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Optimizing Biorefineries

Austrian Stakeholder Workshop of IEA Bioenergy Task 42 "Biorefining"

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Content

- Downstream Processing in Biorefineries
  - „Lignozellulose Biorefinery“ (Wood and Straw)
    - Pretreatment
    - Separation processes
    - Membrane processes
- Process Optimization by Process Simulation
  - Mass- and Energy Balance
  - Exergy Analyses
  - Heat Integration (Pinch, HEN)
- Summery

- Upstream (e.g. Biomass collection)

- Pretreatment reactor
- Solid-liquid separation
- Washing (multistage)
- Concentration (e.g. membranes)
- Product purification
- Solvent recovery
- Concentrating liquid stream (MSEvap)
- By-product treatment

Lignozellulose

- Cellulose, Hemicellulose, Lignin, others
  - Cellulose: Polymer von β-(1-4)-Glucose (C6)
  - Hemicellulose: Polymer of various C5 and C6 sugars
  - Acetic acid
  - Lignin: Phenolic Polymer
  - Ash
  - „Extractives“



Lignocellulosic - Pretreatment

- Mechanical size reduction
- Physical-chemical pretreatment
  - Hydrothermal (hot water treatment)
  - „Steam Explosion“(SO_2, H_2SO_4, Organic Acids, CO_2,…)
  - Diluted acid treatment
  - Caustic treatment (lime, NaOH, NH3 (Ammonia fiber explosion AFEX)
  - CO_2 explosion
- Chemical pretreatment
  - Oxidation (O_2, O_3)
  - Sulfit (SPORL)- oder Sulfat (Kraft)- cooking
  - Organosolv
    - Alcell process (APR Prozess): countercurrent extraction using ethanol (60%) („Lignol“ delignification process)
    - Organocell process (MD Prozess): Methanol (50%) / NaOH
  - Ionic liquids
- Biological treatment (fungi)

Pretreatment Processes

Research Topics

- Mechanical size reduction
- Physical-chemical pretreatment
  - Hydrothermal (hot water treatment)
  - „Steam Explosion"(SO_2, H_2SO_4, Organic Acids, CO_2,…)
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Hot Water Extraction / Organosolv

Wheat Straw

Water or Ethanol/Water

→ **Pretreatment**

↓

Vakuum Filtration

↓

Centrifugation

↓

Solution

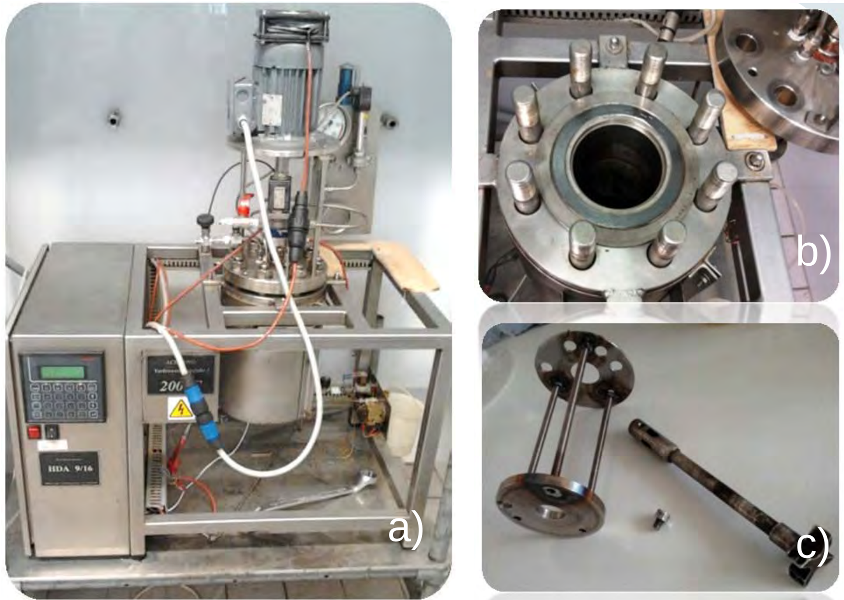


Fig. 6. High pressure autoclave (a) used, its reaction chamber (b) and stirrer (c) used in this study

