



# 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 (1<sup>st</sup> Generation)

## Ethanol

Sugar beet  
Wheat  
Corn  
Sugarcane

## Biodiesel

Rapeseed  
Soybean  
Sunflower

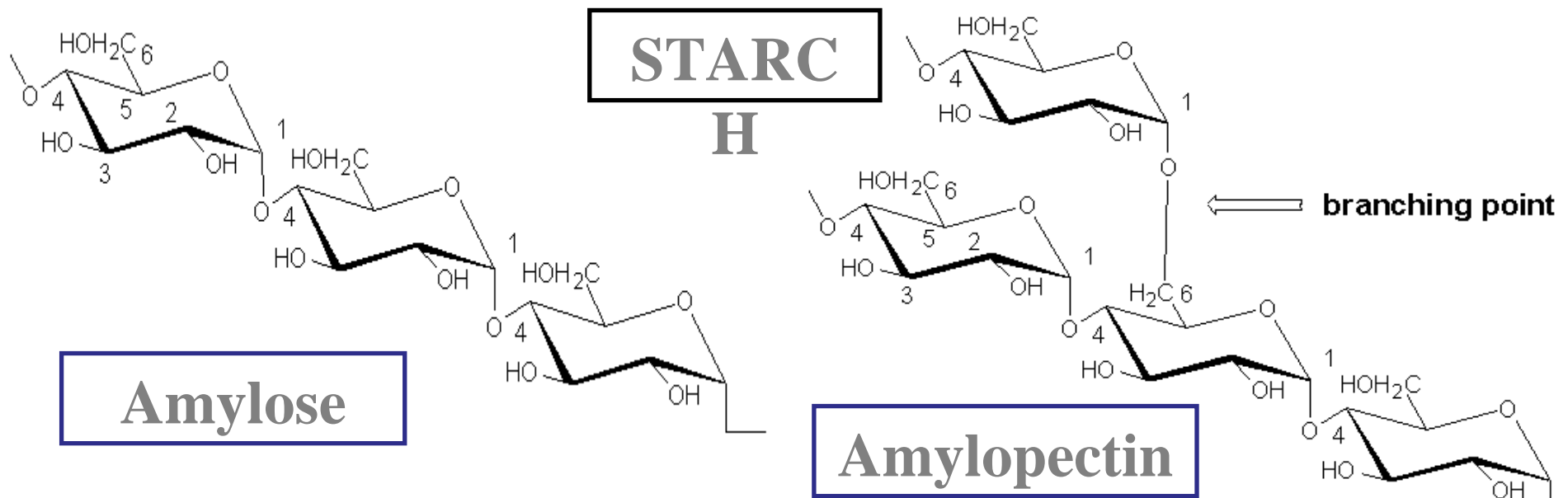
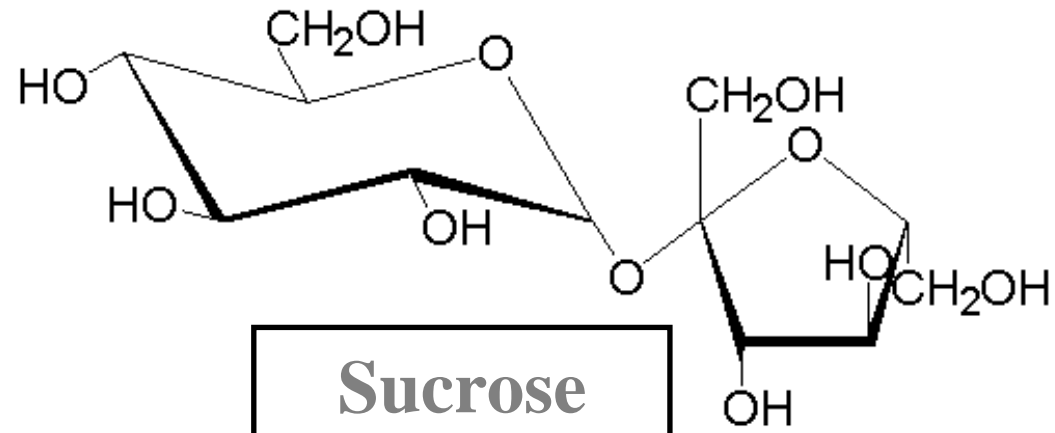
- First generation biofuels come from food or oil crops.



# Foods Are Ideal Chemically



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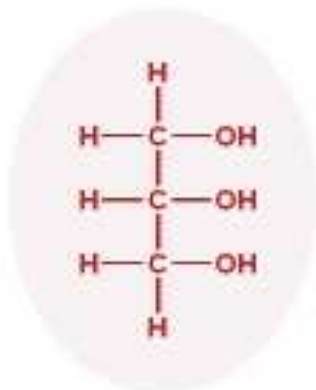




