugars → **Metabolic products:** acids, alcohols, …

Enzyme discovery from bioresoureces

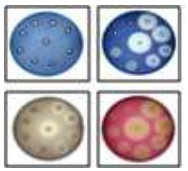
BIOTEC Culture collection

Screening of microbial isolates producing target enzymes

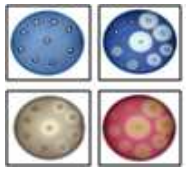


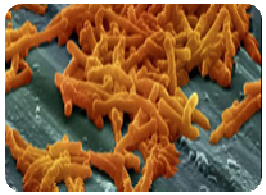
Environmental metagenomes

Jae Sorn Hot Spring
Plasmid: 200 Mb

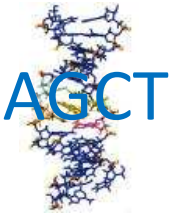


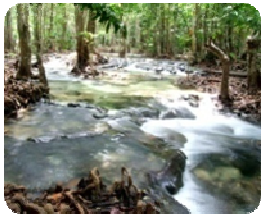
Termite gut
Fosmid: 2 Gb



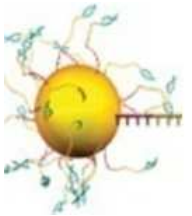


Microbial consortium
Fosmid: 4 Gb

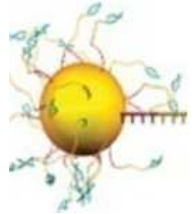




Peat swamp forest
Fosmid: 2 Gb

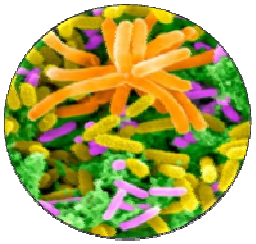


Industrial bagasse collection site
Fosmid: 4 Gb



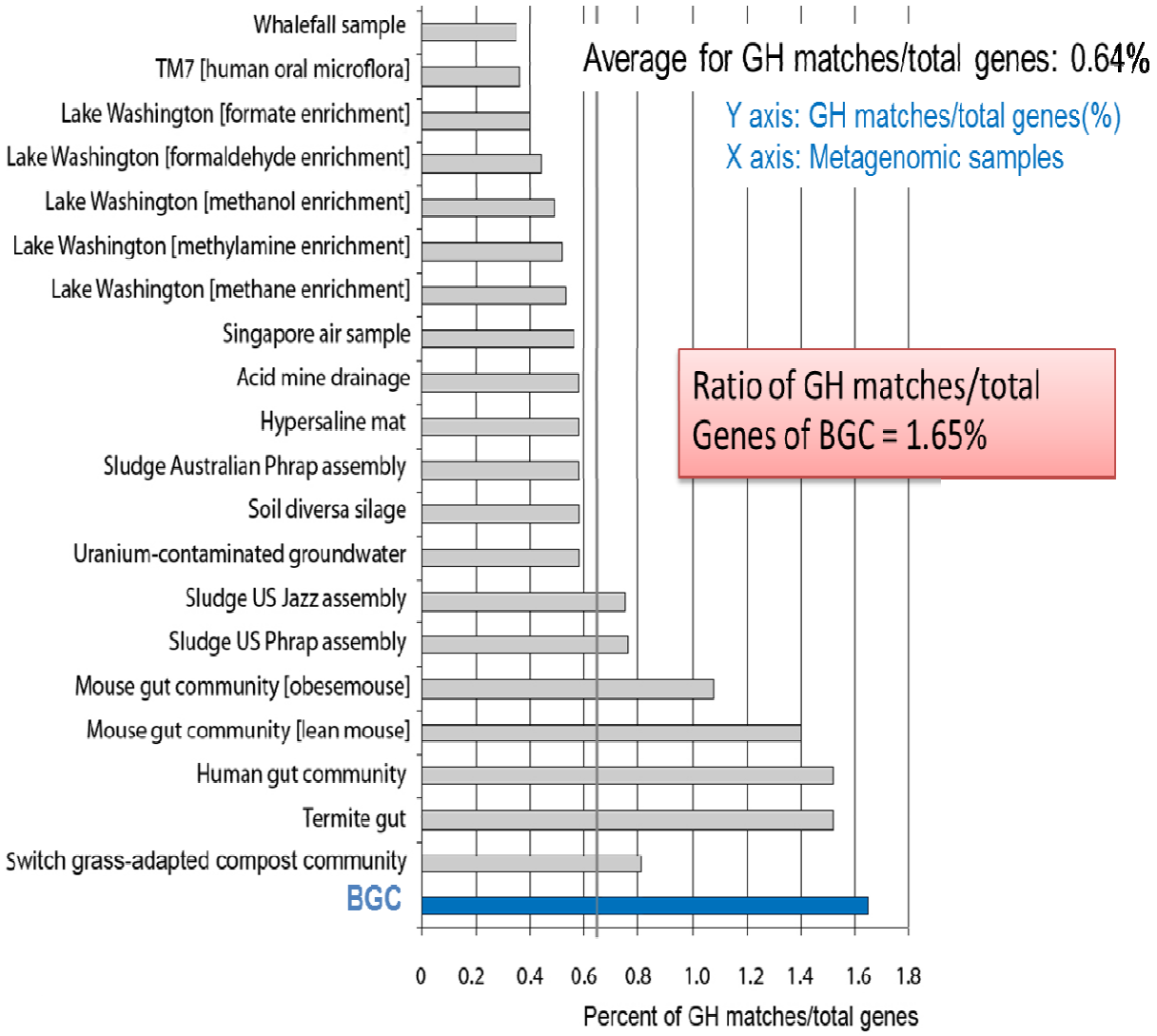
Cellulases and Hemicellulases from microbial bioreources

