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Welcome to

EEN-E2002 Combustion Technology

Lecture on 6 Mar 2019

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v. 02 / 5 Mar 2019

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Contents

Today's topics:

- Learning Exercise 4 / observations
- Boiler heat and mass balances (cont'd)
- Boiler fuels, fuel properties

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Learning Exercise 4

- So far, 43 students have submitted solutions
- 24 individual submissions, 5 pairs, 3 triplets

Working together was far more interesting than working alone on learning exercises. One had more time to put on specific parts of the assignment and also the help of another in times of uncertainty.

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Learning Exercise 4

- Late submissions will not be accepted after Sunday, 10 March

  (model solution of LE 4 will be uploaded to MyCourses on Monday, 11 March)

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Learning Exercise 4

- Turnitin originality analysis:

  no plagiarism issues were recognized

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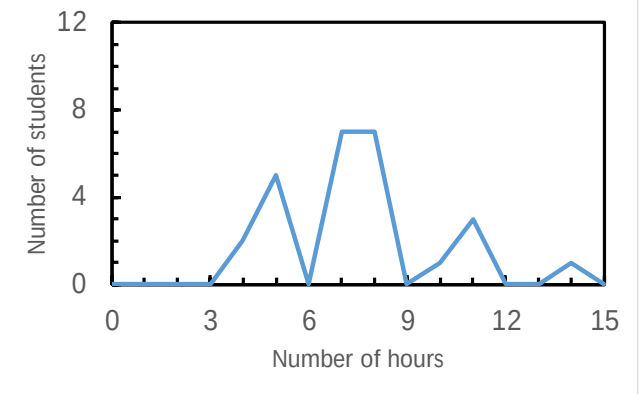
Learning Exercise 4

- Time spent on LE 4:



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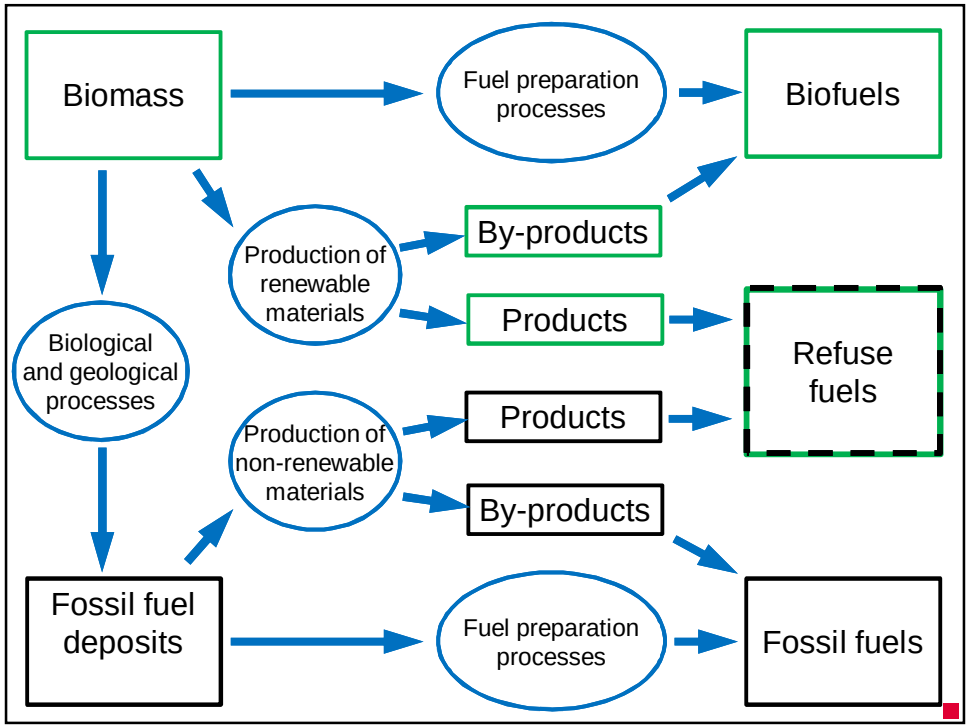
Fuels and fuel properties

Origins of boiler fuels: see next slide



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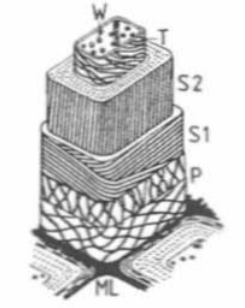
Plant biomass