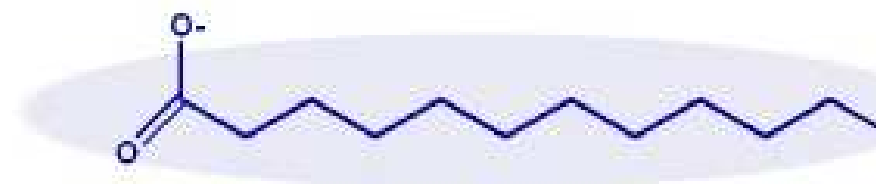
*Glycerol*

# Fats/Oils are Also Easy!

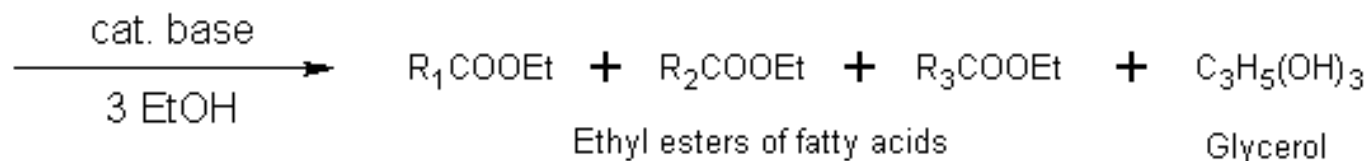
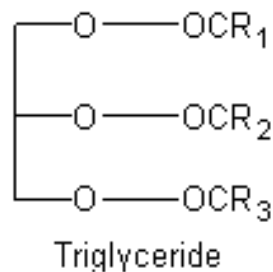
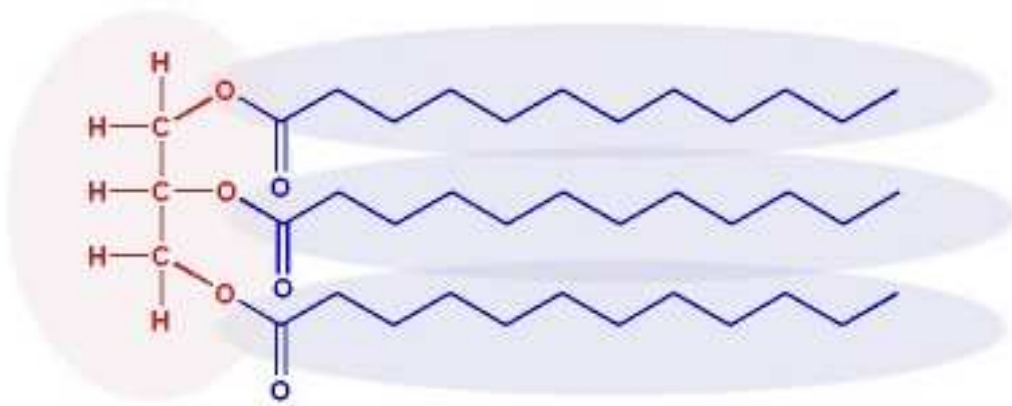
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*A "free" Fatty Acid*



*Triglyceride*





# Problems with 1<sup>st</sup> Gen Feedstocks



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- High establishment, maintenance costs (esp. EU).
- Poor energy ratios.
- High CO<sub>2</sub> 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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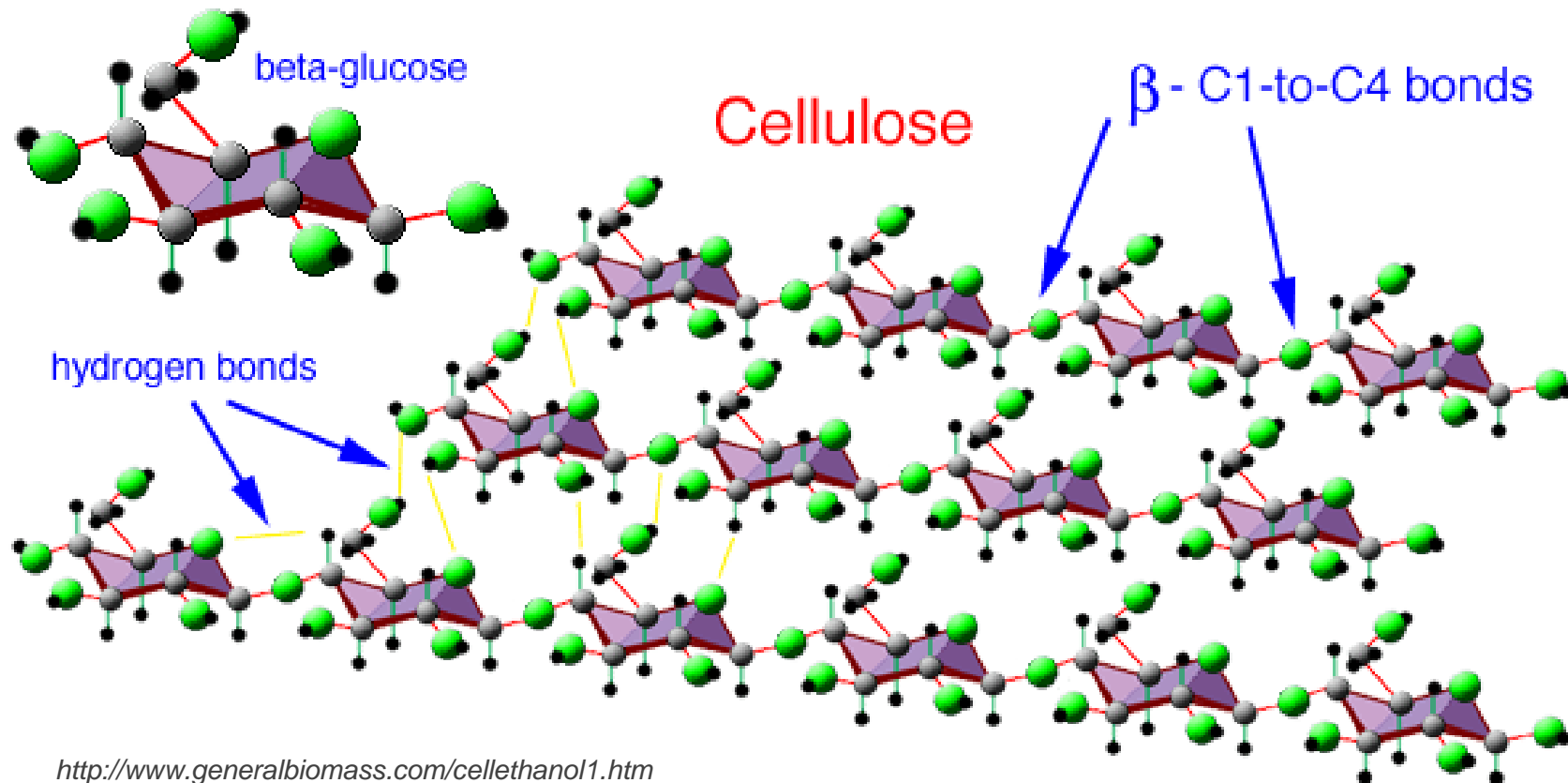