Environmental community



Symbiotic stable consortia

Cultured microorganism s

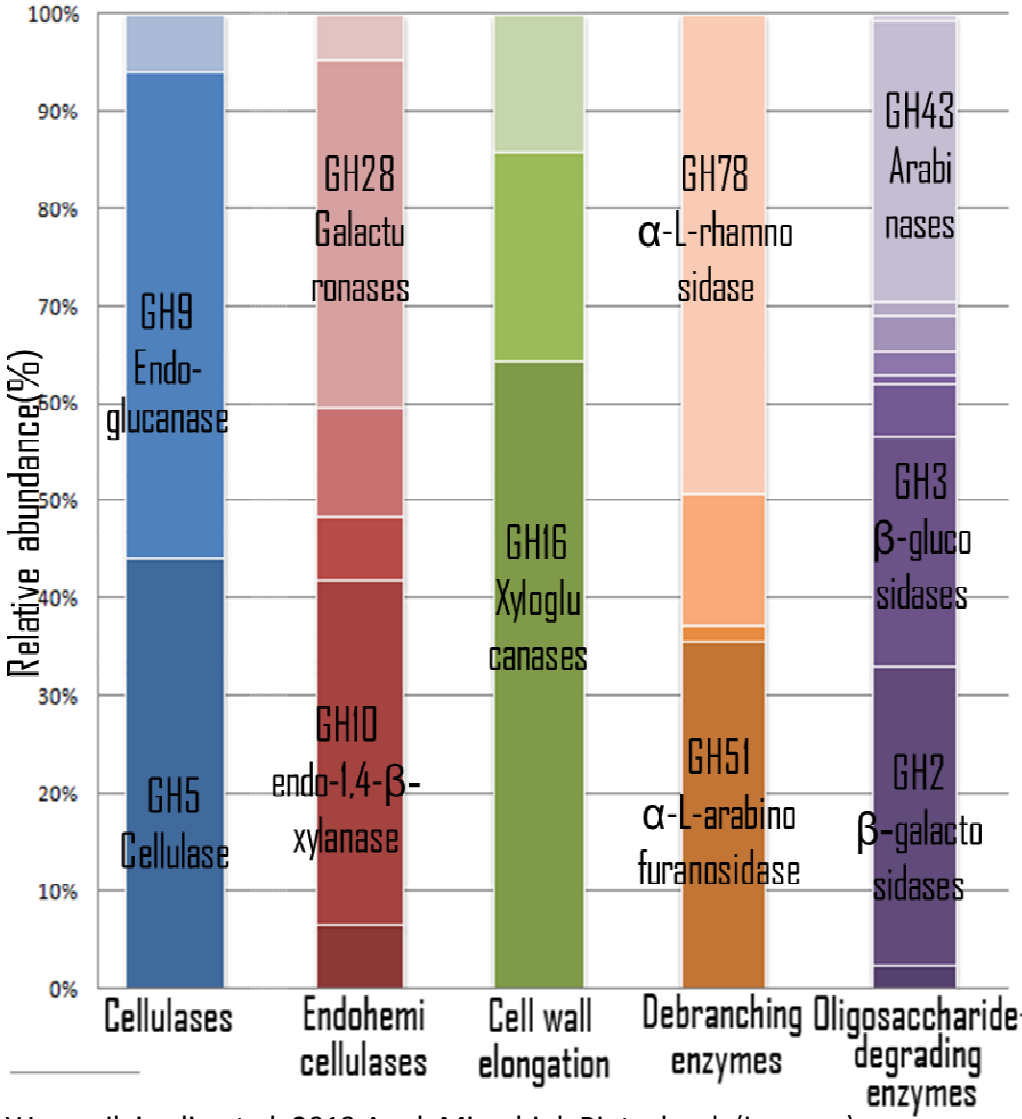


BGC: Bagasse

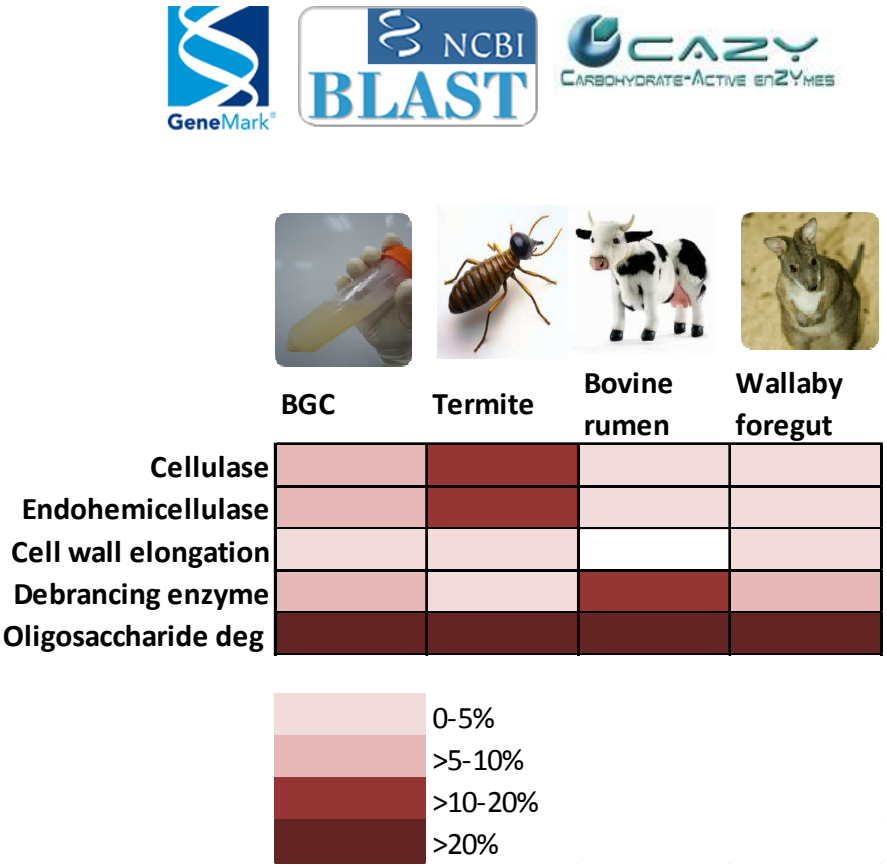
CRC: Cow rumen

ASC: Pulp AS

Identification of lignocellulolytic enzymes from biomass degrading consortium BGC metagenome shotgun pyrosequencing



Wongwilaiwalin et al. 2013 Appl. Microbiol. Biotechnol. (in-press)

