1st International Bioenergy and Biorefinery Forum

Monday 13 March 2017

UNIVERSITY OF SURREY

and

IBEST Advancing cross-disciplinary knowledge and education in Biorefinery Engineering

Presents

Ultimate Waste Valorisation

by

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UNIVERSITY OF BATH

Ultimate MSW valorisation

Chemicals

Biofuels and bioenergy

Recovered materials

Baled newsprint from MRF

Garden waste

Food waste

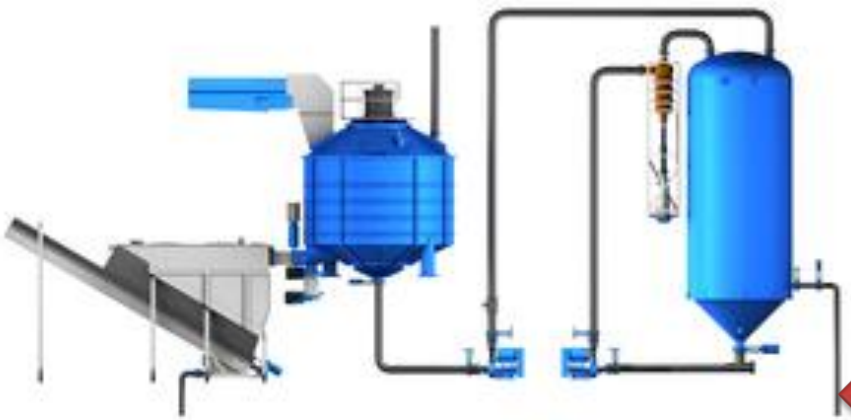
You may need discolouring and detoxification

Mixing and size reduction

Feedstock ready for chemical valorisation

Pulping: e.g. Supercritical water extraction at 420ºC and 230 bar

Feedstock ready for chemical valorisation



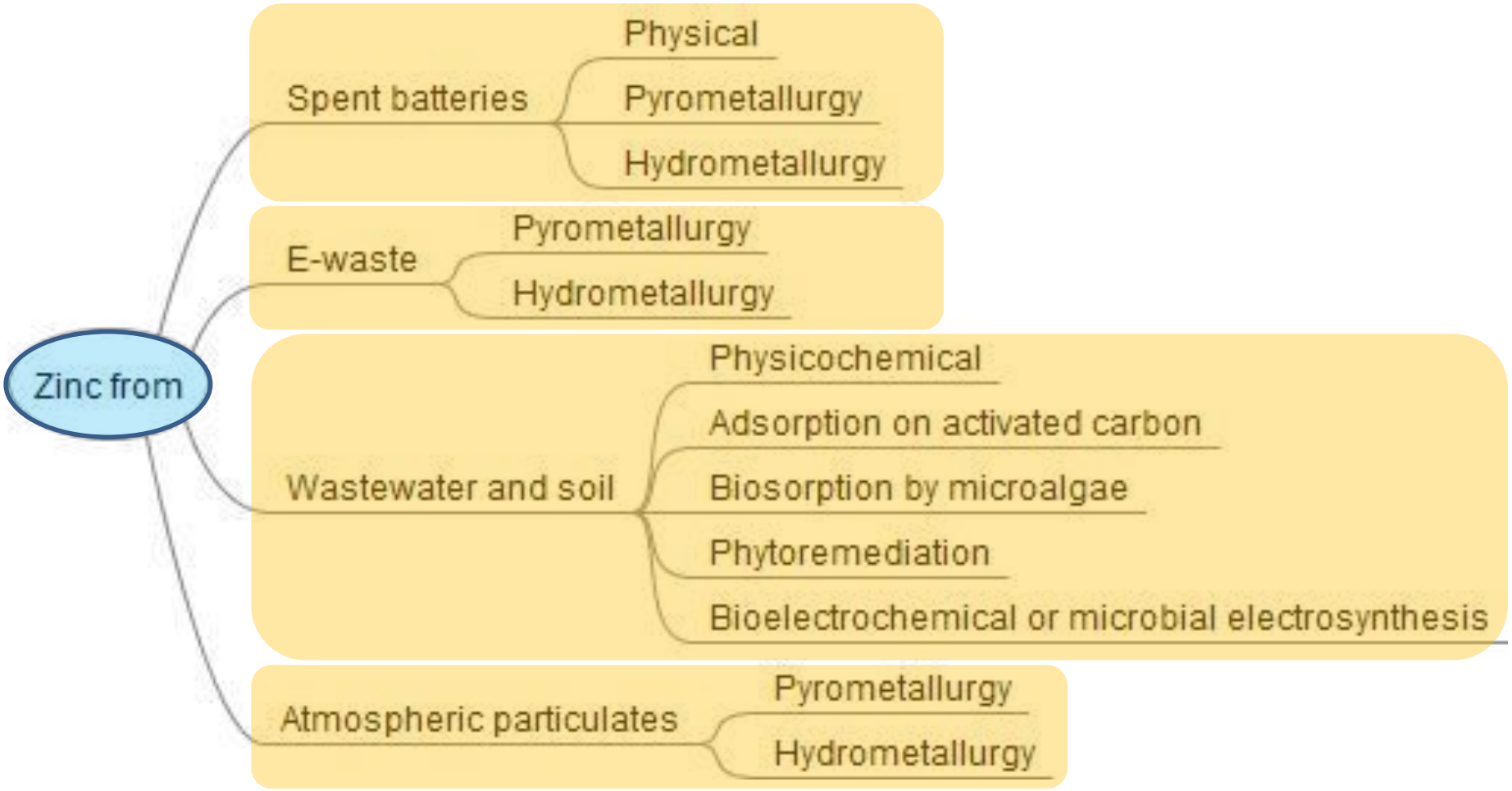
Fermentable organics

Fibre

Solids, e.g. heavy metals in water

Photo courtesy: http://www.bta-international.de/en/der-bta-prozess/der-bta-prozess0.html

Technologies for heavy metal recovery from wastewaters: Remember **heavy metals are important resources too!**



