Introduction to Biorefining

With the support of the Seventh Framework Programme.

Daniel Hayes

DIBANET Networking Day

13/12/10

Current Biomass Uses

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- Combustion (e.g. wood chip boilers, incineration)
- Liquid Biofuels (1st Generation)

Ethanol	Biodiesel
Sugar beet	Rapeseed
Wheat	Soybean
Corn	Sunflower
Sugarcane	

- First generation biofuels come from food or oil crops.

Foods Are Ideal Chemically

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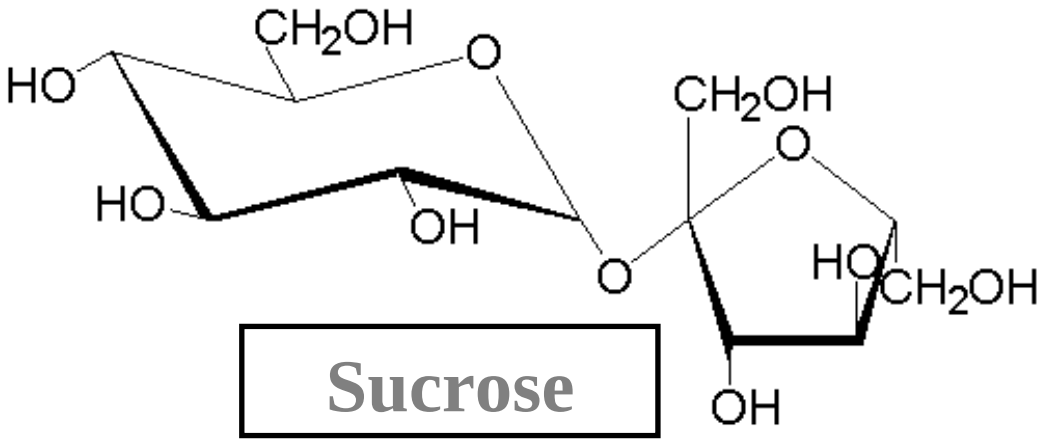
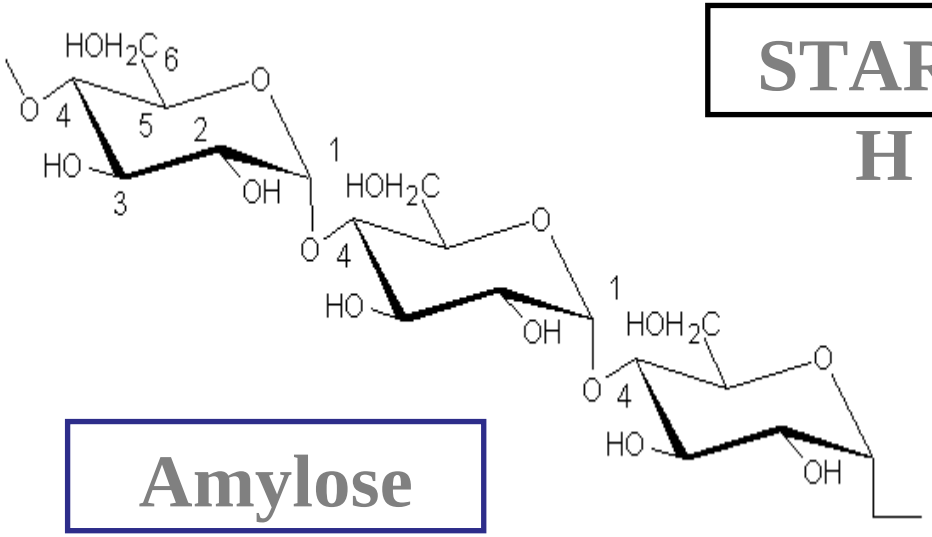
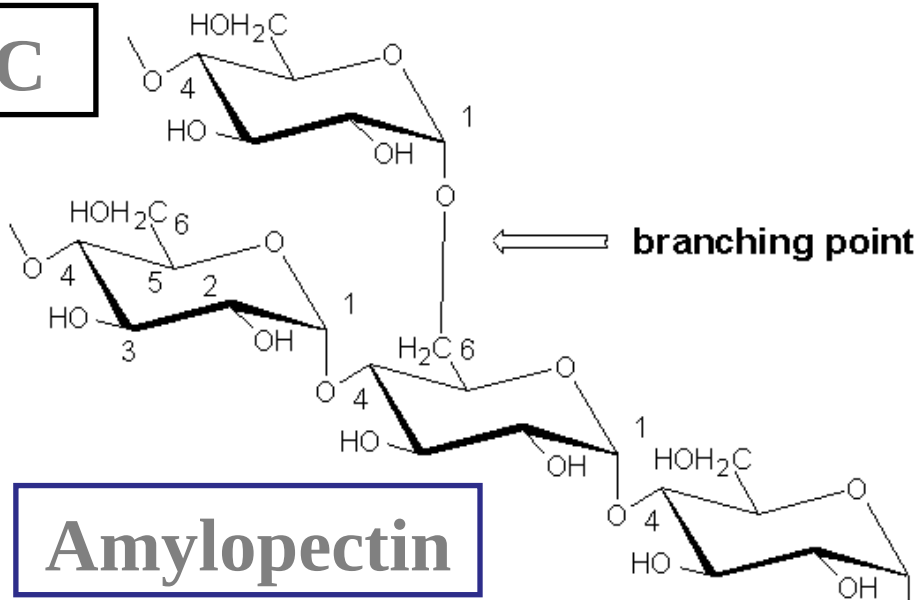