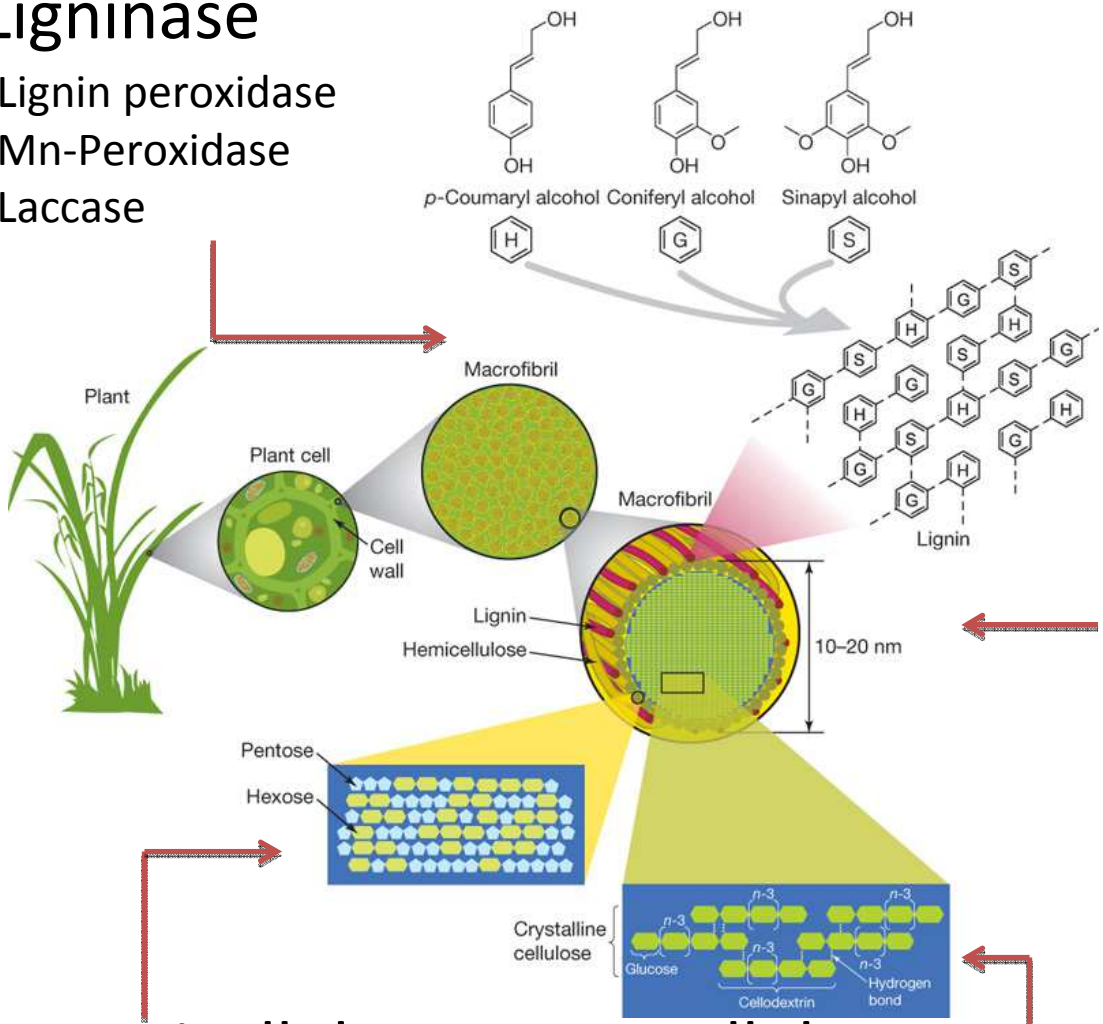


- 957 ORFs were annotated to GH in 69 families
- > 50% were classified into 5 families of the biomass degrading enzyme