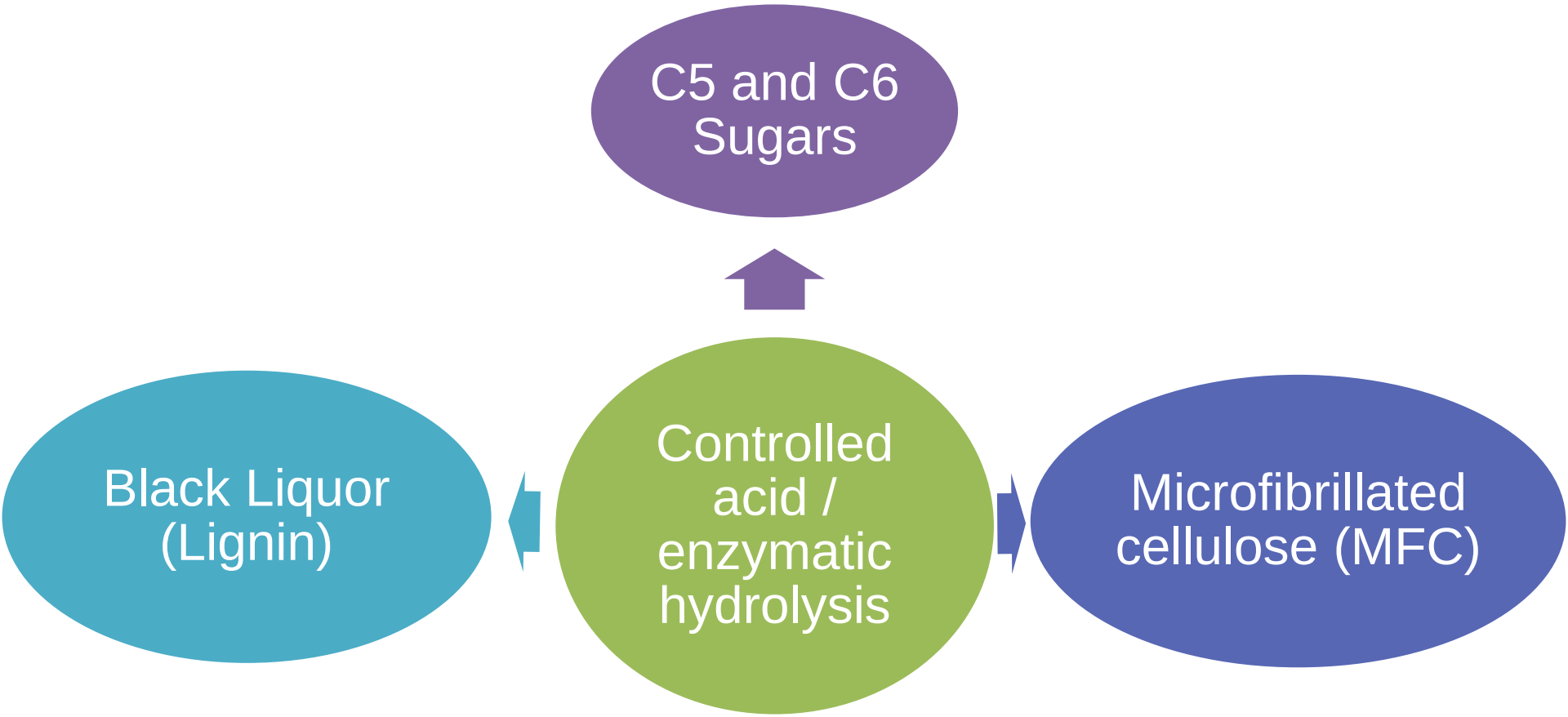
Find out technologies for high purity heavy metal recoveries

Please look out for a poster from Mobolaji Shemfe

Fibre to products

Fibre

Organic platform

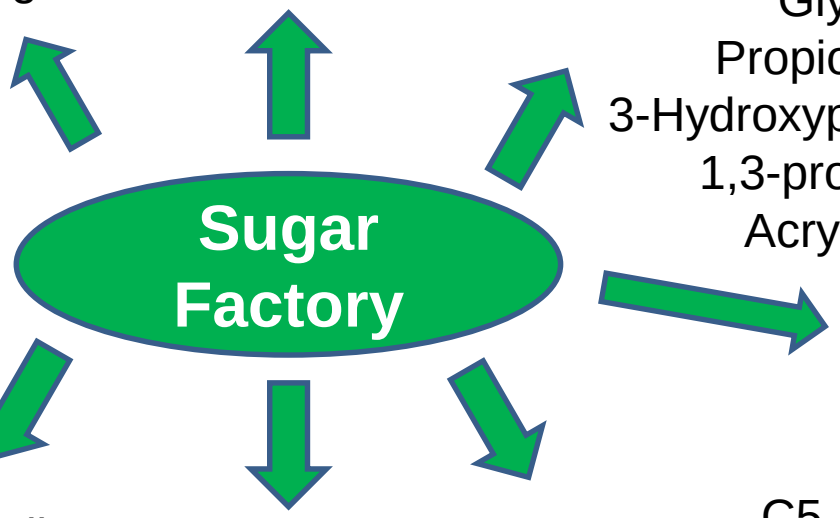


Microfibrillated cellulose (MFC): Application in cosmetics (after conditioning)

- ✓ Properties wanted in cosmetic products: good skin feel, desired rheological properties and improved stability of formulations.
- ✓ MFC is made of cellulose sources, a natural raw material which is an increasing trend in cosmetics.
- ✓ can be prepared by different processes

Source: http://blog.exilva.com/author/rebecca-blell

Sugars to products



C1
Syngas
Biogas

C2
Ethanol

C3
Acetic acid
Lactic acid
Glycerol
Propionic acid
3-Hydroxypropionic acid
1,3-propanediol
Acrylic acid

C4
3-Hydroxybutryolactone
Malic acid
Theonine
Succinic acid
Aspartic acid
Fumaric acid

C5
Arabinoxylan
Furfural
Levulinic acid
5-Hydroxymethylfurfural
Xylitol
Xylonic acid

C6
Glucaric
Gluconic acid
Butanol
1,4-butanediol
Sorbitol
Adipic acid
Citric acid
Caproate

>C6
Caprylate
Polyhydroxyalkanoates
(PHA)

Lignin to products
(apart from its usual heat and power generation application)