Sucrose

STARCH



Amylose



Amylopectin

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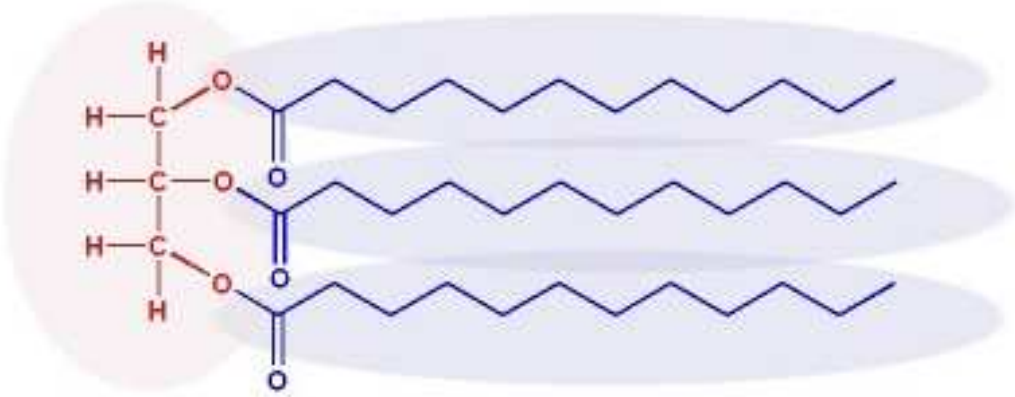
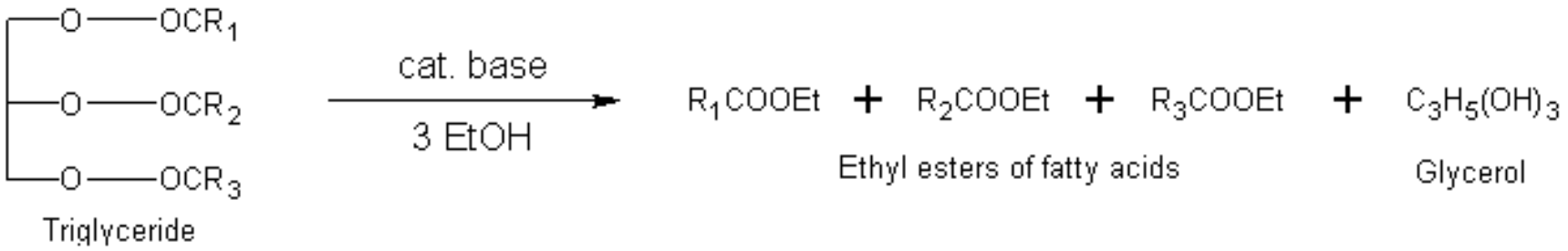
Fats/Oils are Also Easy!

Glycerol

A "free" Fatty Acid

Triglyceride





Problems with 1st Gen Feedstocks

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- High establishment, maintenance costs (esp. EU).
- Poor energy ratios.
- High CO_2 emissions.
- Food versus fuel.
- Most of crop is not utilised.
- Sugarcane ethanol is the exception but there only a portion of the crop is used.

Use Different Feedstocks!

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- Lower cost:
  - waste/residues
  - Sustainable energy crops, marginal land.
- Biomass where most of crop can be utilised.
- Such biomass tends to be lignocellulosic (cellulose, hemicellulose, lignin).
- Typical grasses/woods

  45% cellulose, 25% hemicellulose, 25% lignin

Biorefineries

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- Analogous to oil refineries.
- Obtain different saleable products from the different chemical constituents of biomass.
- A range of potential products are possible ranging from low volume and high value (specialty chemicals) to high volume and lower value (biofuels)

Cellulose

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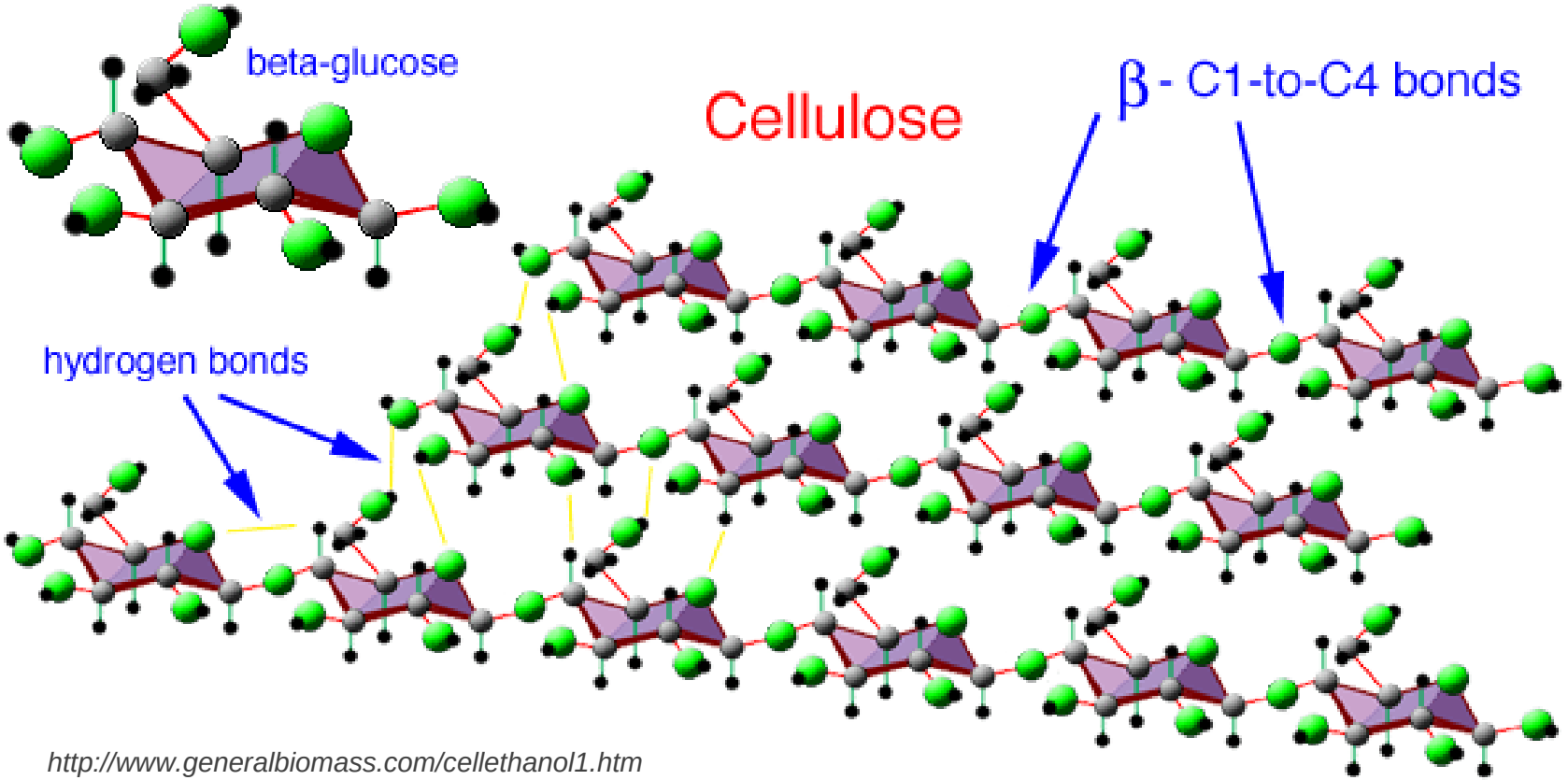