- Analogous to oil refineries.
- Obtain different saleable products from the different chemical constituents of biomass.
- A range of potential products are possible ranging from low volume and high value (specialty chemicals) to high volume and lower value (biofuels)



# Cellulose

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

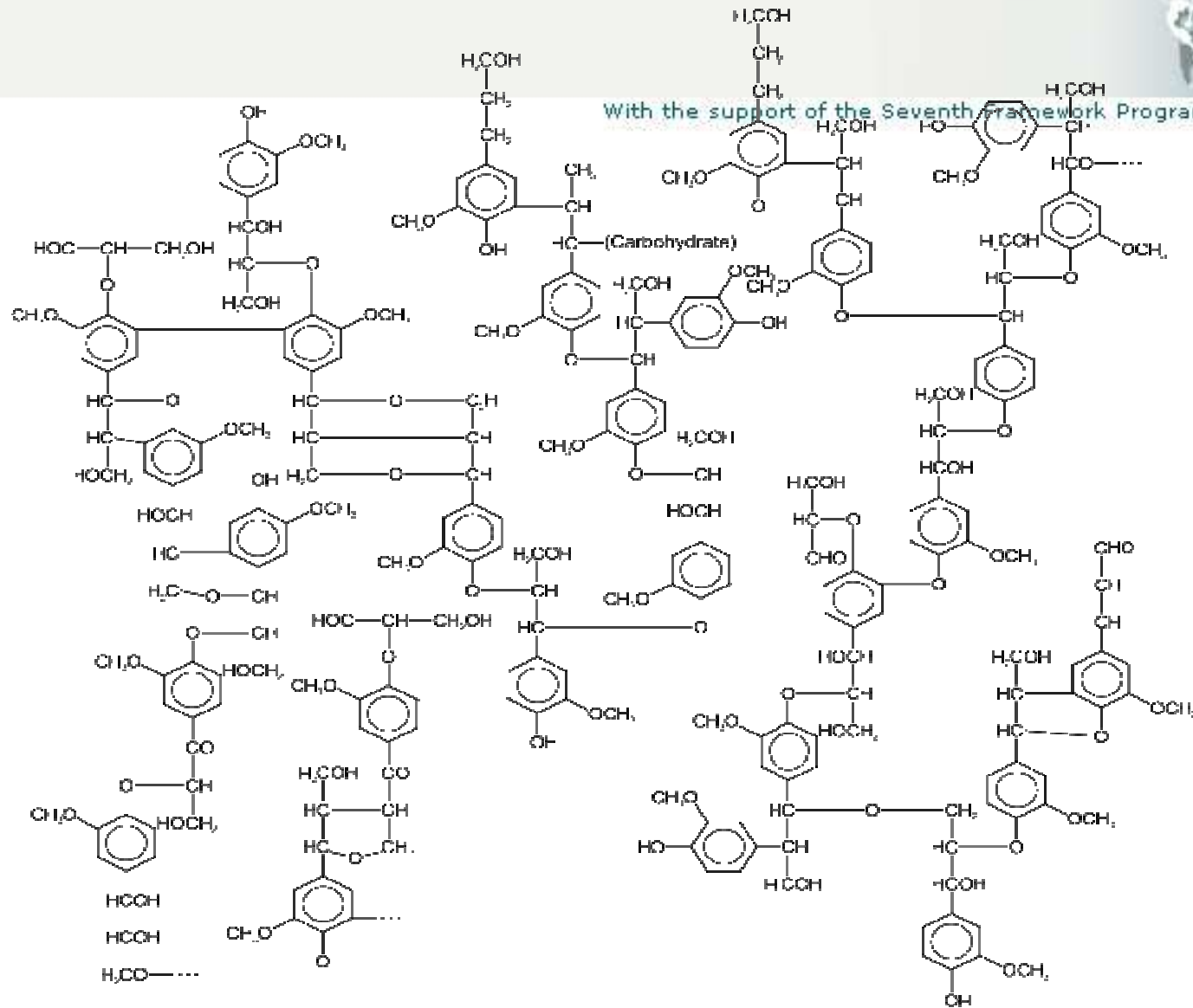




# Lignin

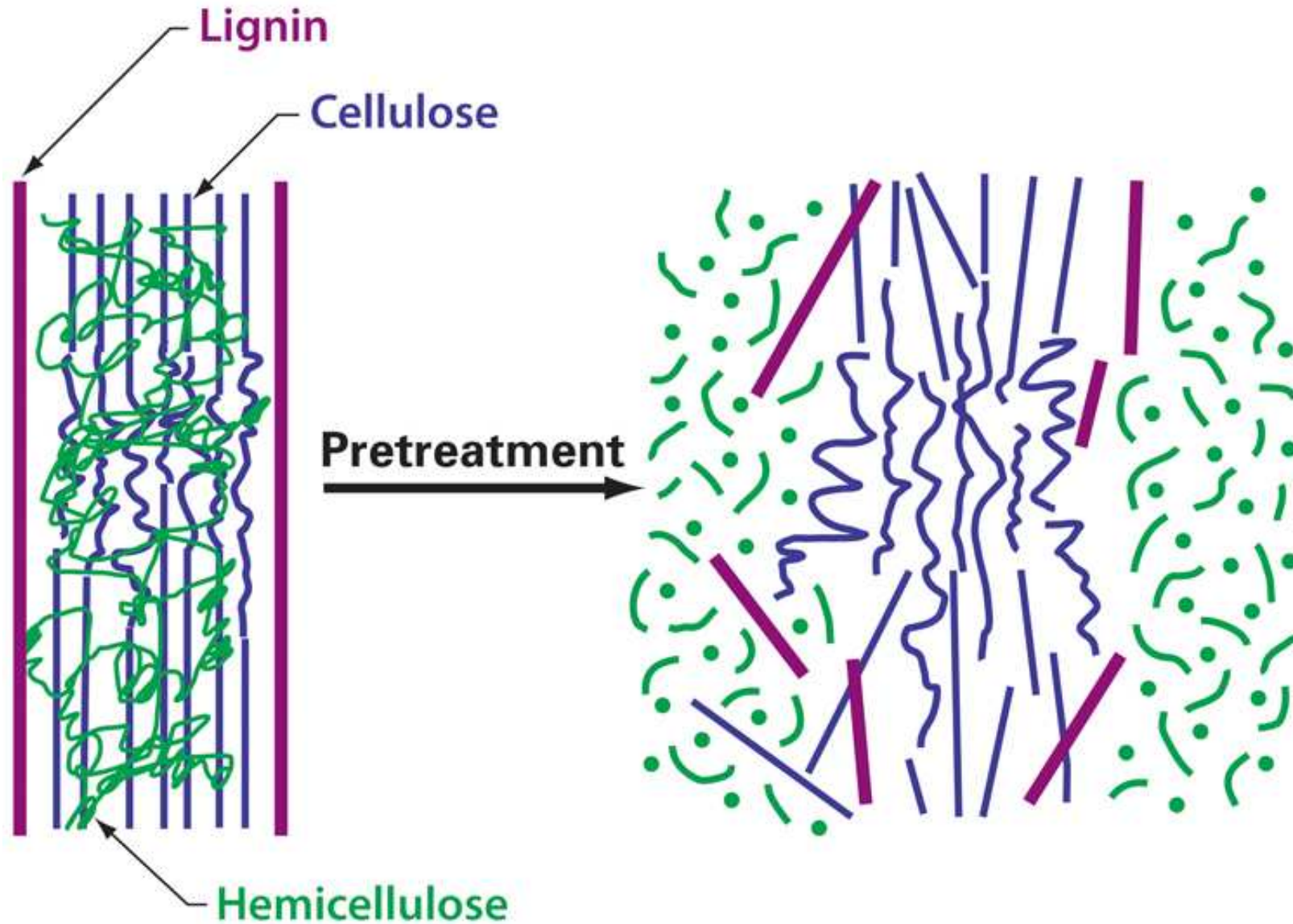


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[http://en.wikipedia.org/wiki/File:Lignin\\_structure.svg](http://en.wikipedia.org/wiki/File:Lignin_structure.svg)