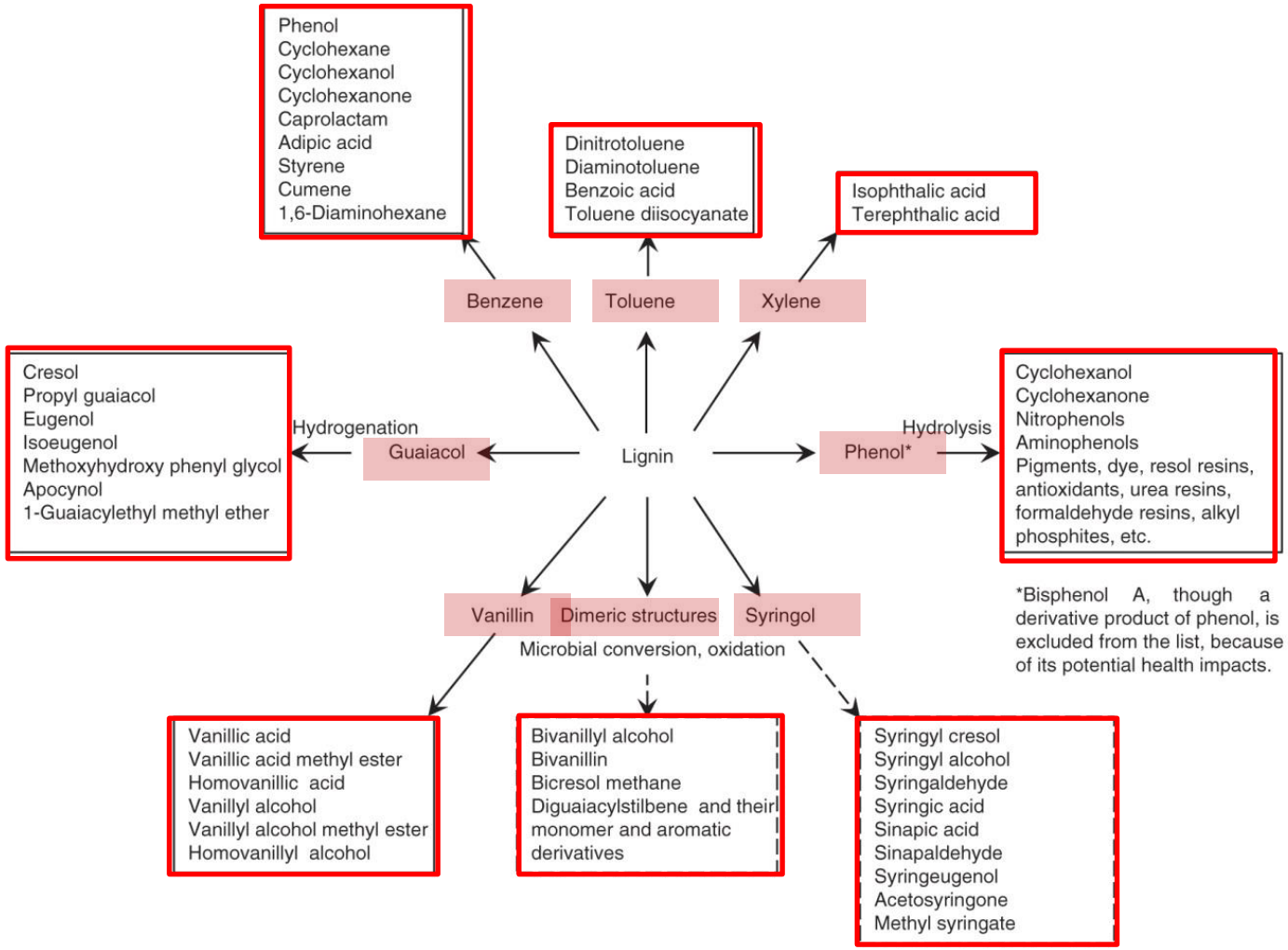
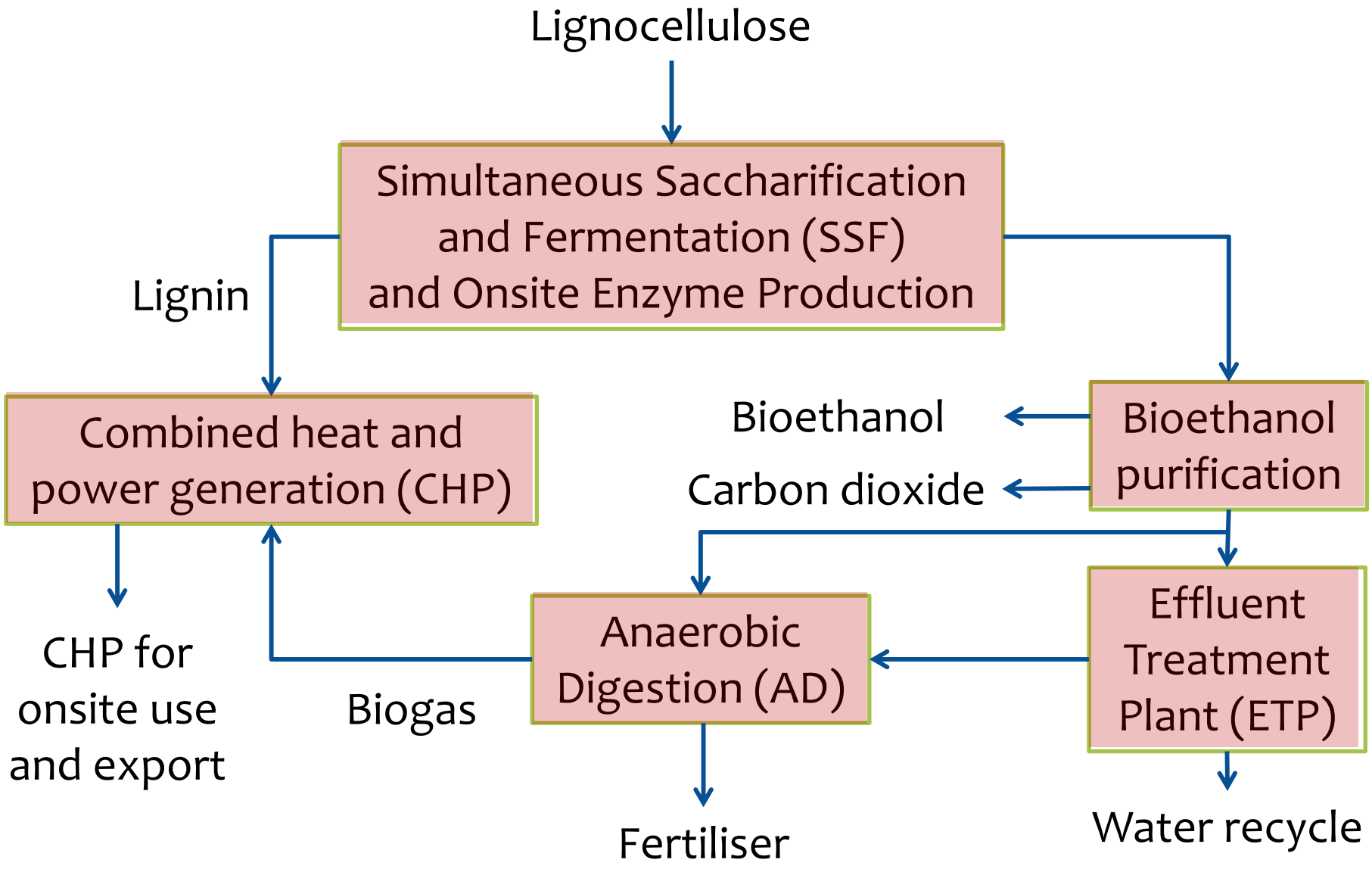


Figure 1.8 *Chemicals from lignin. The chemistries and markets are yet to be fully known for the blocks and arrows shown in dotted lines.*

Biorefineries and Chemical Processes: Design, Integration and Sustainability Analysis, First Edition.
Jhuma Sadhukhan, Kok Siew Ng and Elias Martinez Hernandez.

Companion Website: http://www.wiley.com/go/sadhukhan/biorefineries

Common approach: **Bioethanol from sugar fermentation** or from fermentable organics



Innovation opportunity: Priority or **‘sleeping giant’** chemicals from sugars

- Levulinic acid
- 5-hydroxymethylfurfural (5-HMF)
- Furan-2,5-dicarboxylic acid (FDCA)
- Succinic acid
- Lactic acid

Enormous application potentials

Cosmetic industry

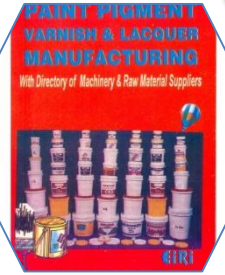
Pharma-ceuticals

Specialty chemicals

Food industry

Agro-chemicals

Fuels



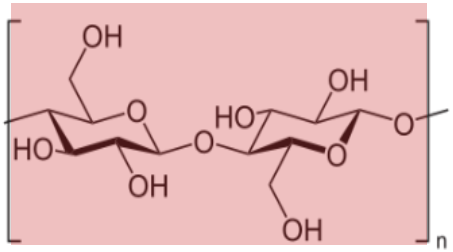
Pigments

Plastics

Please be prepared to see fundamental mechanistic steps

Levulinic acid and HMF

By controlled acid hydrolysis process



Cellulose
(***C***)

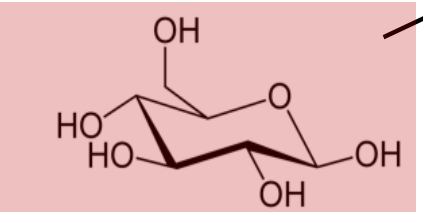
r_d

Decomposition products

r_0

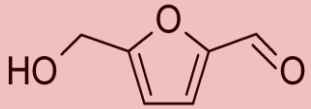
r_2

Humins



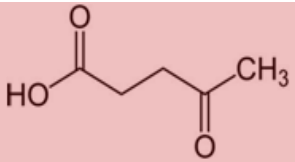
Glucose
$C_6H_{12}O_6$
(***G***)

H^+
$-3H_2O$
r_1



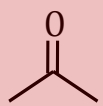
5-HMF
$C_6H_6O_3$
(***HMF***)