http://www.generalbiomass.com/cellethanol1.htm

Hemicellulose

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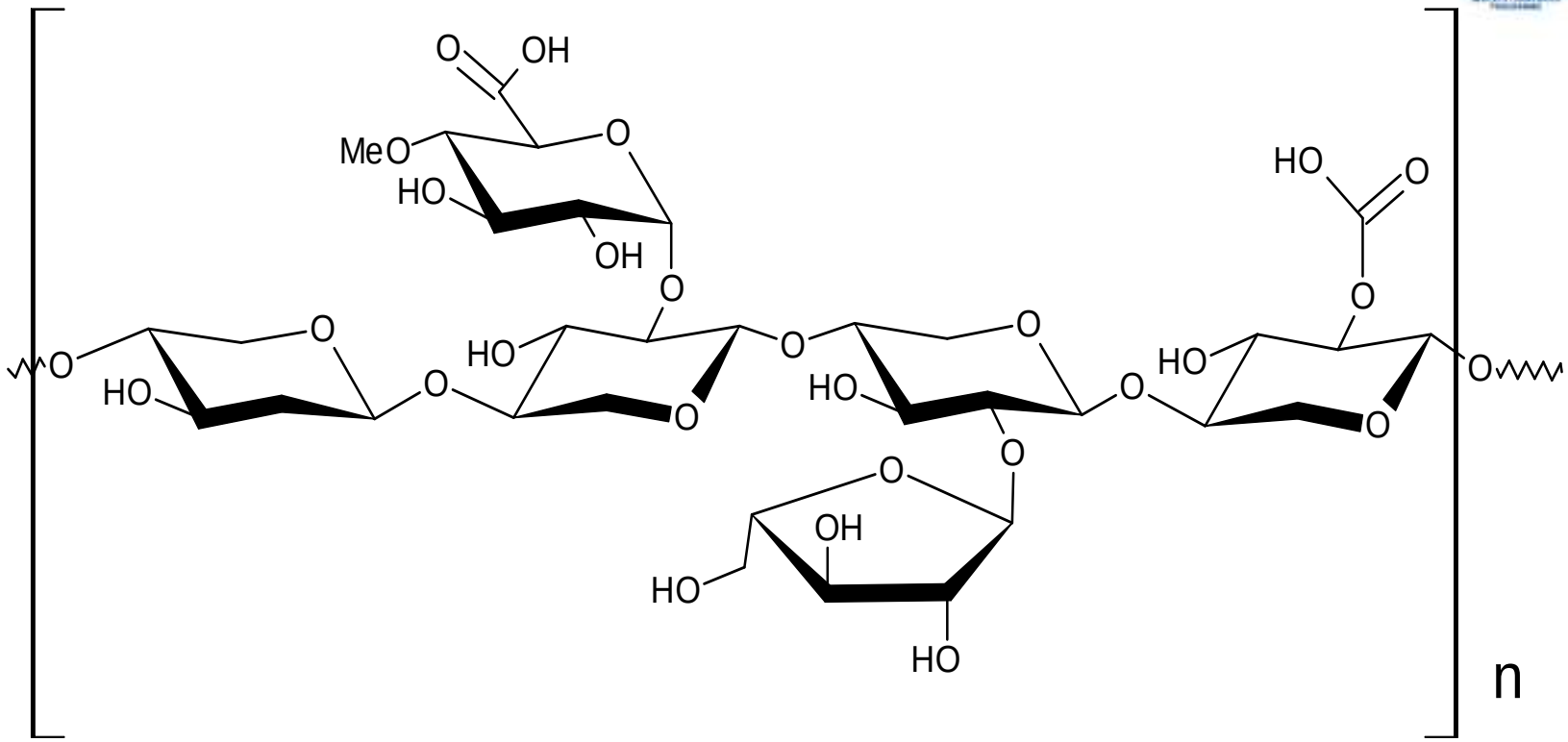

