



Energy research Centre of the Netherlands



# HYBRID STAGED THERMOLYSIS TO VALORISE BIOMASS

Paul de Wild, March 11, 2009

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## INTRODUCTION

- Lignocellulosic biomass is a very attractive candidate for green energy carriers, chemicals and materials.
- Cheap and efficient fractionation technology to separate biomass into its main constituents is highly desirable.
- A biorefinery approach in which the fractionation is integrated with subsequent processing steps, offers the best solution for a cost-effective and environmentally sound valorisation of biomass.

## OBJECTIVE

- Proof of principle of a hybrid staged thermolysis approach for the production of furfural and levoglucosan from biomass.

# SOME PRODUCTS FROM WOOD DERIVED CHEMICALS



**PHENOLS**

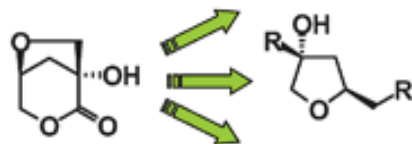


**LEVOGLUCOSAN**

**MACROLIDE ANTIBIOTICS**



nanopowder  
pyrolysis



**FURFURAL**

**CHAR**



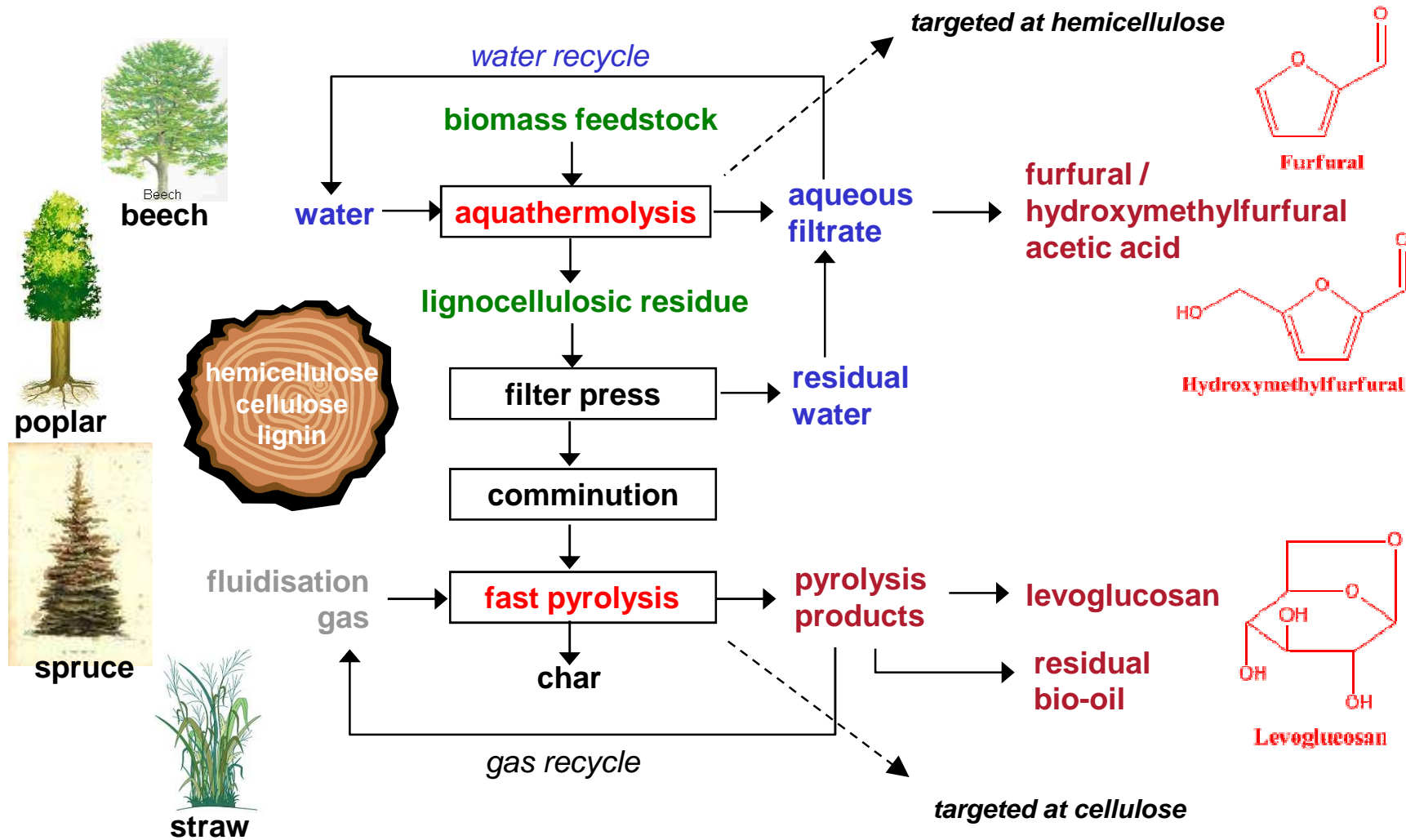