H^+
$+2H_2O$
r_3



Levulinic acid
$C_5H_8O_3$
(***L***)

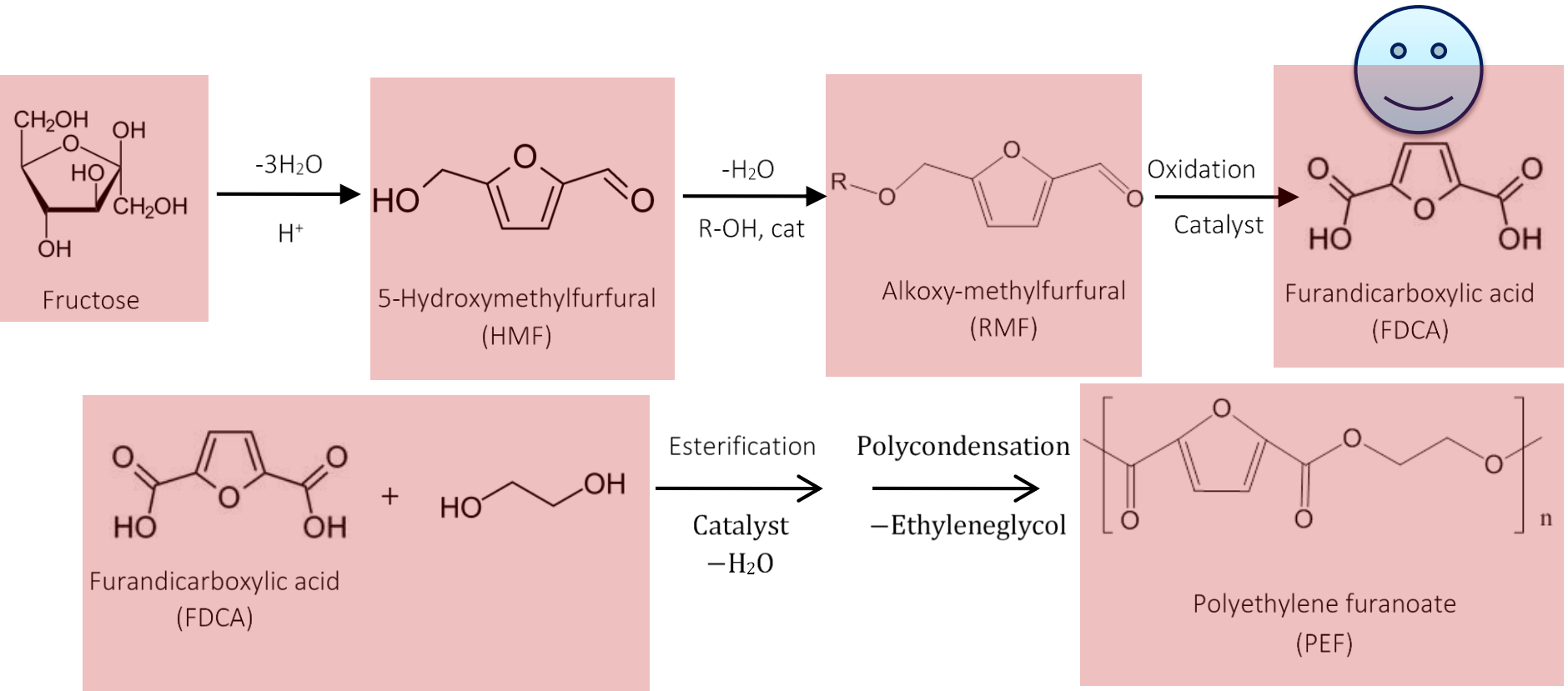
+



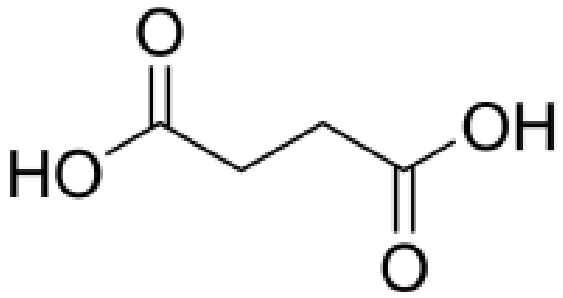
Formic acid
CH_2O_2
(***F***)

FDCA

By catalytic or biochemical conversion process



Succinic acid



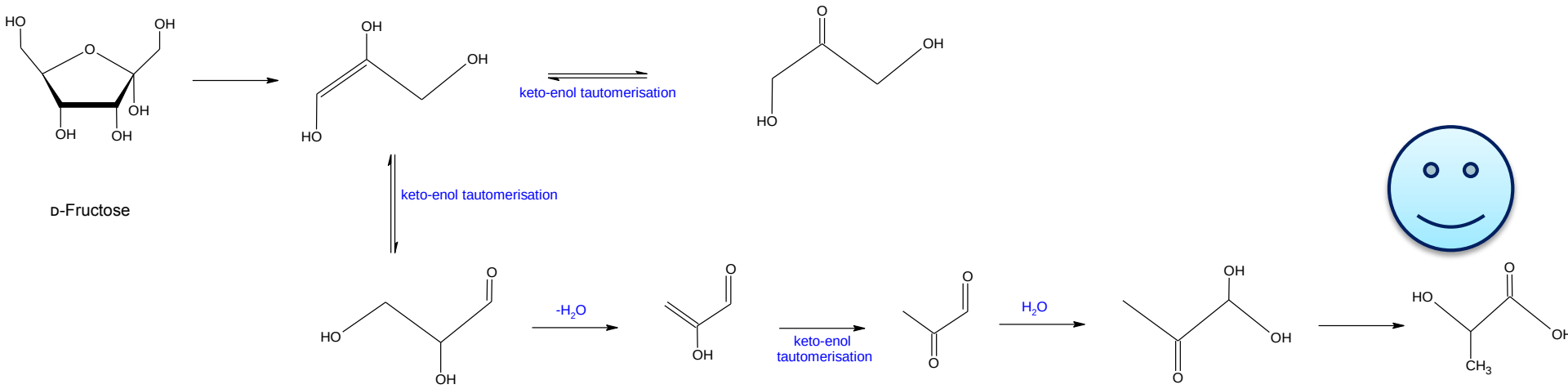
Too many mechanistic steps… will take a whole day to show the details

Ref: “Alternative Building Block Chemicals from Biomass - A Holistic Critical Review for their Sustainable Production” working draft