HEMICELLULOSE

Lignin

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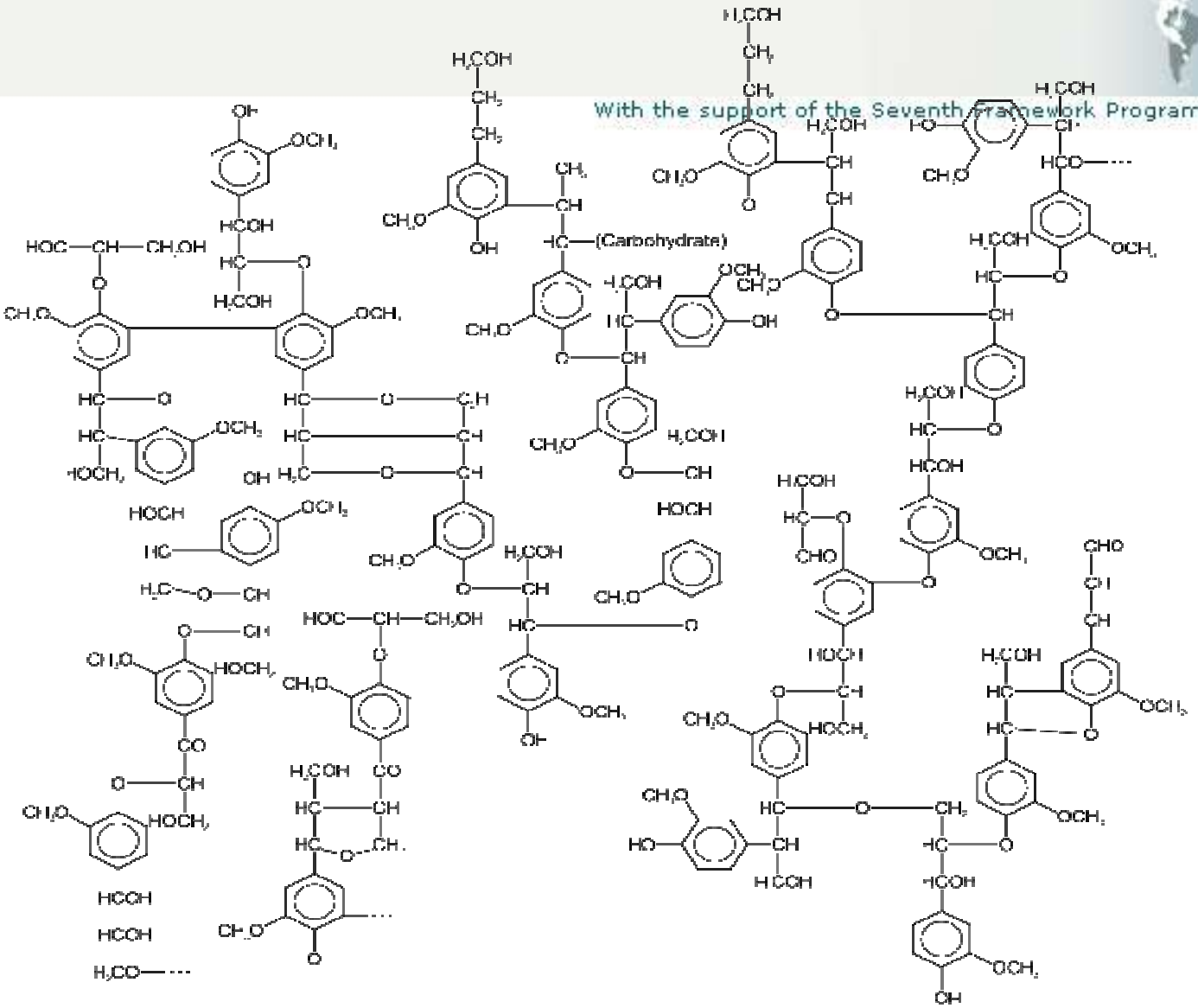
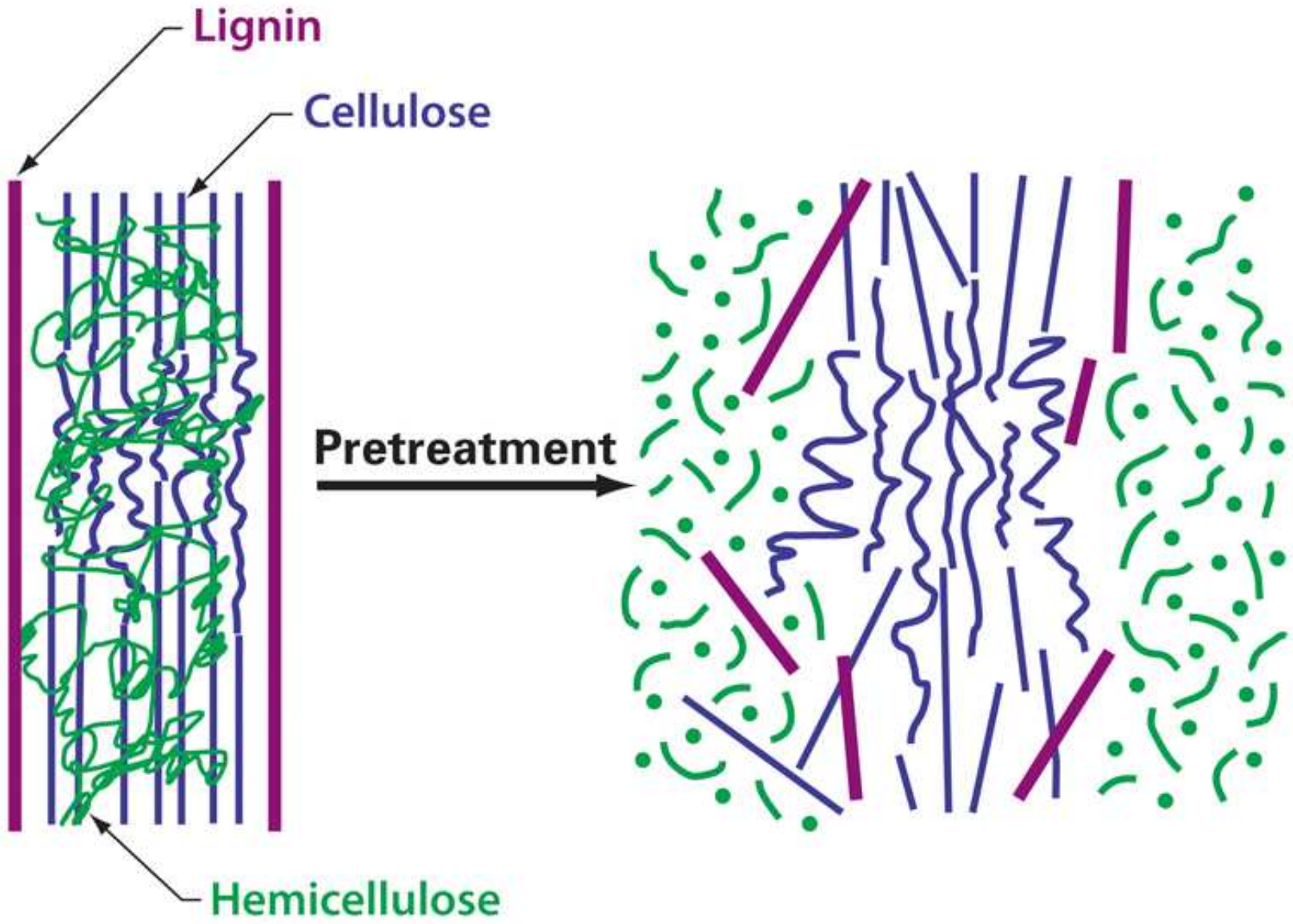