# Challenges in Processing Lignocellulosics





# Lignocellulosic Biorefinery Technologies



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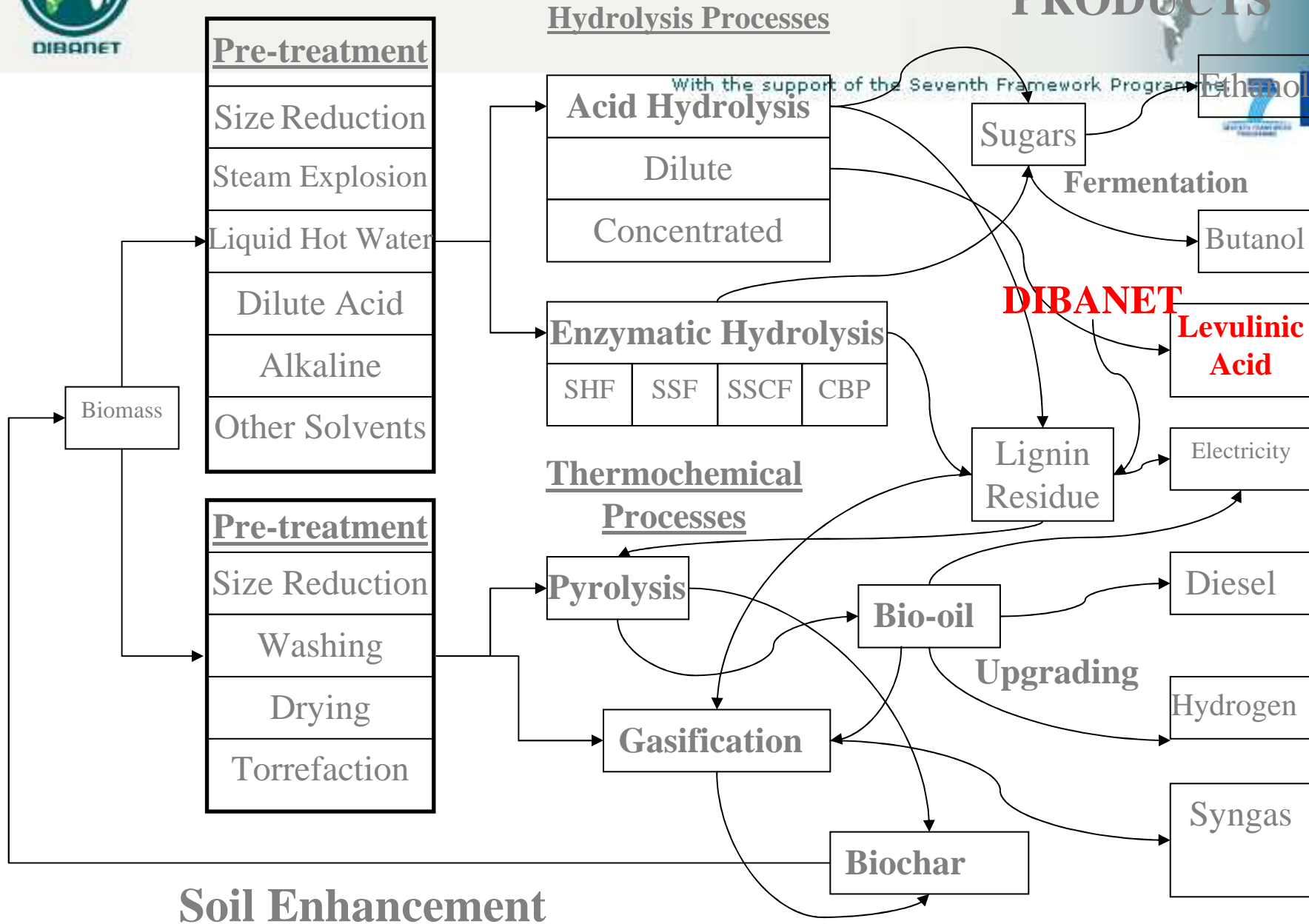


- Polysaccharide **Hydrolysis** to monosaccharides:
  - Dilute acid hydrolysis
  - Concentrated acid hydrolysis
  - Enzymatic hydrolysis
  - Steam Auto-hydrolysis
  - conversion to saleable products e.g. ethanol, furfural
- **Thermochemical** - Gasification and pyrolysis. Produce liquid product, biochar and combustible/reformable gas.