Lactic acid

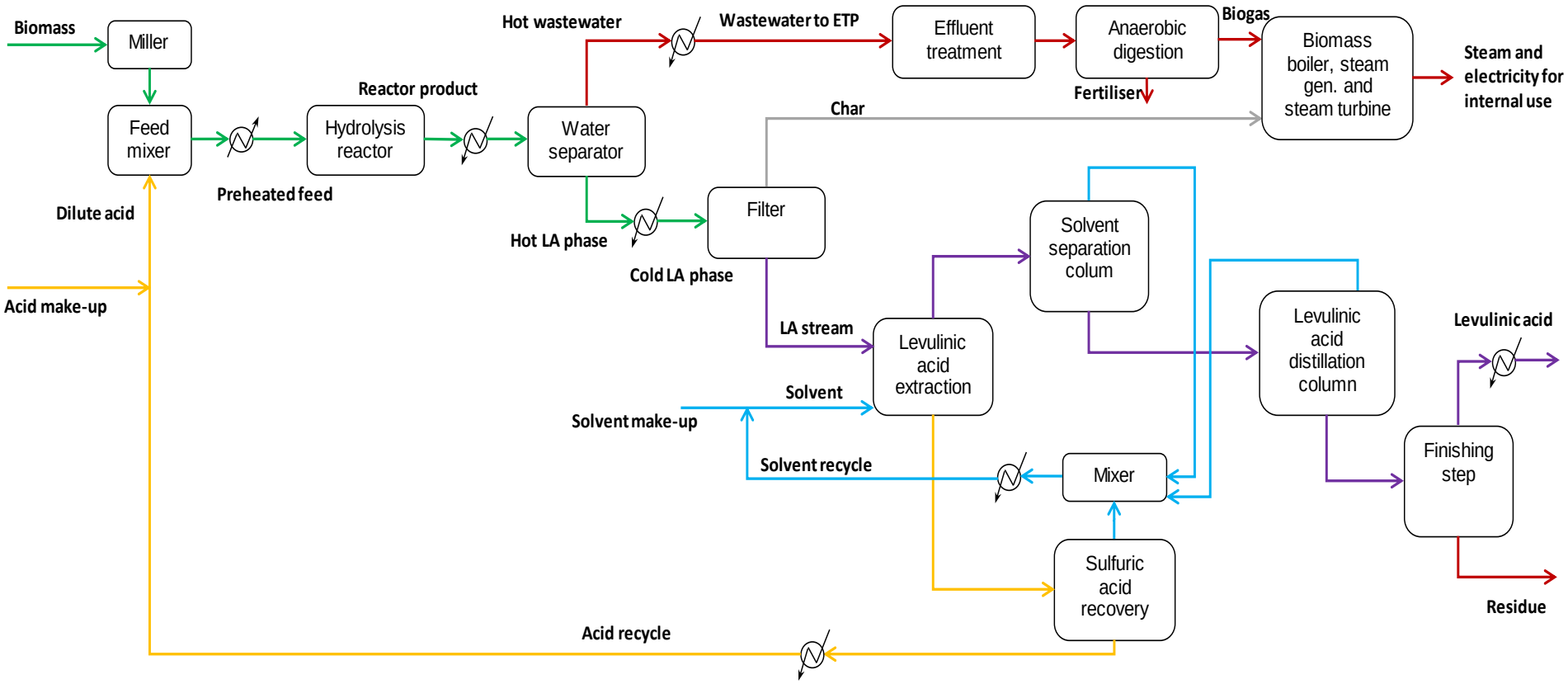
By fermentation

Fructose to Lactic acid

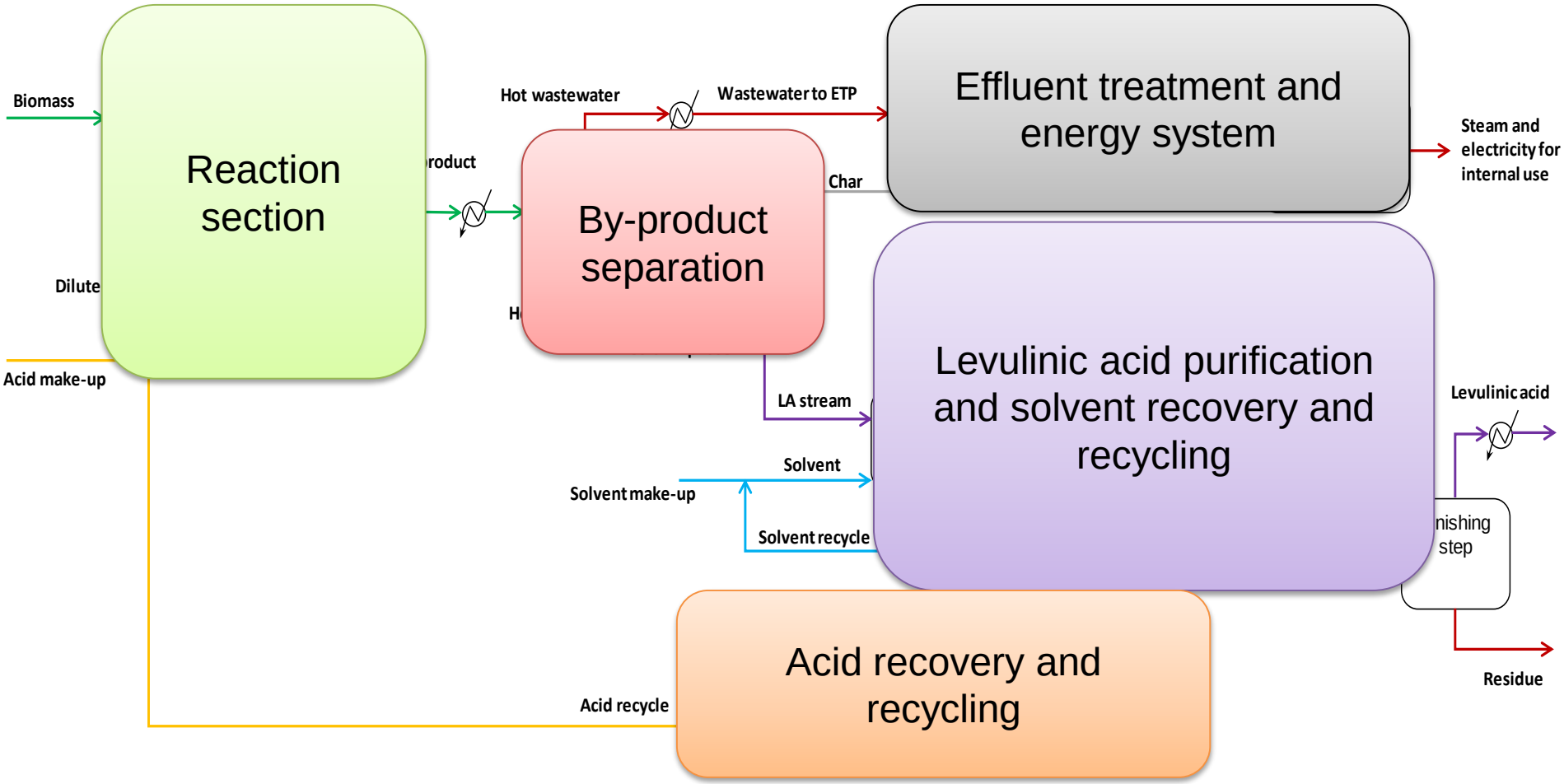


Mechanistic diagram courtesy: Kok Siew Ng