Plant biomass = fibers + glue

cellulose lignin



Schematic drawing of wood structure

Source: R. Alén, Structure and chemical composition of wood (in: Stenius (ed.), Forest Products Chemistry, 2000)

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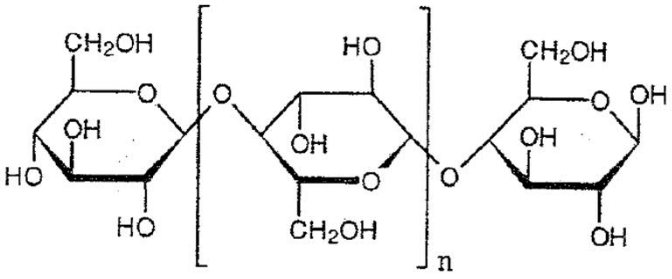
Structure of cellulose



- Chemical formula: $(C_6H_{10}O_5)_n$
- Degree of polymerization of wood cellulose: $n \approx 10\,000$

Source: R. Alén, Structure and chemical composition of wood (in: Stenius (ed.), Forest Products Chemistry, 2000)

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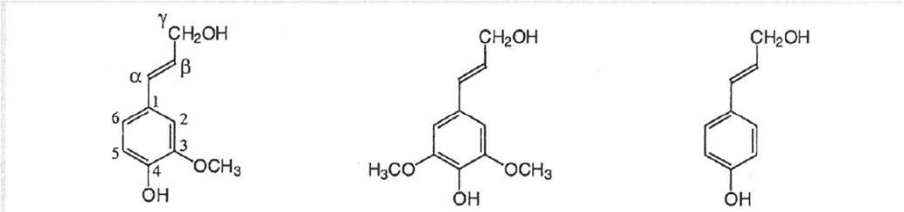
Lignin precursors



trans-Coniferyl alcohol *trans*-Sinapyl alcohol *trans-p*-Coumaryl alcohol

Figure 18. The building units (C_6C_3 precursors) of lignin.

Source: R. Alén, Structure and chemical composition of wood (in: Stenius (ed.), Forest Products Chemistry, 2000)

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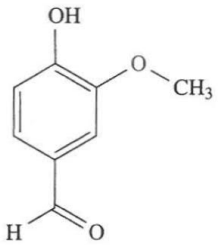
Sidetrack: specialty chemicals

nature, vanillin (**23.20**), present in oil of vanilla, contains an ether functionality, as well as an aldehyde and aromatic –OH (a *phenolic* group).



(23.20)

Source: C. E. Housecroft & E. C. Constable, Chemistry, 2nd ed., Prentice-Hall, 2002. p. 741.

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Sidetrack: specialty chemicals

BIOMASS AND BIOENERGY 46 (2012) 46–59

Available online at www.sciencedirect.com

SciVerse ScienceDirect

http://www.elsevier.com/locate/biombioe

History and future of world's most advanced biorefinery in operation

Gudbrand Rødsrud, Martin Lersch, Anders Sjöde*

Borregaard Industries Ltd, P.O. Box 162, NO-1701 Sarpsborg, Norway

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Vanillin is produced from lignin after purification and by air oxidation with catalyst [15,16]. At some stage, the petrochemical route to vanillin and ethyl vanillin seemed to outperform the biomass based route because of cost efficiency. Fortunately, now the vanillin from lignin is preferred in some markets due to high quality and the green image.

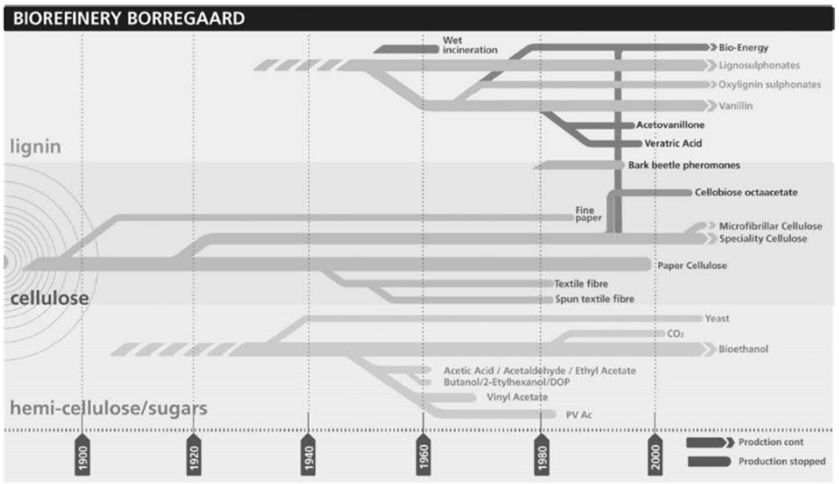

Fig. 1 – Dynamics of the 120 year history of the Borregaard biorefinery.