Product T : 160-200°C

Shell T: 220°C

Treatment t: 30 -90 min

Ethanol/Water: 0-80/100-20

Solid:Liquid: 1:10

Particle Sice: 3 mm

Results - Hot Water Extraction / Organosolv

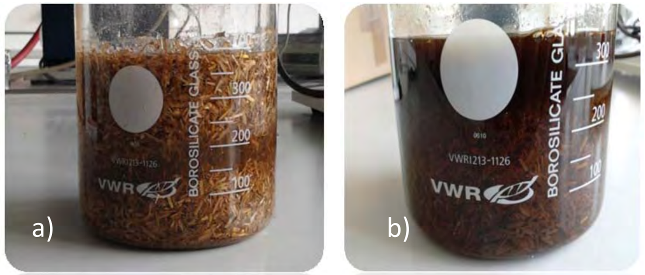
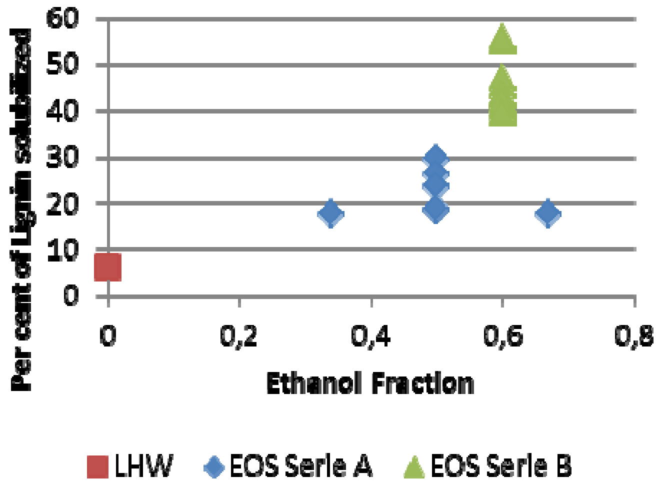
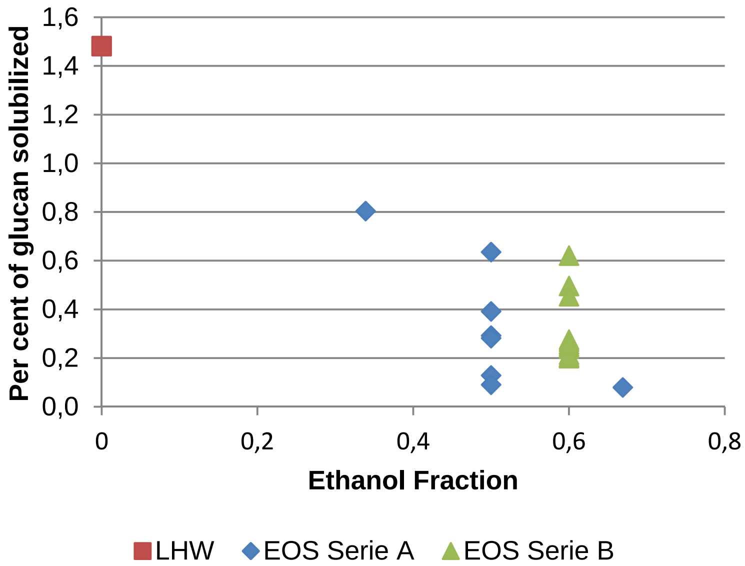
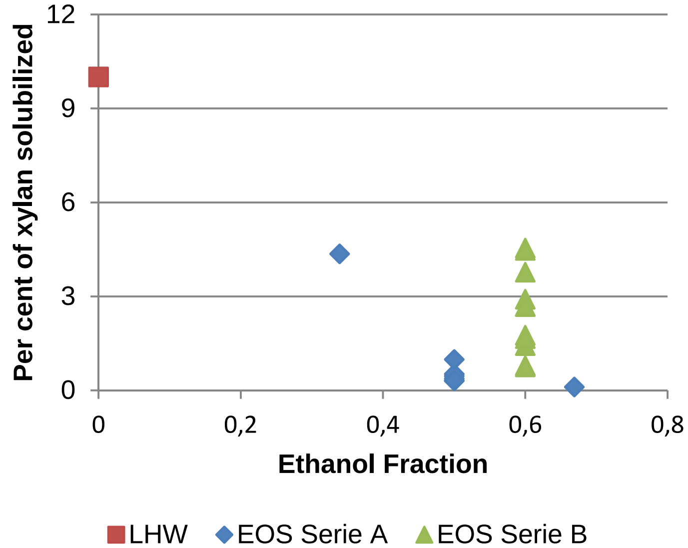


Fig. Mixtur for (a) und nach Behandlung (b).