# Biorefining Pathways



## PRODUCTS





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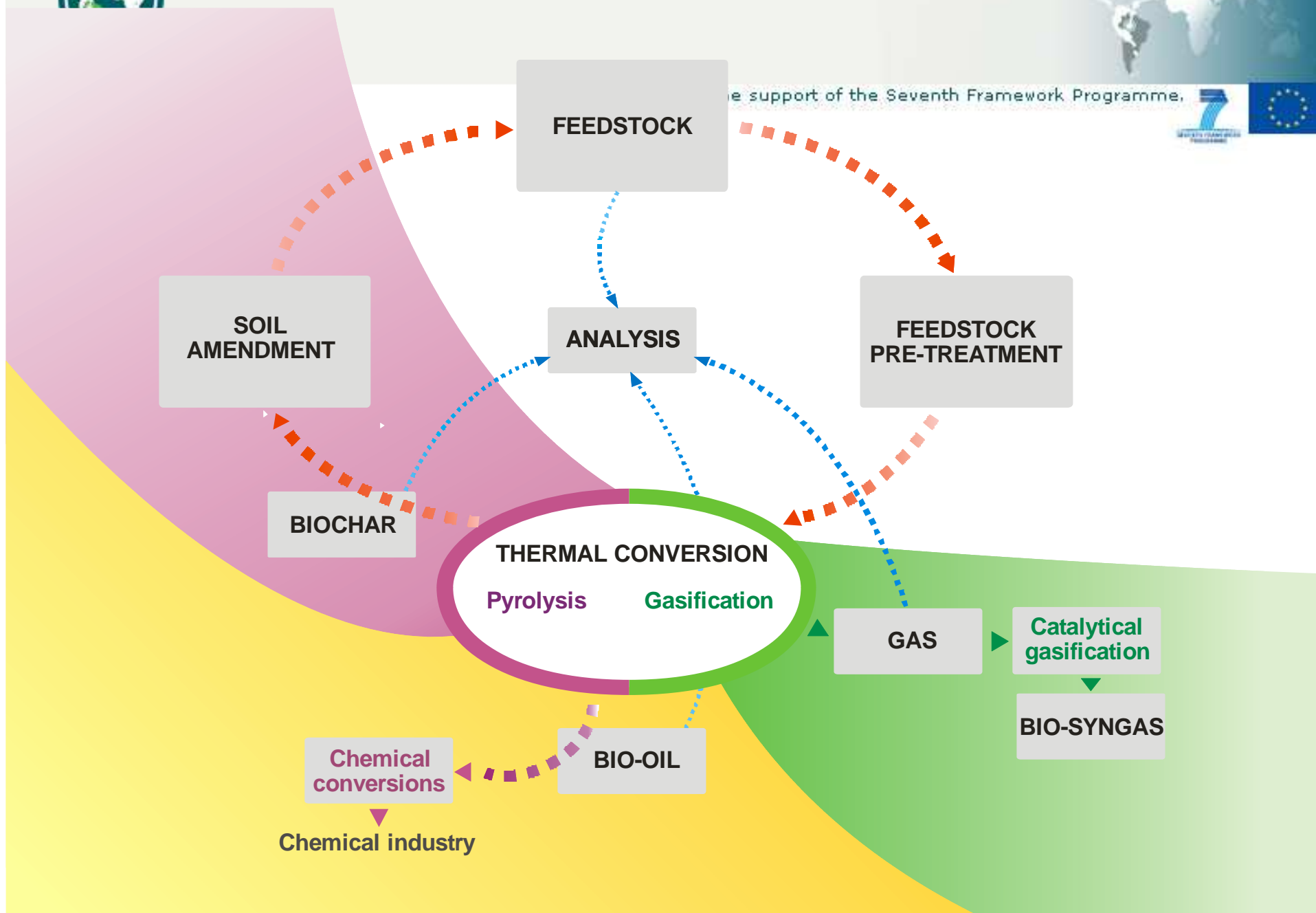
- Many hydrolysis technologies focus on ethanol production.
- Yields from glucose not optimised.
- May not allow efficient utilisation of C5 sugars.
- Maximum theoretical yields of ethanol is approximately 50% of mass of carbohydrate.
- Fermentation may result in saleable mass halving.
- The production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



# Thermochemical Conversion of Biomass



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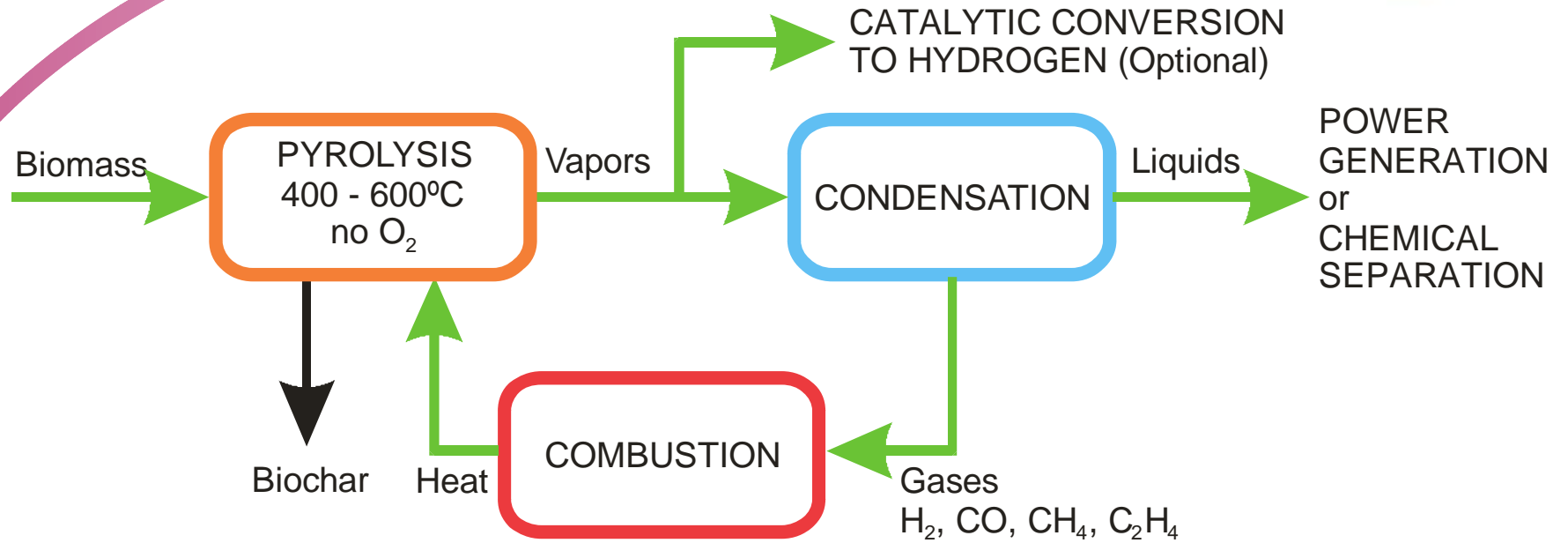