Development of biomass-degrading enzyme system

Ligninase

- Lignin peroxidase
- Mn-Peroxidase
- Laccase



BIOTEC Culture Collection

Microbial consortia

Metagenome

Accessory enzymes & proteins

- Esterase
- Expansin

Hemicellulase

- Xylanase
- Mannanase

Cellulase

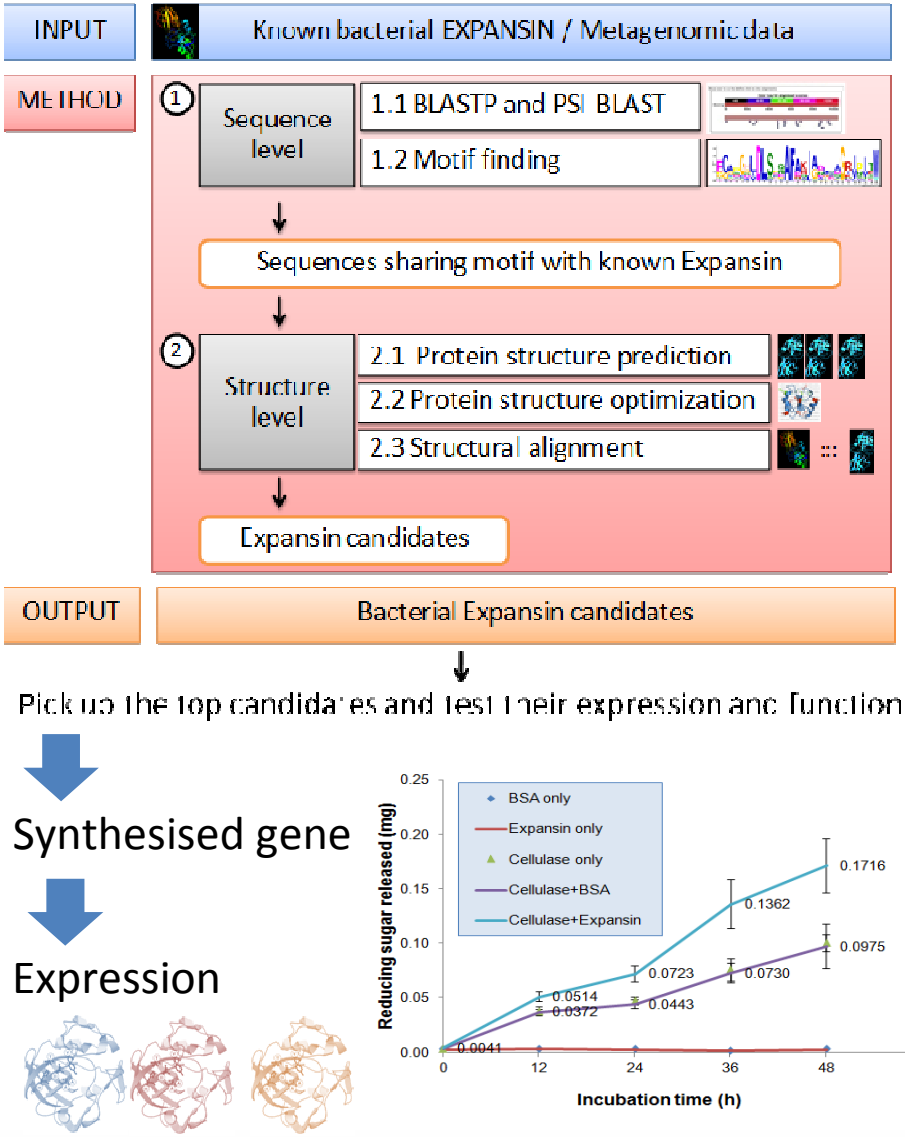
- Endoglucanase
- Exoglucanase
- β-Glucosidase