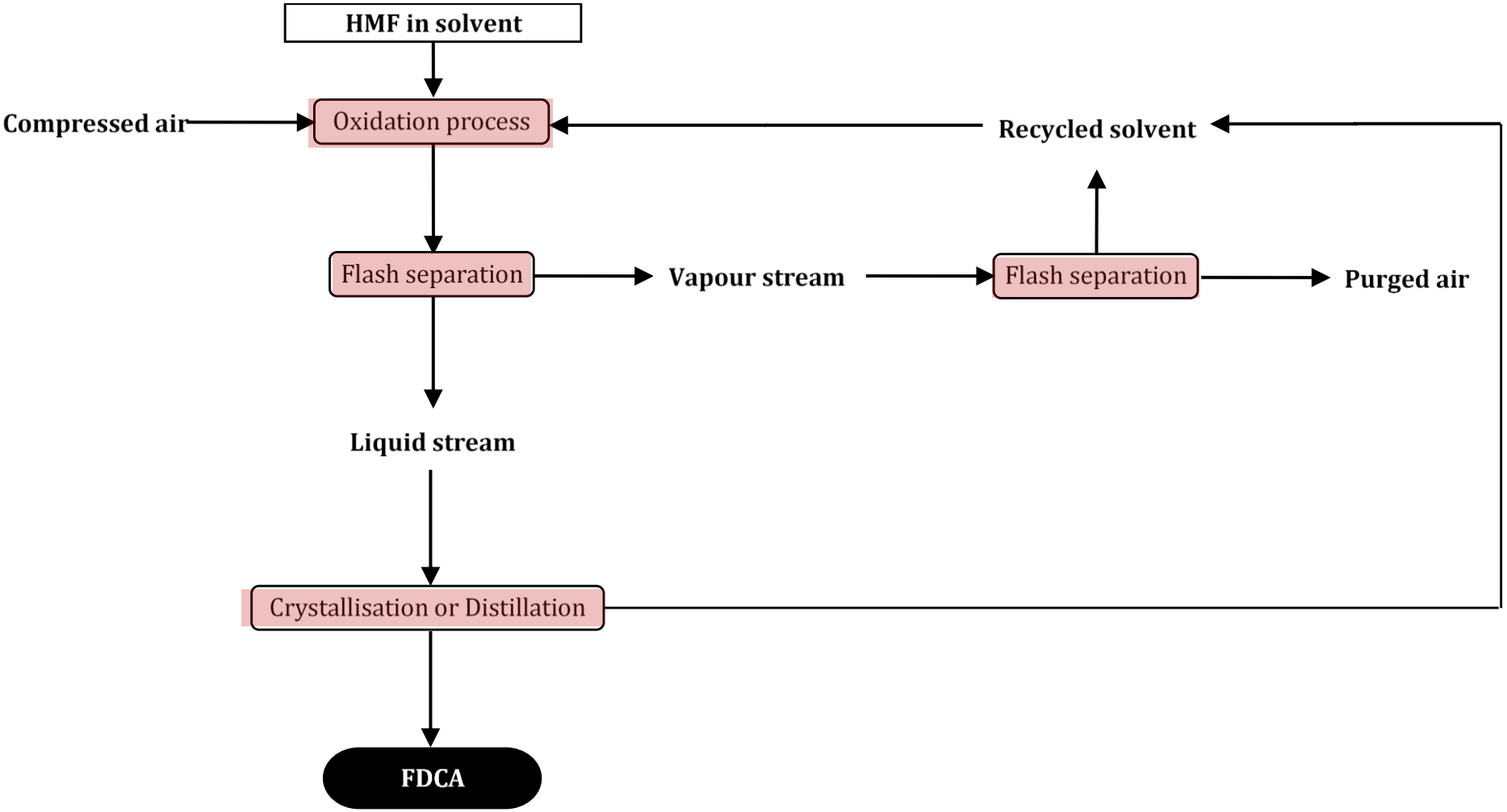
Process of making Levulinic acid and HMF



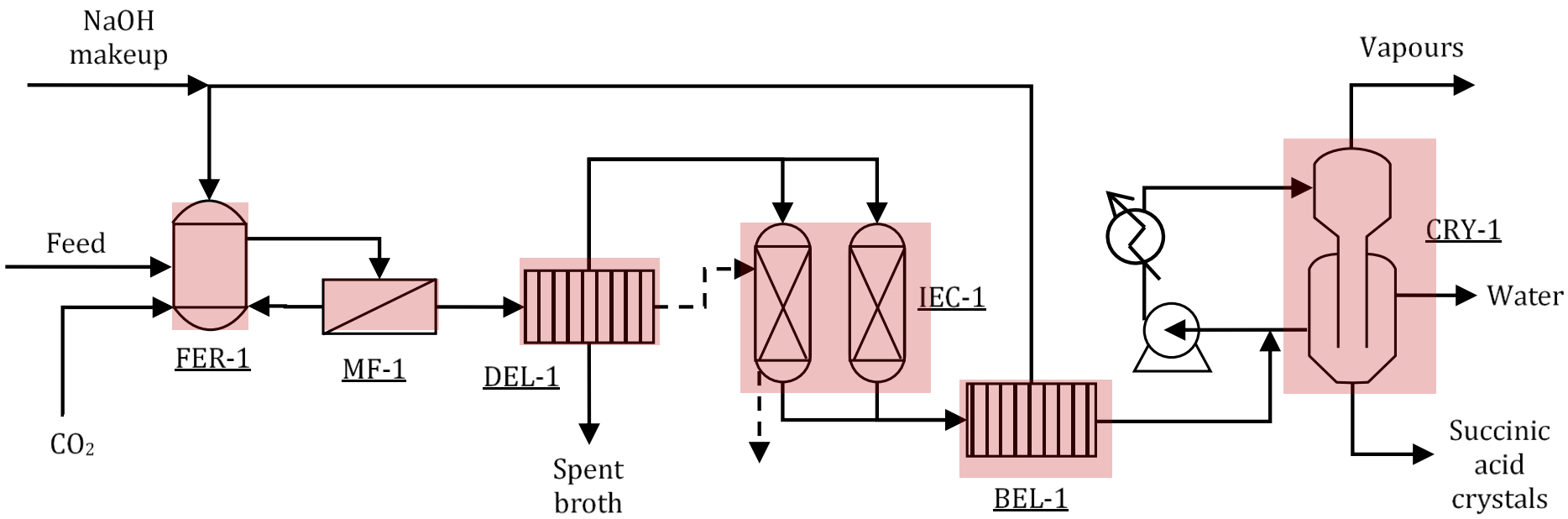
Process of making Levulinic acid and HMF