http://en.wikipedia.org/wiki/File:Lignin_structure.svg

Challenges in Processing Lignocellulosics



Lignocellulosic Biorefinery Technologies

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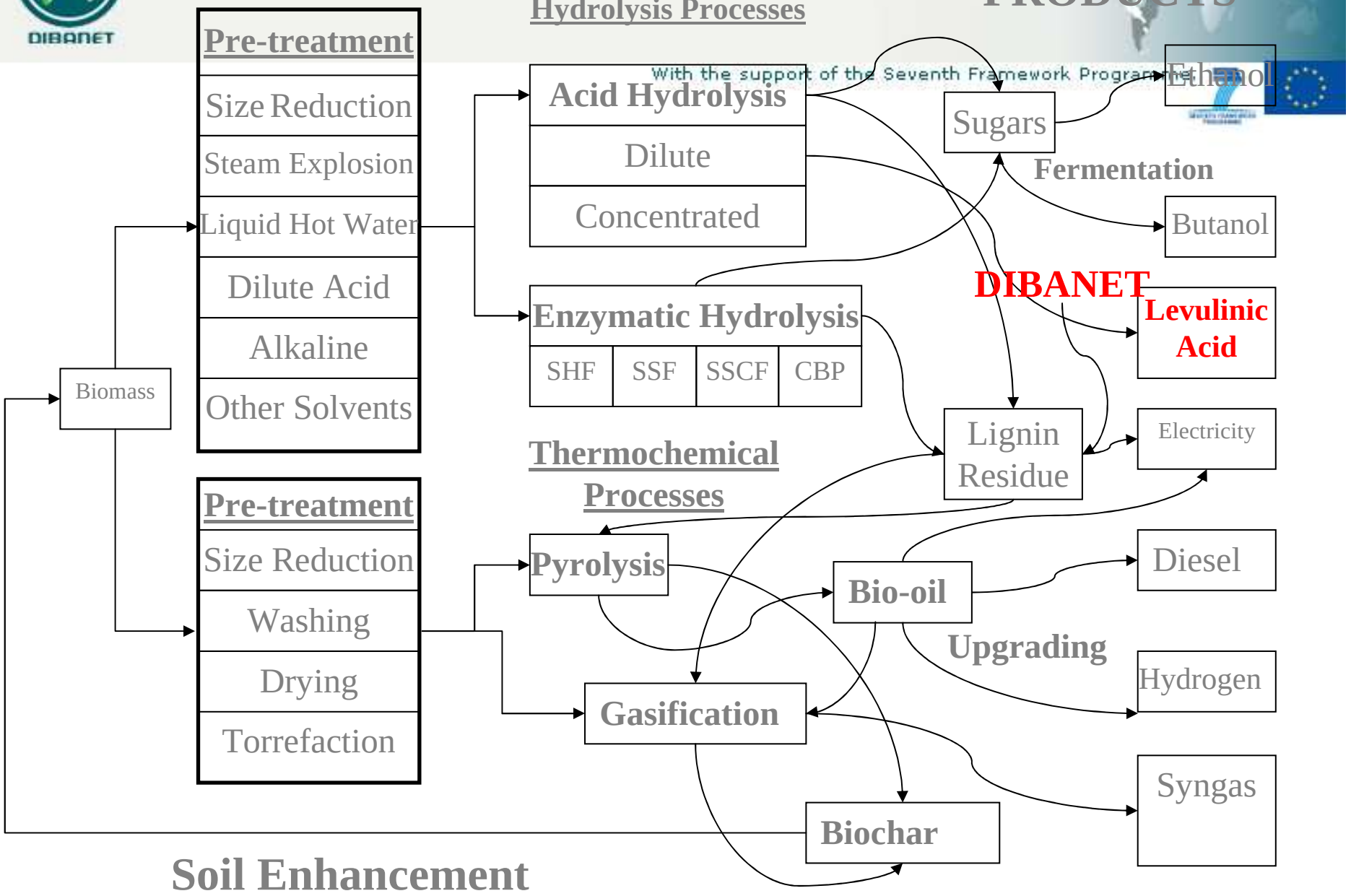
- Polysaccharide Hydrolysis to monosaccharides:
  - Dilute acid hydrolysis
  - Concentrated acid hydrolysis
  - Enzymatic hydrolysis
  - Steam Auto-hydrolysis

  → conversion to saleable products e.g. ethanol, furfural
- Thermochemical - Gasification and pyrolysis. Produce liquid product, biochar and combustible/reformable gas.

Biorefining Pathways



Hydrolysis Techniques

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- Hydrolysis can occur with concentrated or dilute acids, enzymes, or thermochemical procedures.
- Acid hydrolysis:
  - Catalyst to break glycosidic bonds at low/high temperatures.
  - Possible for many feedstocks.
  - Non-selective action, can produce undesirable byproducts.
- Enzymatic hydrolysis:
  - Theoretically highly selective, high monomer yields.
  - Current costs are high, enzyme loss, pretreatment.
  - Treatment of waste materials may be more difficult.
  - Massive research underway → holy grail is a single organism that can hydrolyse biomass and produce the final product (e.g. ethanol) in a single reactor – CBP.
  - Current techniques focus on multiple reactors, SHF, and on a variety of microorganisms/enzymes for hydrolysis/fermentation.
- Thermal hydrolysis (e.g. steam auto hydrolysis):
  - Only suitable for hemicelluloses.

Ethanol or Something Else?