Biomass-degrading enzyme discovery

Accessory enzyme from BCC

www.biotec.or.th/enzymecatalog

Expansin from bioinformatics

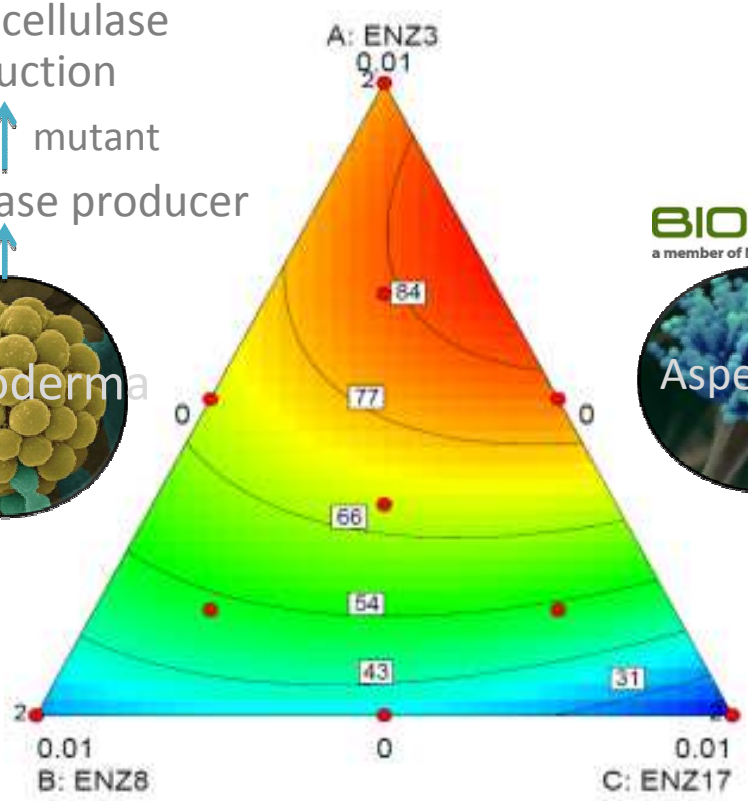


Synergistic lignocellulolytic enzyme system for hydrolysis of local agricultural biomass

On-site cellulase production

mutant

BCC cellulase producer



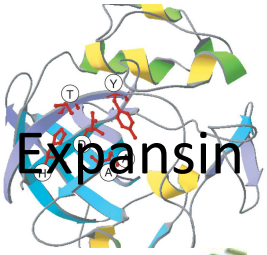
SSF

Accessory enzymes

Efficiency

Specificity

Expansin homologs
HCD fermentation
from metagenome



Suwannarangsee et al. 2012
Bioresour Technol. 119:252-61

Ternary enzyme mixture

Celluclst™:BCC199:Expansin
41.4:37.0:21.6

- Synergy = 1.7
- 965.4 mg R.S./g (2-fold)
- 356.4 mg R.S./FPU (258%)
- 60% reduction of Celluclast™

Rice straw

Bagasse

Corn stover

Aspergillus aculeatus

Enzyme for cassava processing

A multi-enzyme producing fungal strain isolated from soil in Thailand.

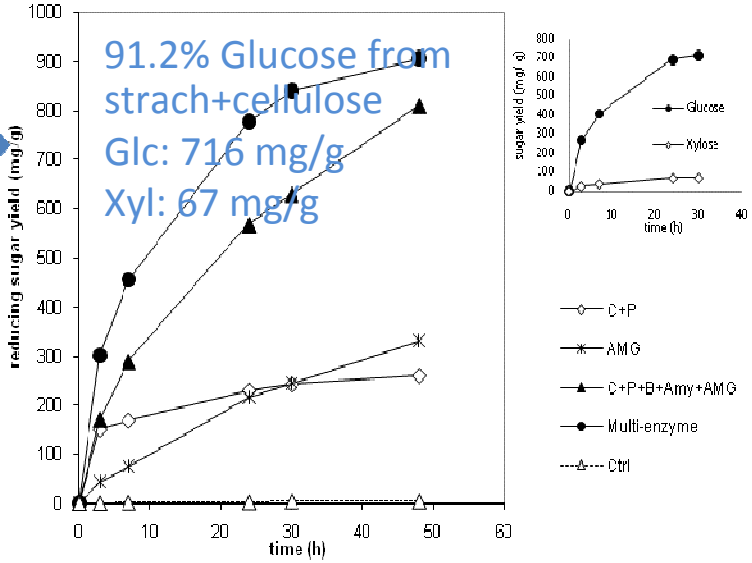
- Multi-activity plant polysaccharide degrading enzymes: RSD amylase, cellulases, hemicellulases and pectinases
- Versatile: high growth rate on various substrates both in SmF and SSF