**White Vinegar**

**ACETIC ACID**

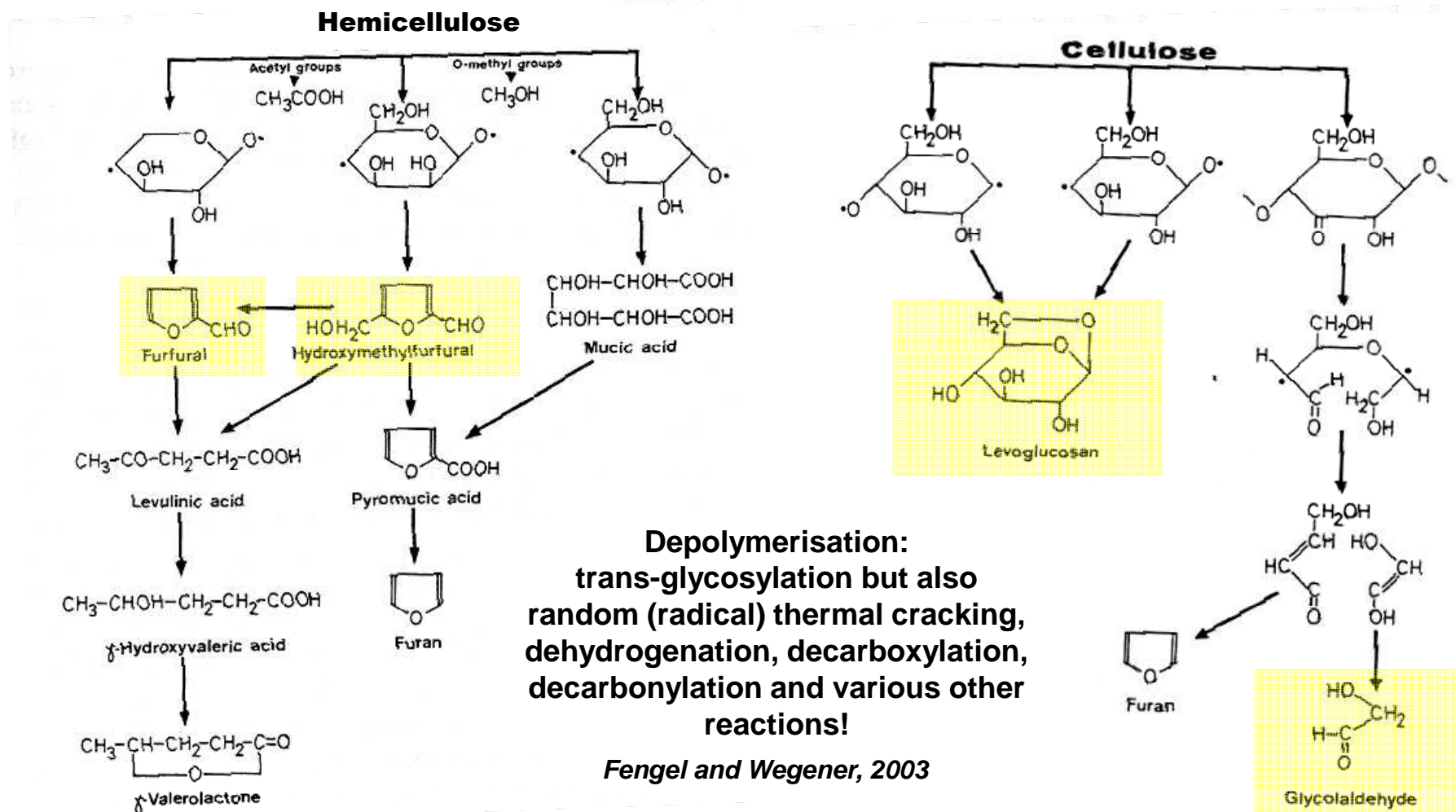




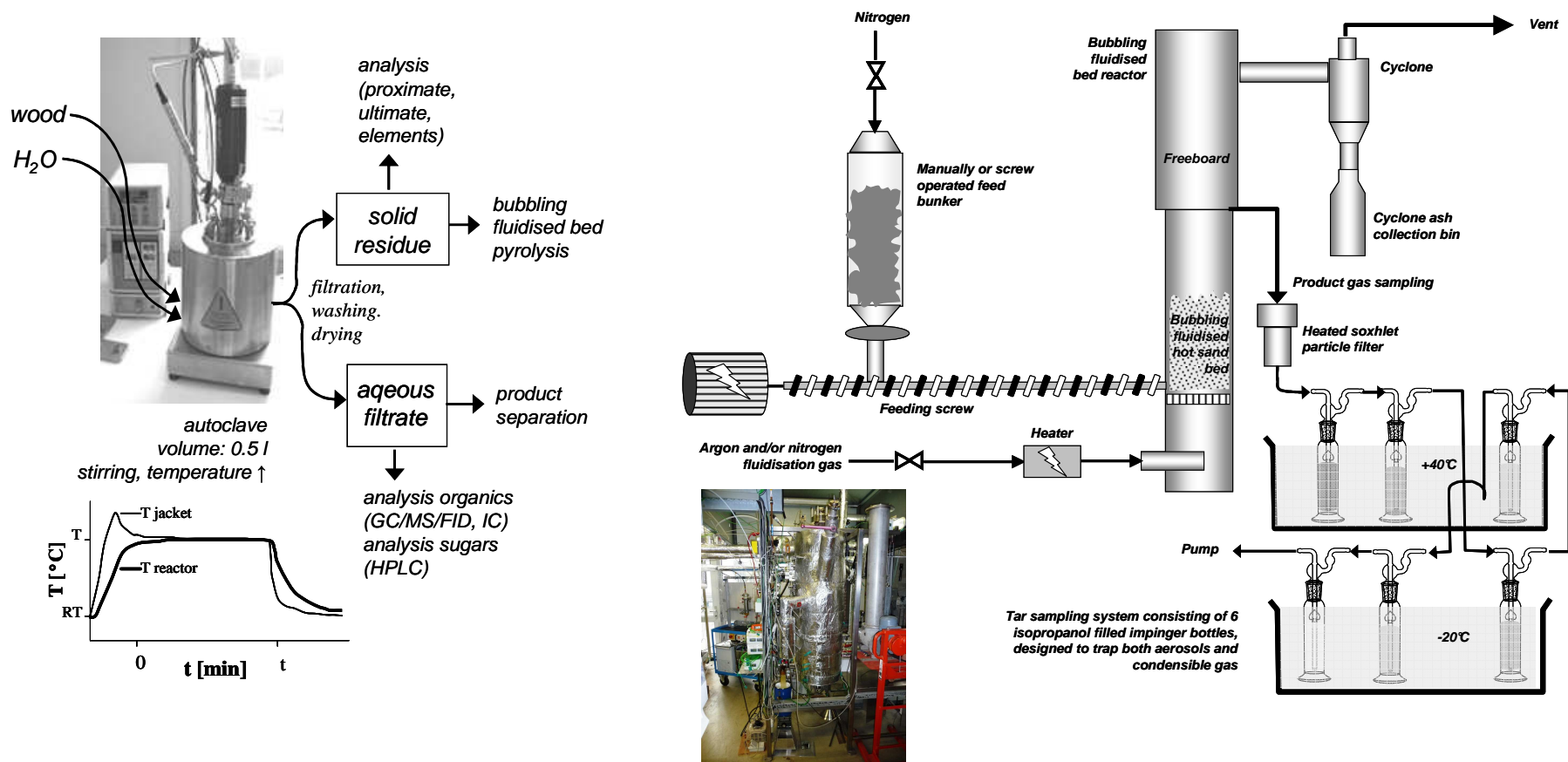
# PROCESS CONCEPT



## Thermal degradation mechanisms of hemicellulose and cellulose



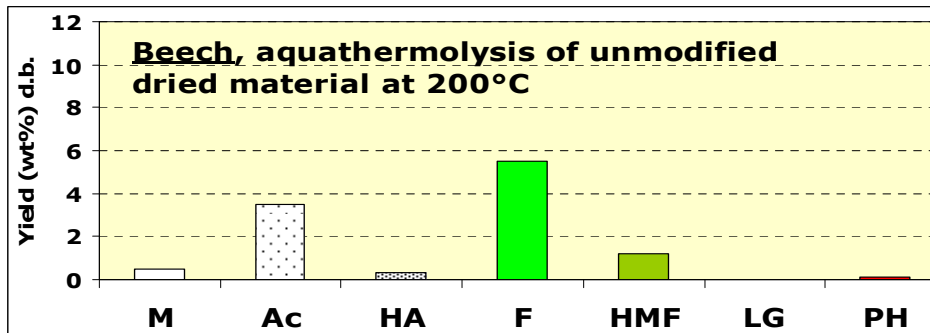
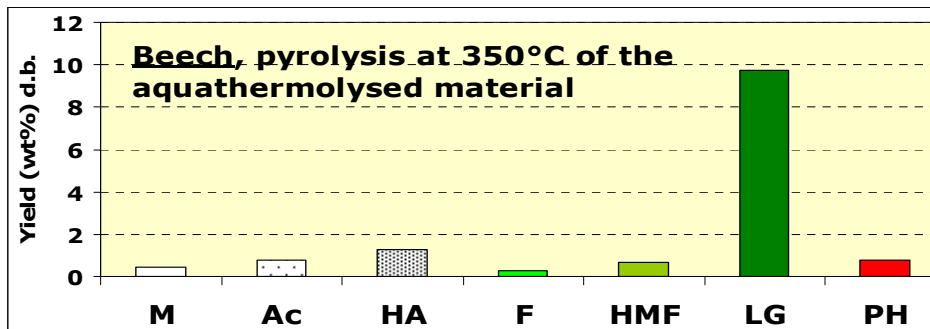
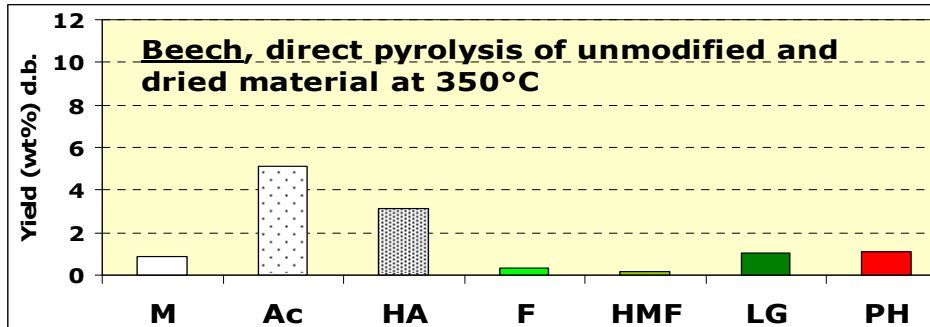
# EXPERIMENTAL APPROACH