Ref.: Weinwurm, Silva, Cunha TU-Wien 2010-12

Results – Organosolv / Lignin

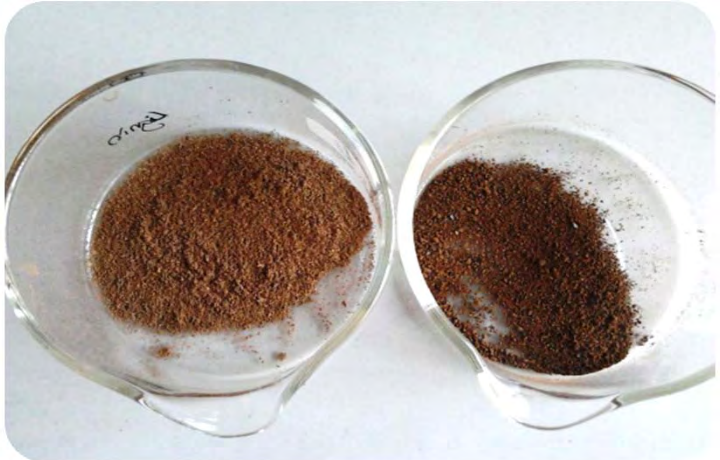


Fig. Lignin sample obtained
pH 1 (right) and pH 2 (left).

Lignin sample	*Polysaccharides content [%]*			***Purity** [%]**
	Uronic acids	**sugars**	**Total**	
pH 1 precipitate	0.6	2.1	2.8	**97,2**
pH 2 precipitate	0.8	4.5	5.3	**94,7**

* in terms of carbohydrates presence.

Ref.: Silva, Weinwurm, TU-Wien 2012

Goals

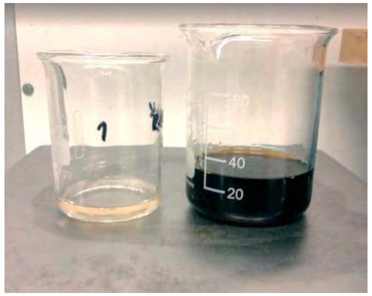
- Concentration of the solution prior to precipitation
- Solvent stable membranes
- Membrane processes
  - Ultrafiltration
  - Nanofiltration
  - Reverse Osmoses

Results – Organosolv / Membrane Separation

Membrane separation

- Ultrafiltration
- Nanofiltration

A - Retentat (left) and Permeat (right)



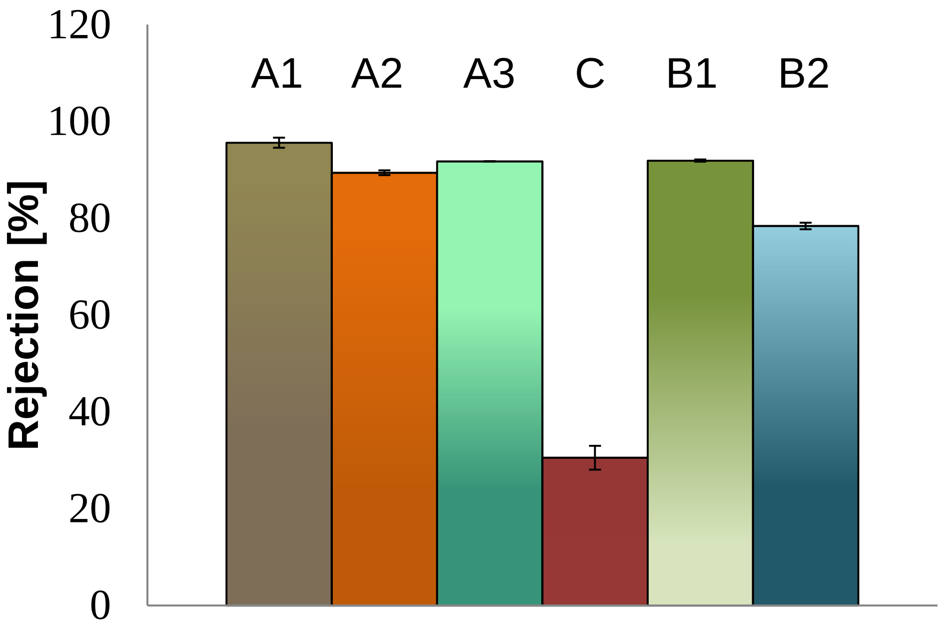
B - Permeat (left) and Retentat (right)