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Conversion of plant biomass to fossil fuels

Plant biomass => Peat => Brown coal => (Hard) coal (Lignite)

Age increases

High in H and O	Low in H and O
High volatiles content	Low volatiles content
Low energy content	High energy content
Hygroscopic	Hydrophobic
Tough	Brittle

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From cellulose to peat

largely excluded. In the presence of bacterial action, chemical decomposition proceeds by a process called humification:

$$\underset{\text{Cellulose}}{2C_6H_{10}O_5} \xrightarrow[\text{Heating}]{\text{Bacterial action}} \underset{\text{Peat}}{C_8H_{10}O_5} + CH_4 + 2CO_2$$

Since the rate of formation of a peat bed is about 3 cm per 100 years, peat is not a renewable resource. Some of the hemicellulose and cellulose is decomposed into humic acid bitumens and other compounds. Peat is usually dark-brown in color and fibrous in character. Since freshly harvested peat typically contains 80 to 90% water, it must be dried before using as a fuel. Peat contains 1 to 10% mineral matter (ash).

Borman & Ragland, p. 50.

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Structure of brown coal

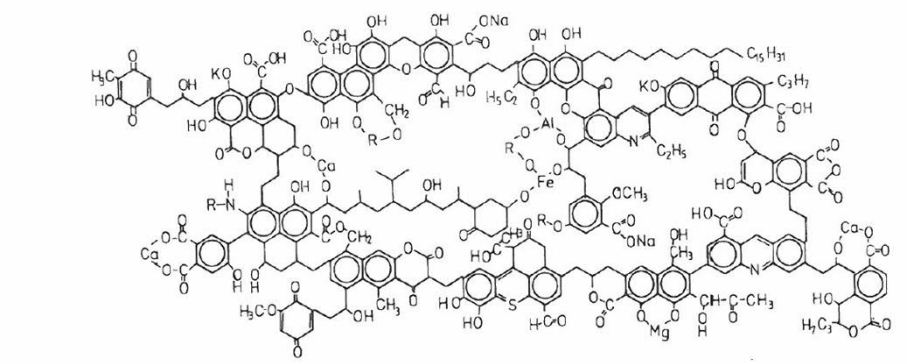

Figure 1 Proposed structural unit of Rheinische Braunkohle, comprising $C_{270}H_{240}N_3S_1O_{90}$

Source: K. J. Hüttinger & A. W. Michenfelder, Molecular structure of brown coal. Fuel 66 (1987) pp. 1164–1165.

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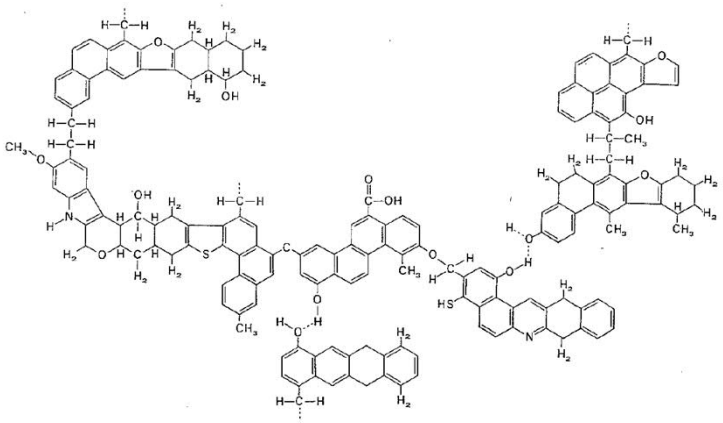
Structure of coal (generic)



Source: L. D. Smoot & P. J. Smith, Coal Combustion and Gasification, Plenum Press, 1985. p. 27.