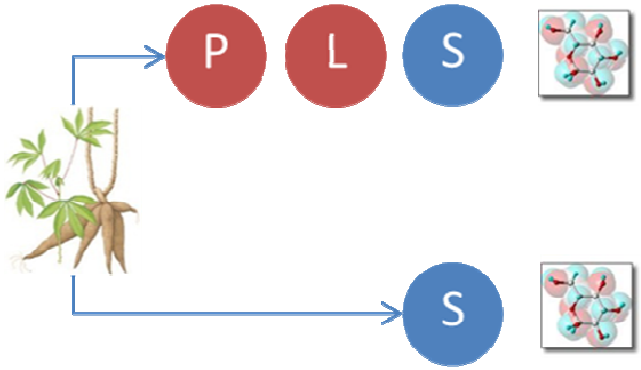
A. aculeatus

DoE (SSF)

Up-scaling production

Pilot-scale production by SSF & downstream processing

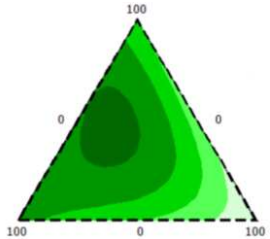




Rattanachomsri et al. (2009)
J Biosci Bioeng 107; 488-493

Viscosity reduction in very high gravity fermentation

BCC-TR38



DoE

Up-scaling SSF

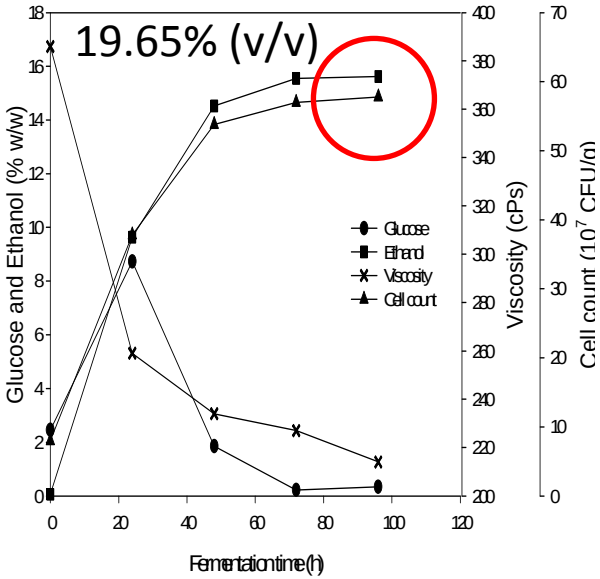
Viscosity reduction in VHG

root

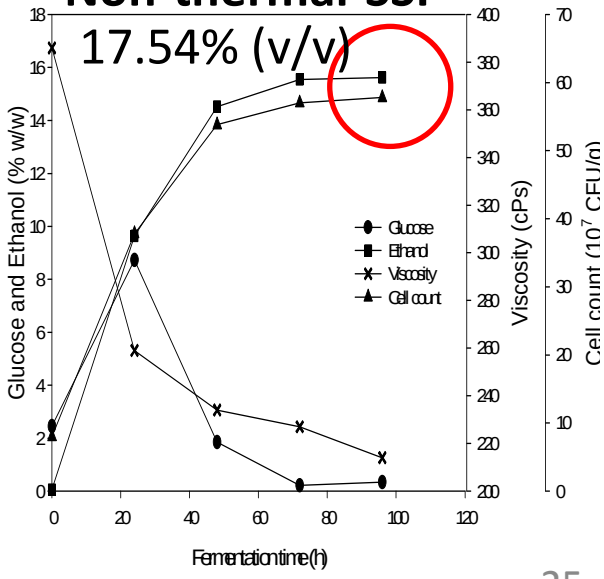
chip

pulp

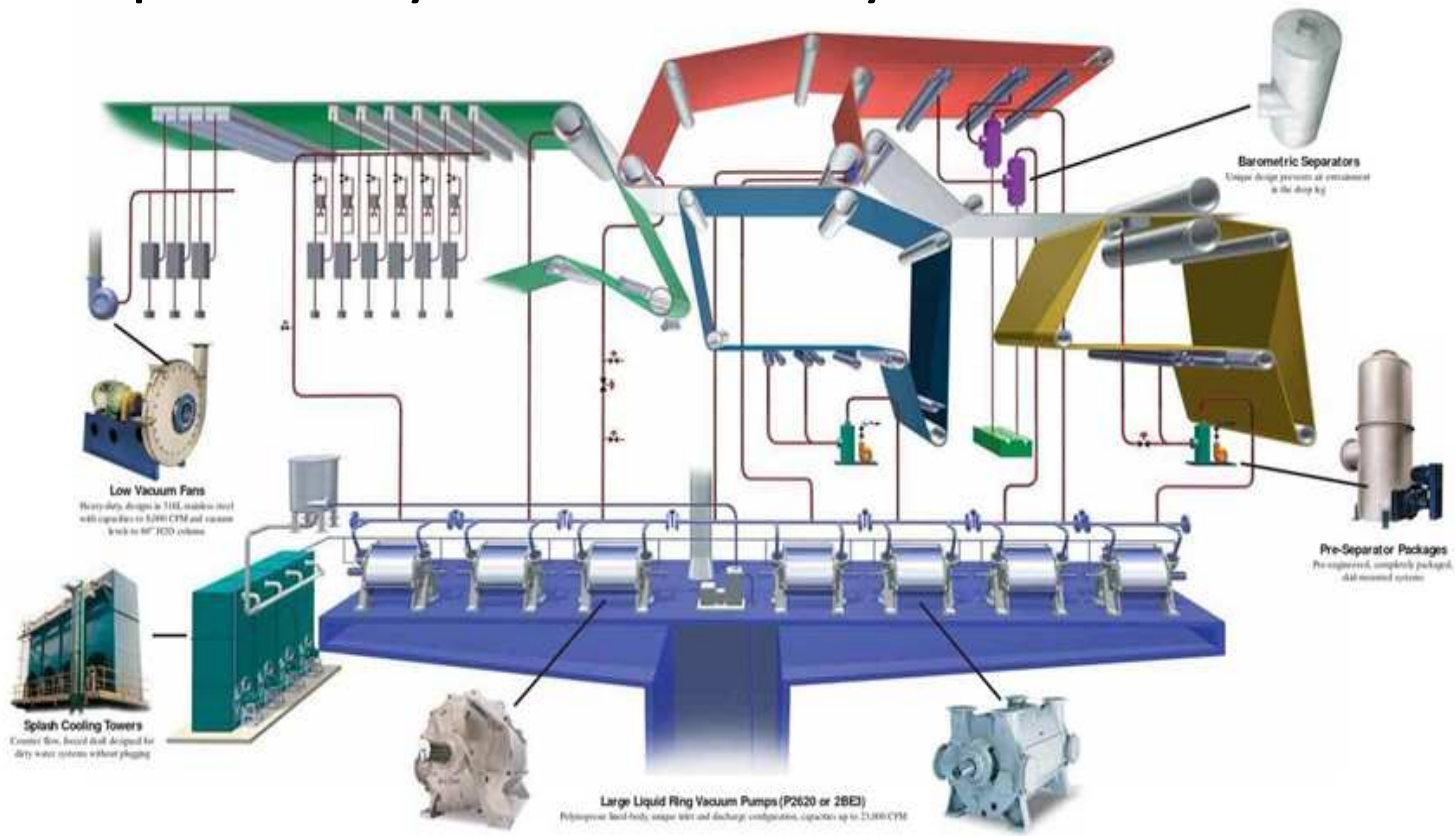
Thermal-SSF



Non-thermal-SSF



Pulp industry for biorefinery



- Pulp
- Commodity chemicals
- Energy

Conclusion & Future prospects

Combined biochemical, molecular metagenomic, and bioinformatic tools have been used for exploration of microbial bioresources for various biotechnological applications with the focus on the prospective biorefinery industry.

Future R&D will be focused on integration of enzyme-based biocatalytic and catalytic processes for conversion of biomass to valorised fuels, chemicals, and materials in greener and more sustainable bio-industries.

Biorefinery for sustainability of nature and society

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Thank you..

http://www.desktopedia.com/wallpaper/Green-Hill-with-Blue-Sky-Landscape/