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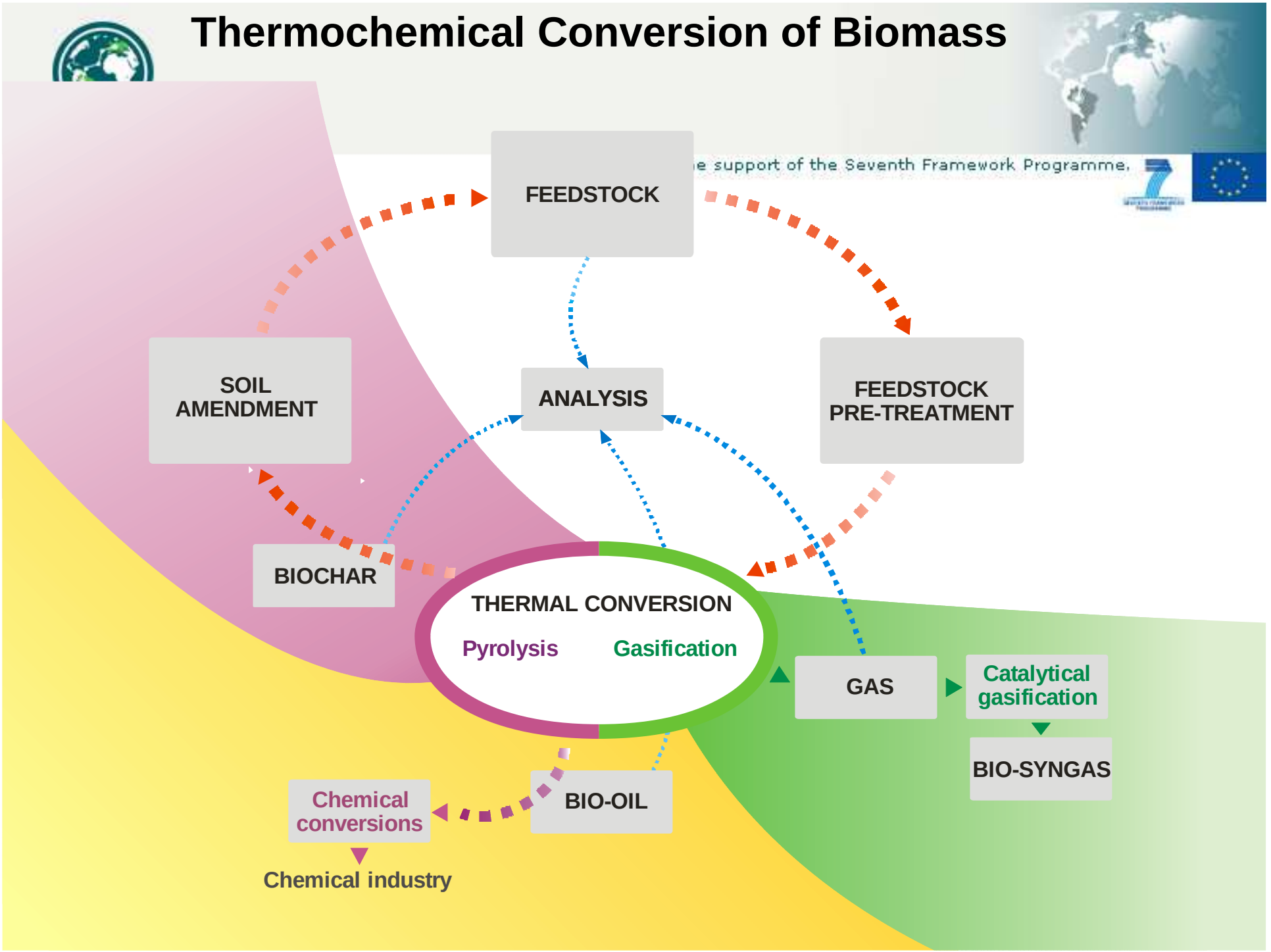
- Many hydrolysis technologies focus on ethanol production.
- Yields from glucose not optimised.
- May not allow efficient utilisation of C5 sugars.
- Maximum theoretical yields of ethanol is approximately 50% of mass of carbohydrate.
- Fermentation may result in saleable mass halving.
- The production of value-added products without biotic activity (e.g. DIBANET) is another option.

Thermochemical Conversion of Biomass



Pyrolysis

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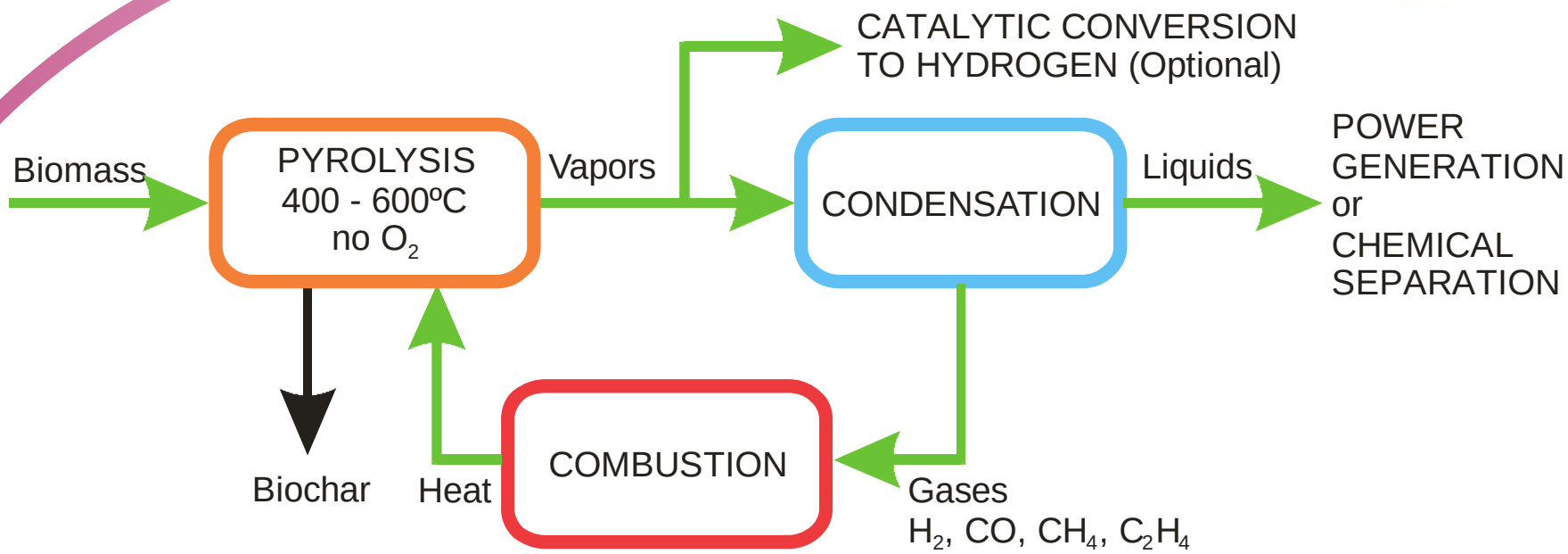