# Pyrolysis



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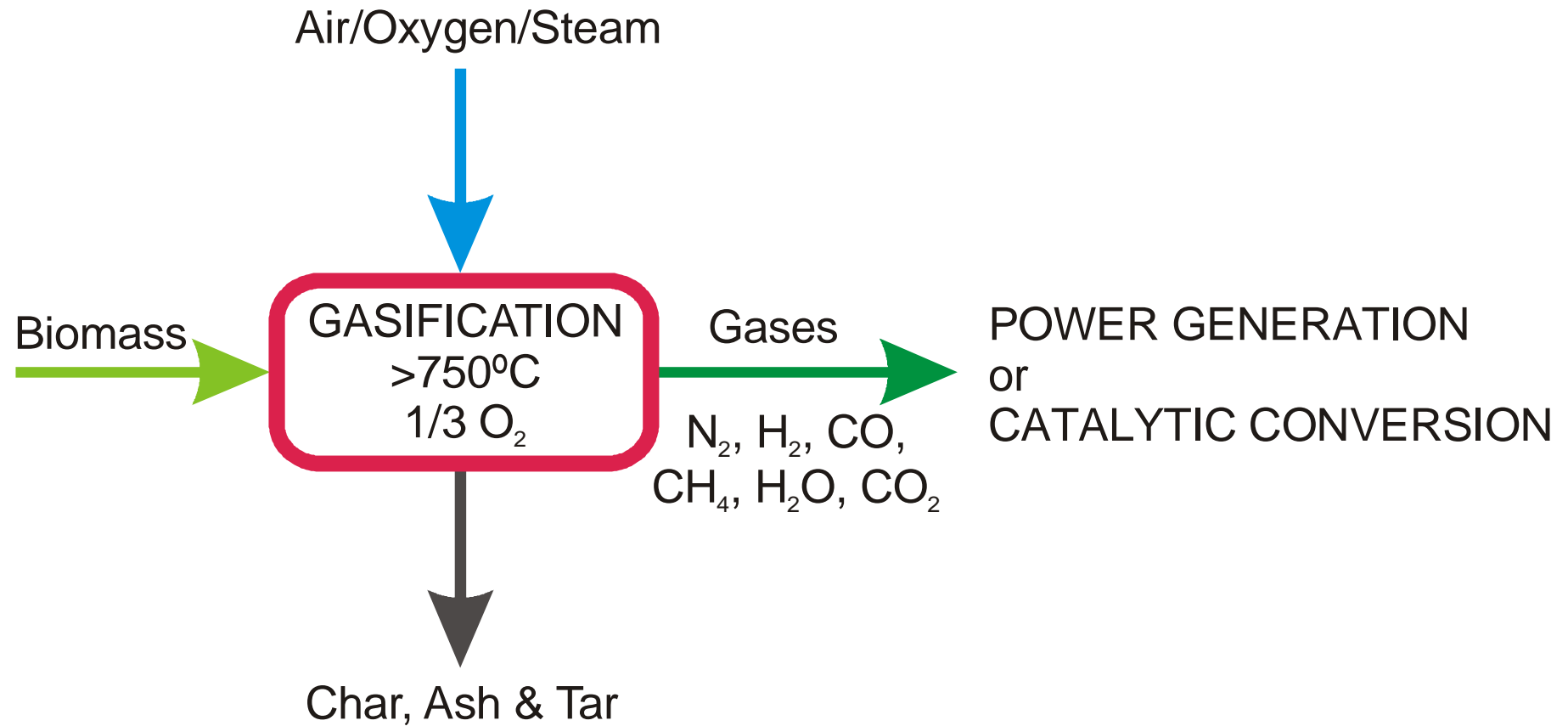




# Gasification



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# Yields in Thermochemical Processes