**Stage 1: aquathermolysis  
(hot compressed water treatment)**

**Stage 2: fast pyrolysis in a  
bubbling fluidised bed**

## PROCESS RESULTS FOR BEECH WOOD CHIPS

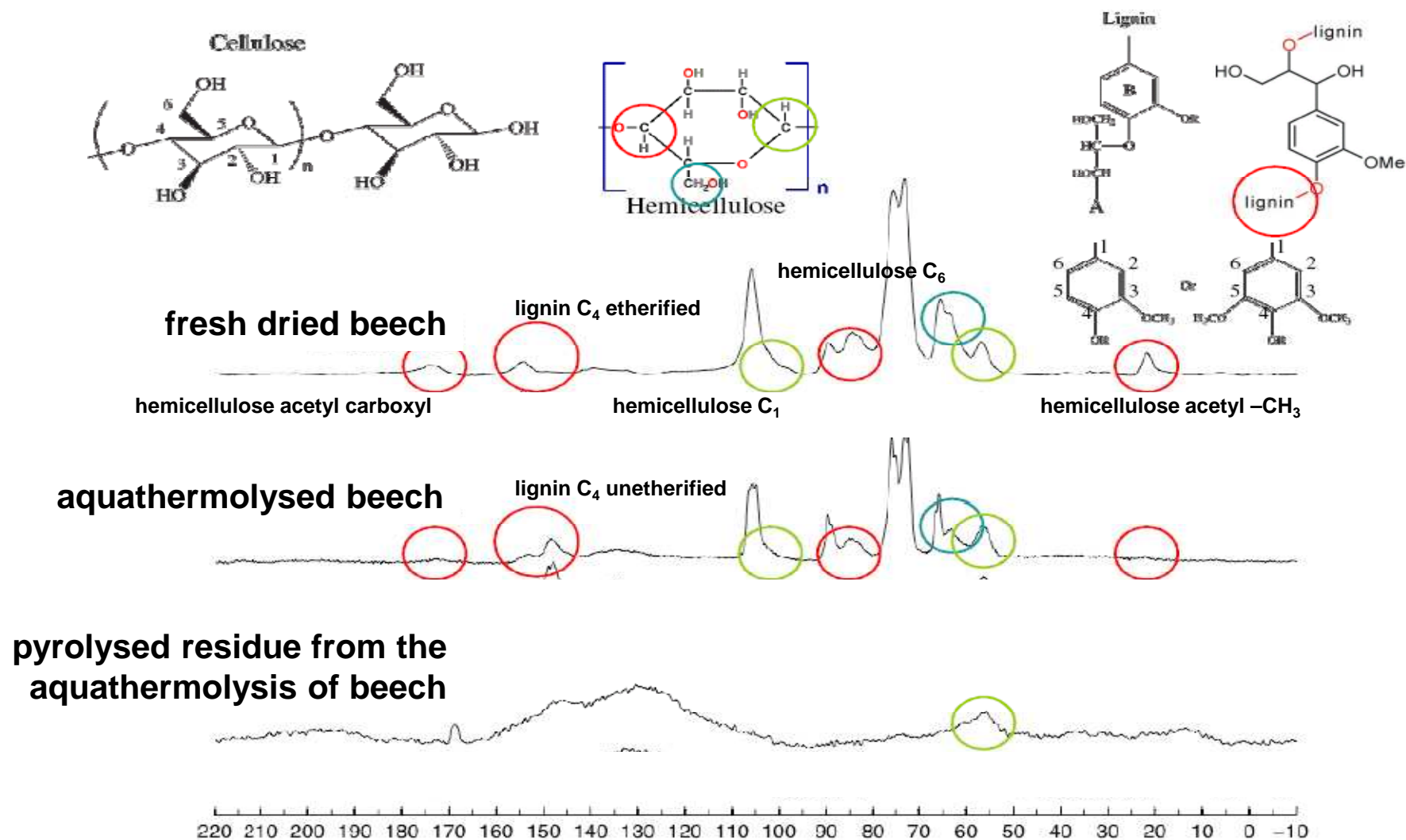


Aquathermolysis – pyrolysis vs direct pyrolysis for beech, showing the much better yields and selectivities of the hybrid approach.

*M = methanol,*  
*Ac = acetic acid,*  
*HA = hydroxyacetaldehyde,*  
*F = furfural,*  
*HMF = hydroxymethylfurfural,*  
*LG = levoglucosan,*  
*PH = phenols*

Experiments with poplar, spruce and straw show similar results.

# <sup>13</sup>C-SS-CP/MAS NMR STUDY ON BEECH





## CONCLUSIONS $^{13}\text{C}$ -SS-CP/MAS NMR STUDY ON BEECH



NMR Facility

- during hydrothermal treatment (200 °C):
  - hemicellulose is lost
  - cellulose is broken up, becomes amorphous
  - lignin is stable, but beta-O-4 hydrolysis
- during pyrolysis (350 °C)
  - cellulose is lost
  - aromatics and aliphatics are formed
  - some lignin remains intact

## CONCLUSIONS

- Proof of principle of the production of furfurals and levoglucosan from lignocellulosic biomass via a hybrid staged thermolysis approach has been delivered for deciduous (beech), coniferous (spruce) and herbaceous (straw) biomass types.
- Results indicate yields around 7 wt% (d.b.) for furfurals and 11 wt% (d.b.) for levoglucosan with ample potential for optimisation.
- Challenges are process integration and efficient separation / purification of the target chemicals from the dilute raw product mixtures.

### Acknowledgements

This work has been conducted as part of the European Commission 6<sup>th</sup> framework programme Integrated Project 'BIOSYNERGY', contract no. 038994. The financial support of the European Commission is gratefully acknowledged.

Special thanks go to Dr. Ernst van Eck and Anton Lunshof of Radboud University Nijmegen, The Netherlands for the the mechanistic NMR study on beech wood



The background of the slide is a photograph of a person walking up a long, stone staircase in a park. The person is wearing a light-colored jacket and dark pants. The staircase is flanked by lush green trees and foliage. The sun is shining brightly from the top left, creating a lens flare effect and casting shadows on the steps. The overall scene is bright and natural.

**Thank you for your attention!**  
**Questions?**