Gasification

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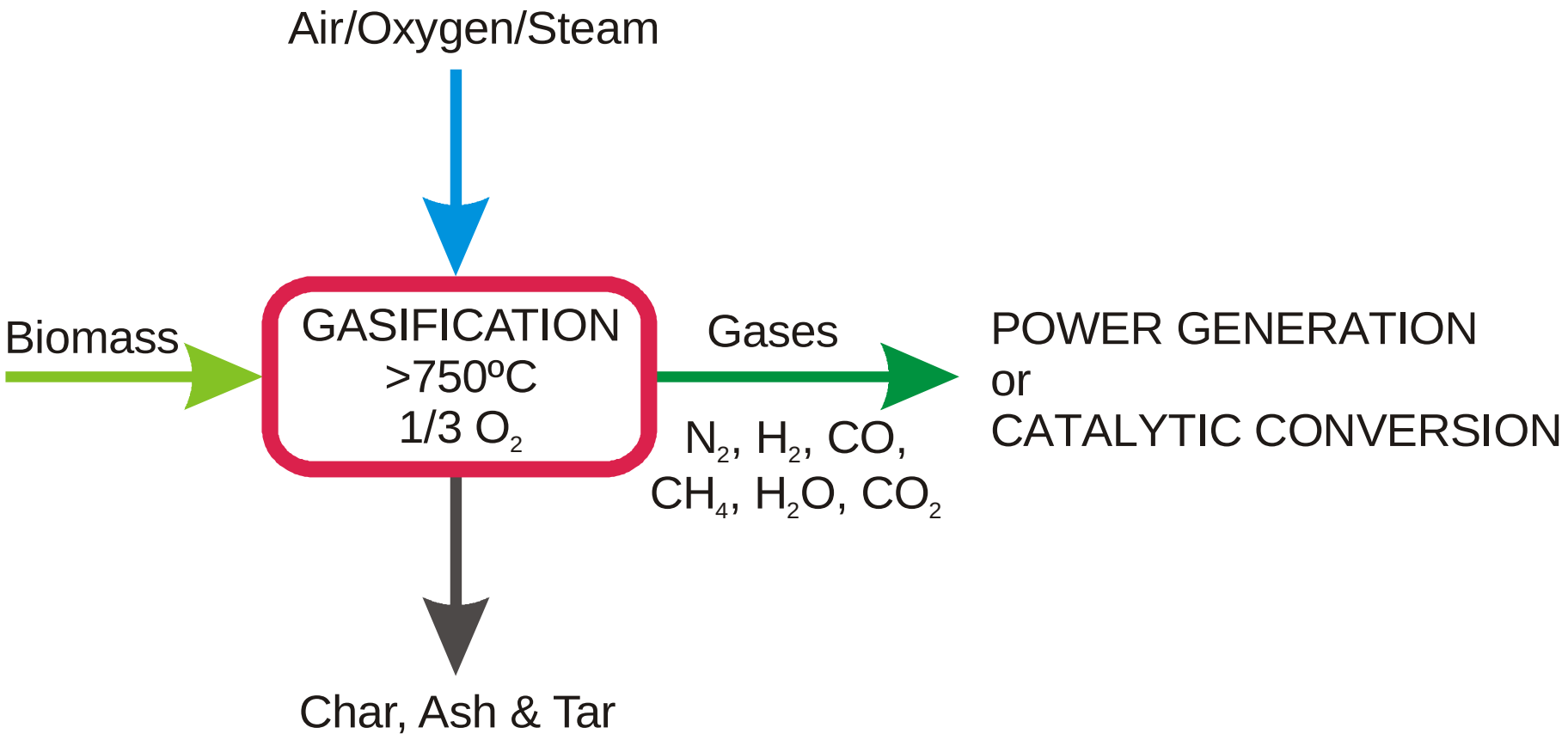
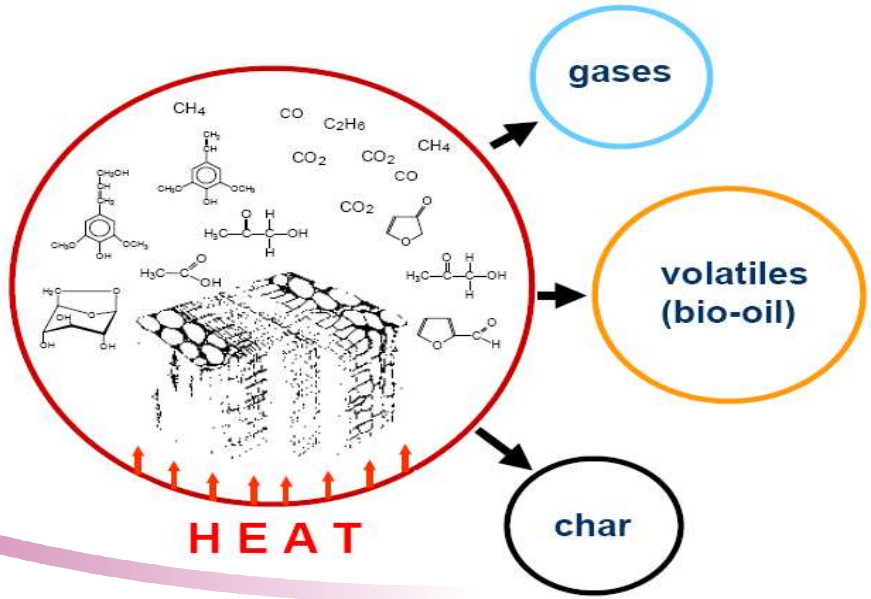


Yields in Thermochemical Processes

with the support of the Seventh Framework Programme.