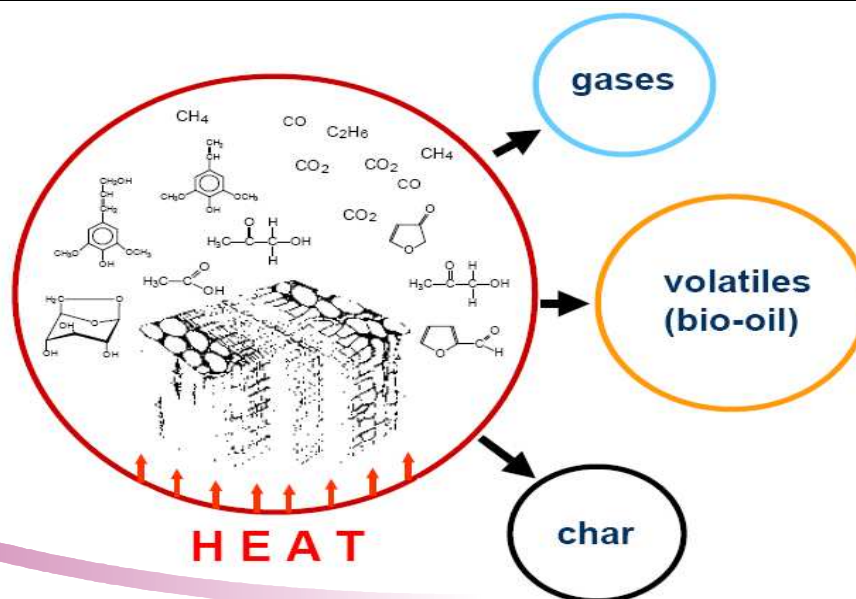


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Table: Typical product yields (dry wood basis) obtained by different modes of pyrolysis of wood

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





# 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
  - Inhomogeneity
- 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.

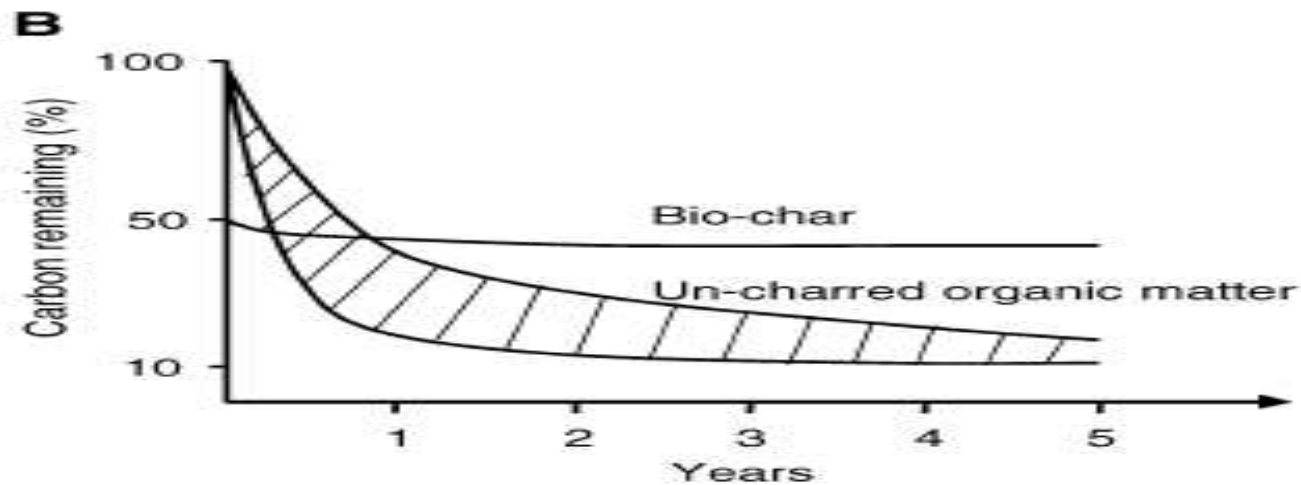
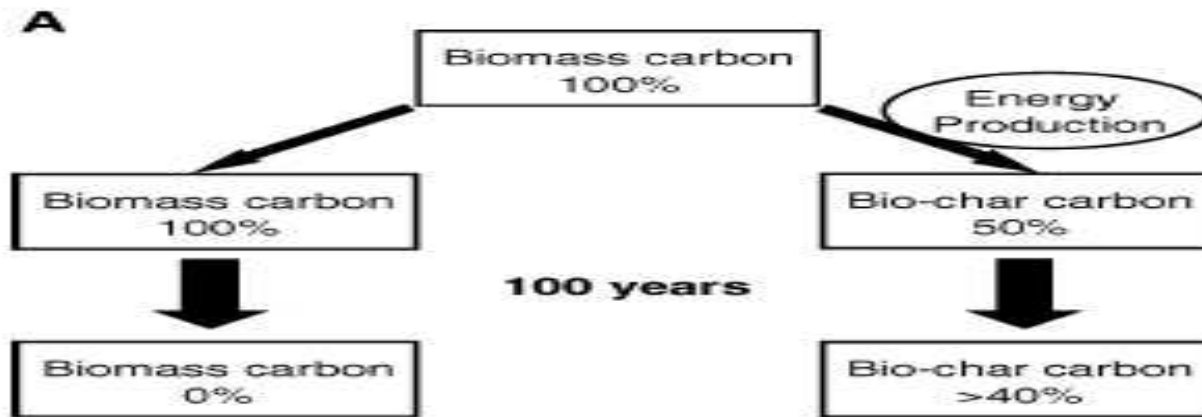




# Locking up Carbon with Biochar



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Source: Lehmann et al., 2006



# Summary

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- There are numerous technological options for the processing of lignocellulosic materials.
- Which technology is used depends on the properties of the feedstock (carbohydrate 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.....