Process of making FDCA

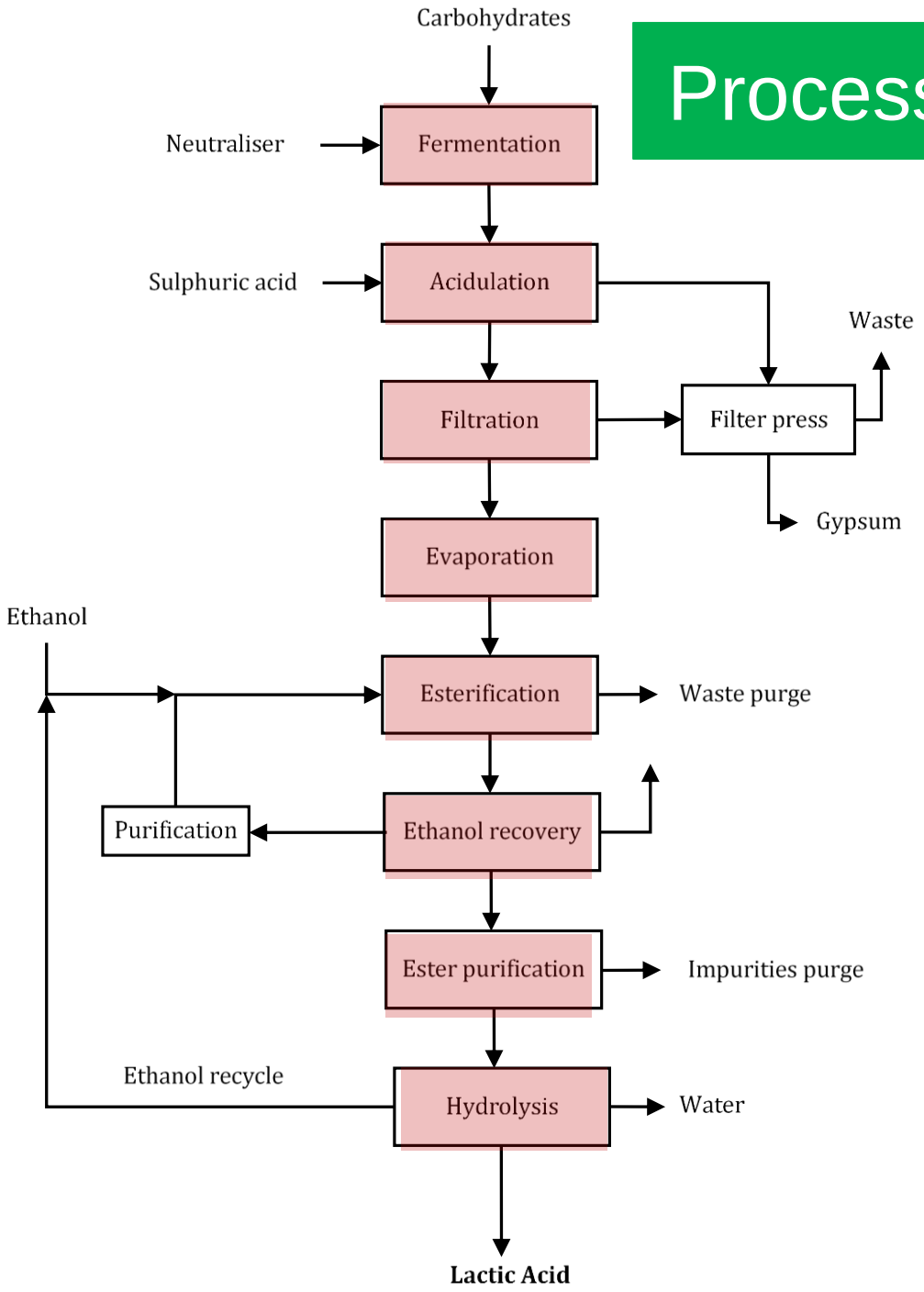


Process of making Succinic acid

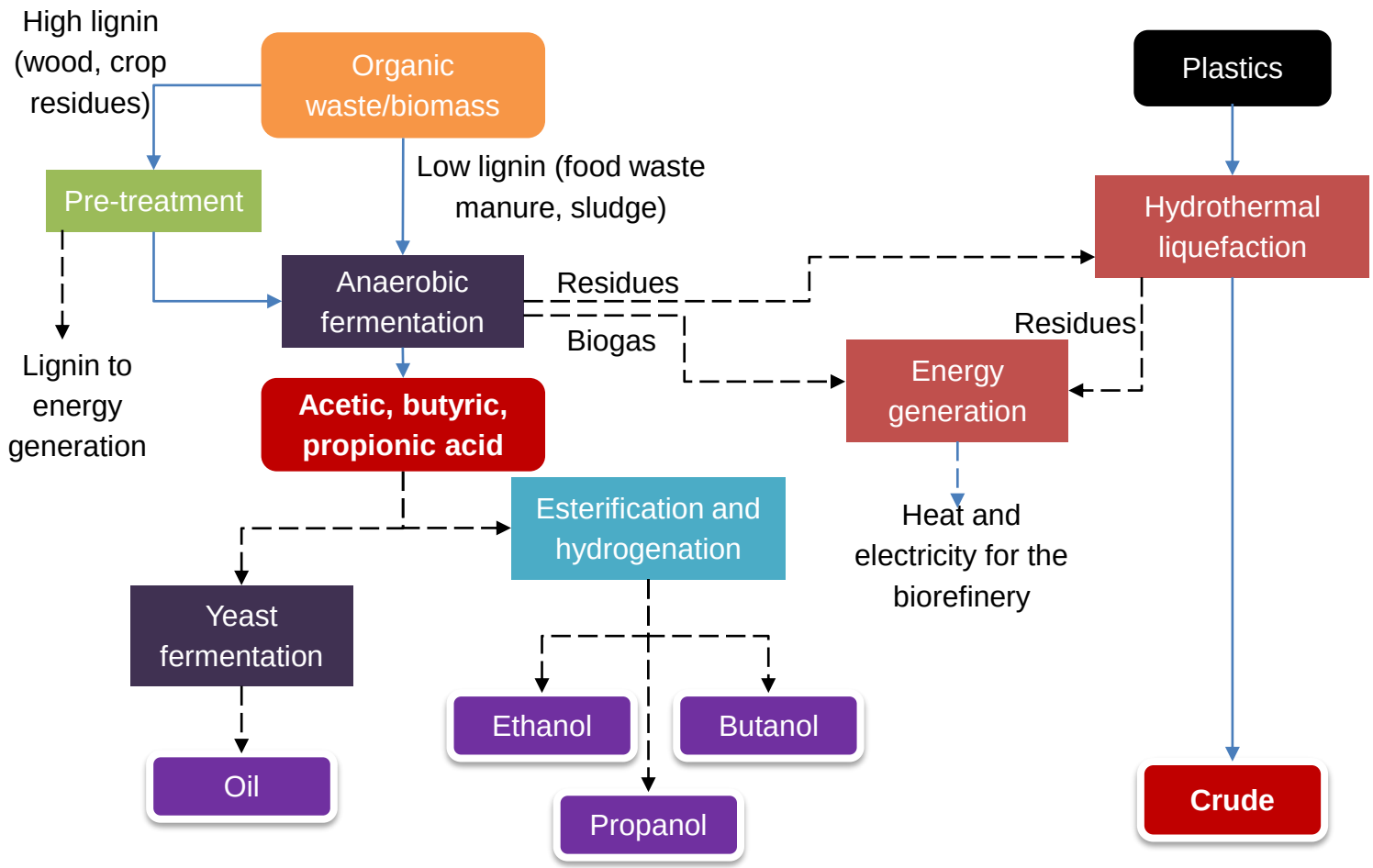


FER: fermenter, MF: microfiltration, DEL: desalting electrodialysis, BEL: bipolar electrodialysis, IEC: ion exchange columns, CRY: crystalliser