Table: Typical product yields (dry wood basis) obtained by different modes of pyrolysis of wood

Mode	Conditions	Liquid	Gas	Char
Fast pyrolysis	moderate temperature, around 500℃, short hot vapour residence time ~1 s	**75 %**	**13 %**	**12 %**
Intermediate pyrolysis	moderate temperature, around 500℃, moderate hot vapour residence time ~10-20 s	**50 %**	**30 %**	**20 %**
Slow pyrolysis (carbonisation)	low temperature, around 400℃, very long solids residence time	**30 %**	**35 %**	**35 %**
Gasification	high temperature, around 800℃, long vapour residence time	**5 %**	**85 %**	**10 %**



Bio-Oil – Needs Upgrading

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- Improve some of Unfavourable Properties:
  - High water content
  - High oxygen content
  - Low heating value
  - Instability
  - High viscosity
  - Low pH
  - High particle content
  - Inhomogenity
- Produce a diesel miscible bio-oil

Biochar Potential

SOIL AMENDMENT

BIOCHAR

- **High surface area and porosity;**
- **Increased plant productivity;**
- **Increase the activity of autotrophic and symbiotic microorganisms;**
- **Trap nitrates, phosphates and anthropogenic organic chemicals;**
- **Sequestering biomass-derived carbon.**

Locking up Carbon with Biochar

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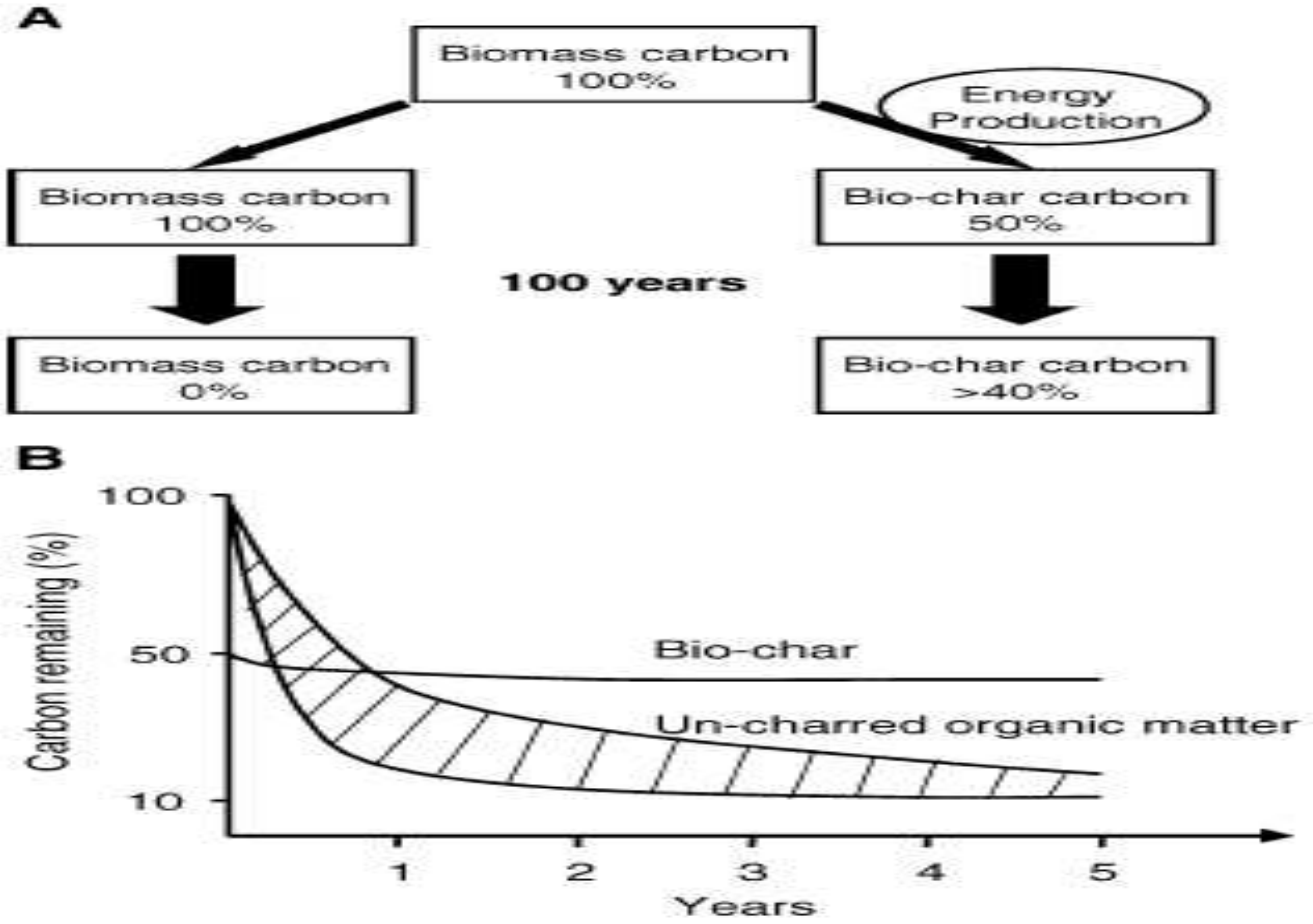

Source: Lehmann et al., 2006

Summary

With the support of the Seventh Framework Programme.

- There are numerous technological options for the processing of lignocellulosic materials.
- Which technology is used depends on the properties of the feedstock (carbohyrdate content, moisture content etc.) and what the desired end products are.
- The DIBANET concept involves a linking of the hydrolysis and thermochemical platforms to allow maximal utilisation of a material and afford feedstock flexibility…..