Process of making Lactic acid



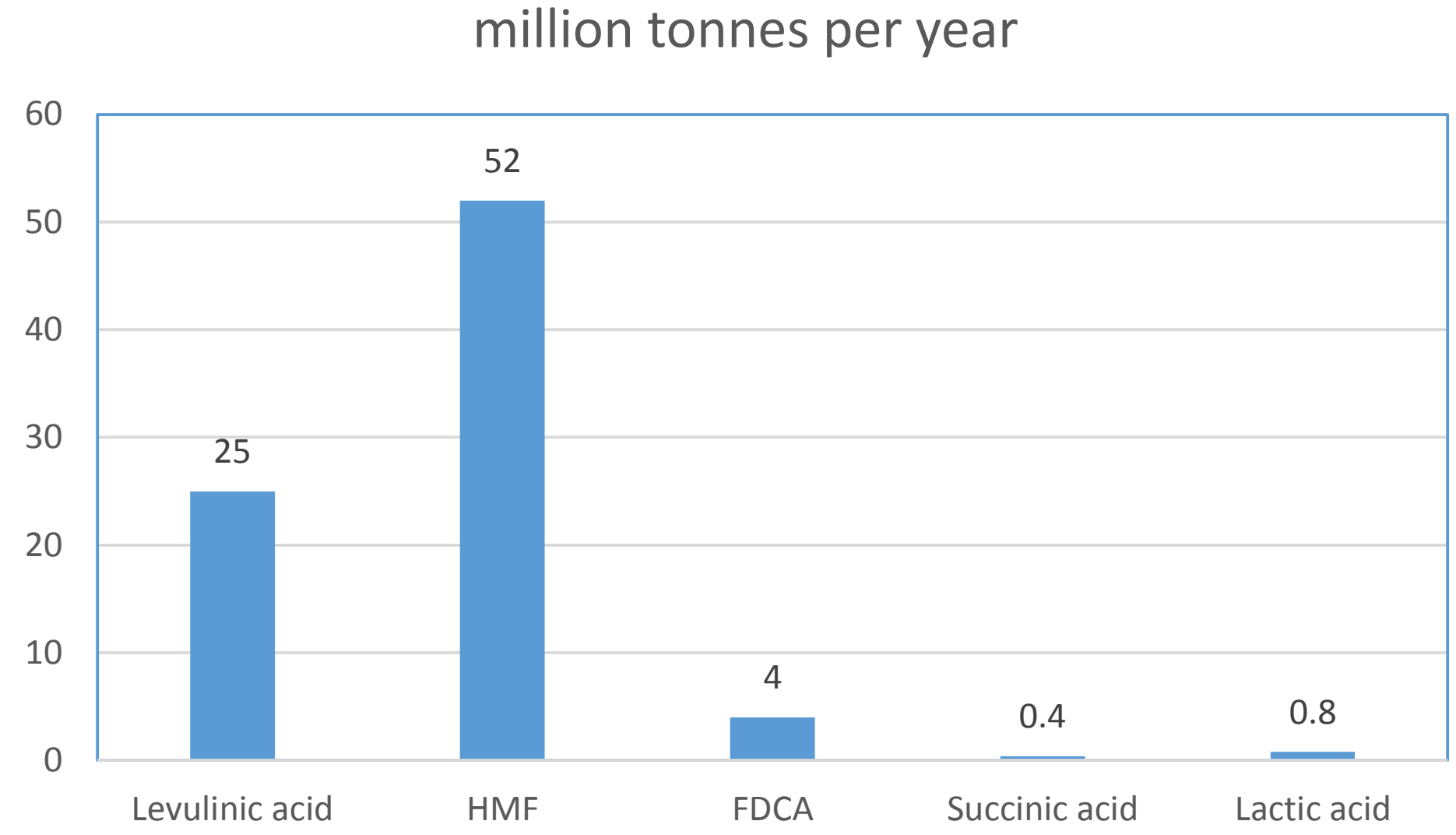
Innovation opportunity: Integrated valorisation into chemicals and fuel



Organic waste as a sustainable feedstock for platform chemicals

Coma, M., Martinez-Hernandez, E., Abeln, F., Raikova, S., Donnelly, J., Arnot, T., Allen, M., Hong, D. & Chuck, C. In : Faraday Discussions. © RSC 2017

Production capacities of priority or **'sleeping giant'** chemicals



How do these production capacities compare with those of petrochemicals?

Petrochemicals consumption:

450 million tonnes by 2018,

w/o accounting for ethylene, which is made from ethanol

Source: http://www.processingmagazine.com/global-petrochemical-market-to-grow-by-6-7-through-2018/

Drivers for industries in targeting chemical products

Economic benefits…
Let's look at some ballpark figures
Price of chemicals: 5-8 $/kg
Price of bioethanol: 0.3-0.5 $/kg

Yield of bioethanol on dry basis of organic feedstocks: ~55%
Yield of chemical on dry basis of organic feedstocks: ~20%

Environmental incentives by replacing petrochemical products

But, capital investment for a chemical factory is three times greater than that for a bioethanol factory

What are the other benefits of resource recovery from wastes?

Avoid municipal solid wastes going to landfills.

Prevent impacts of MSW on human health.

Resource conservation, some materials are rapidly depleting.

Recovering these materials from secondary resources such as wastes is essential to fulfil societal needs.

MSW valorisation gives rise to products that otherwise would be sourced from primary fossil resources.

Key learning points

Waste is an important secondary resource.

Consider material recovery facilities (MRF) for recovery of recyclable products.

Pulping of paper, garden and food wastes gives an organic rich, a fibre and a solid streams.

Acid or enzymatic hydrolysis of organics gives sugars, microfibrillated celluloses and lignin.

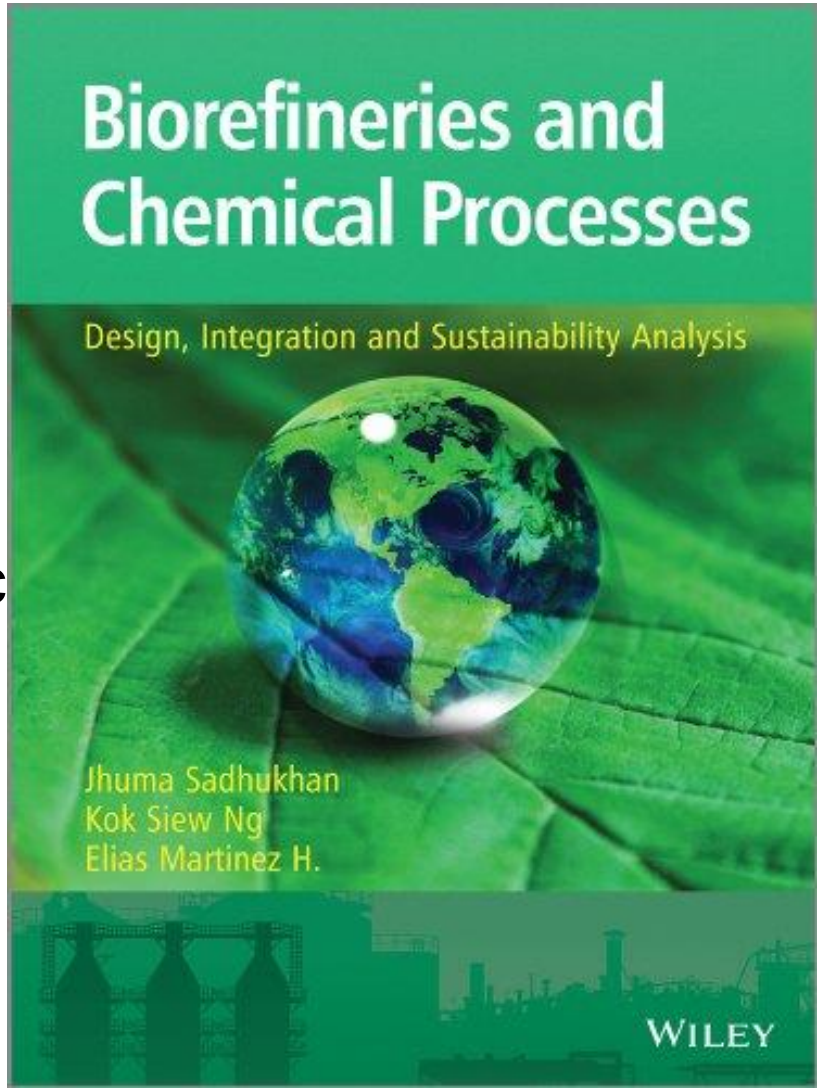
A strong prospect of process innovations around new chemical synthesis from sugars derived from waste.

Would bio-based circular economy require as long as fossil based economy, which took about 100 years, to establish?

Individual process technologies exist at industrial scales.

But "**Process Integration**" like **solving a jigsaw puzzle** for coupling the various processes to reduce cost and attain an economy of scale and overall sustainability needs systematic learning!

Wiley launched an **advanced intensive textbook** to fill this gap, for the purpose of education and R&D of the subject.



Make a choice today!

Thanks

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