C - Permeat (left) and Retentat (right)

Ref.: Silva, Weinwurm, TU-Wien 2012

Results – Organosolv / Membrane Separation

Rejection Coefficient



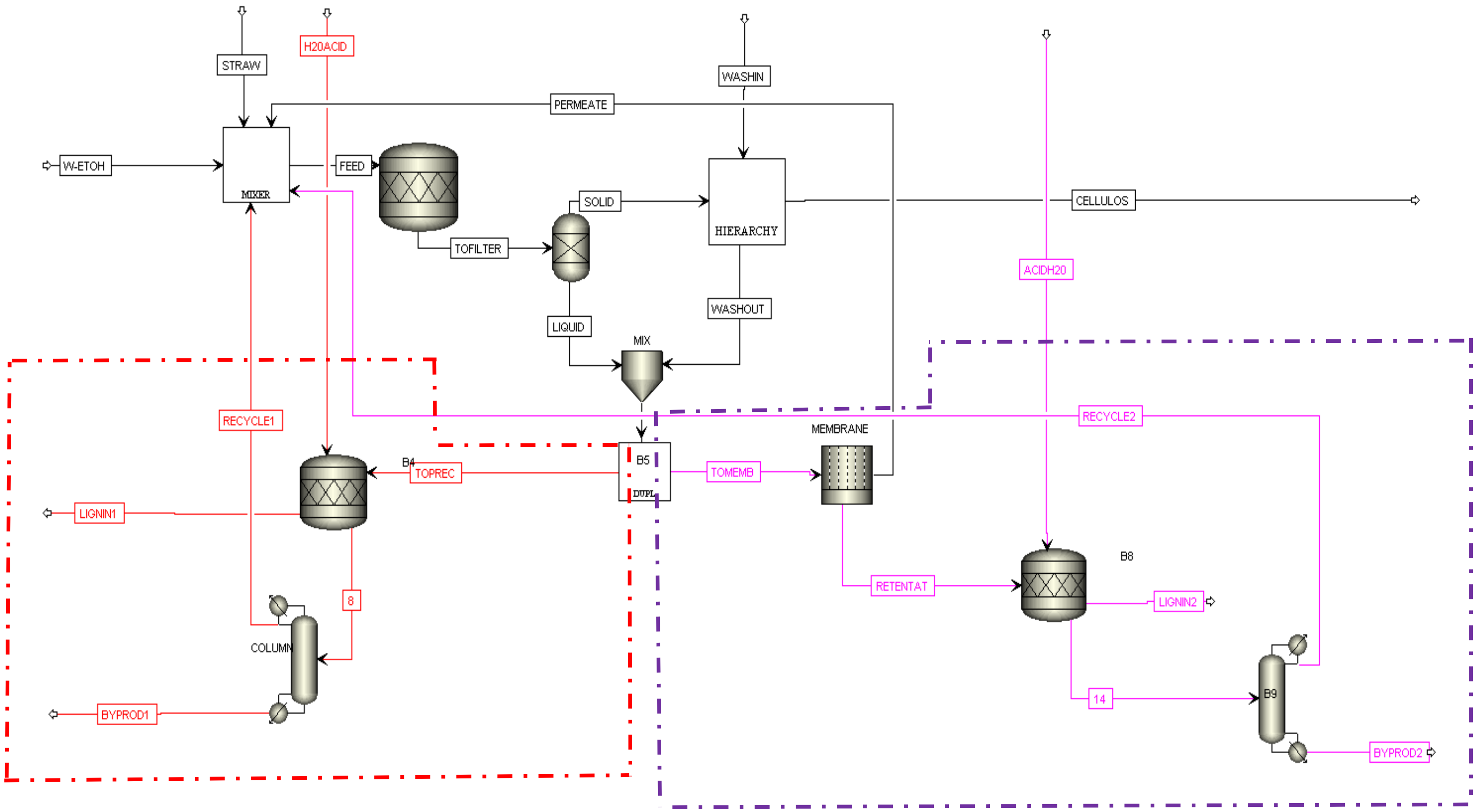
Example
before end after filtration

Example
before end after filtration

Ref.: Silva, Weinwurm, TU-Wien 2012

Process Optimization by Process Simulation

Process Optimization - Organosolv Prozess

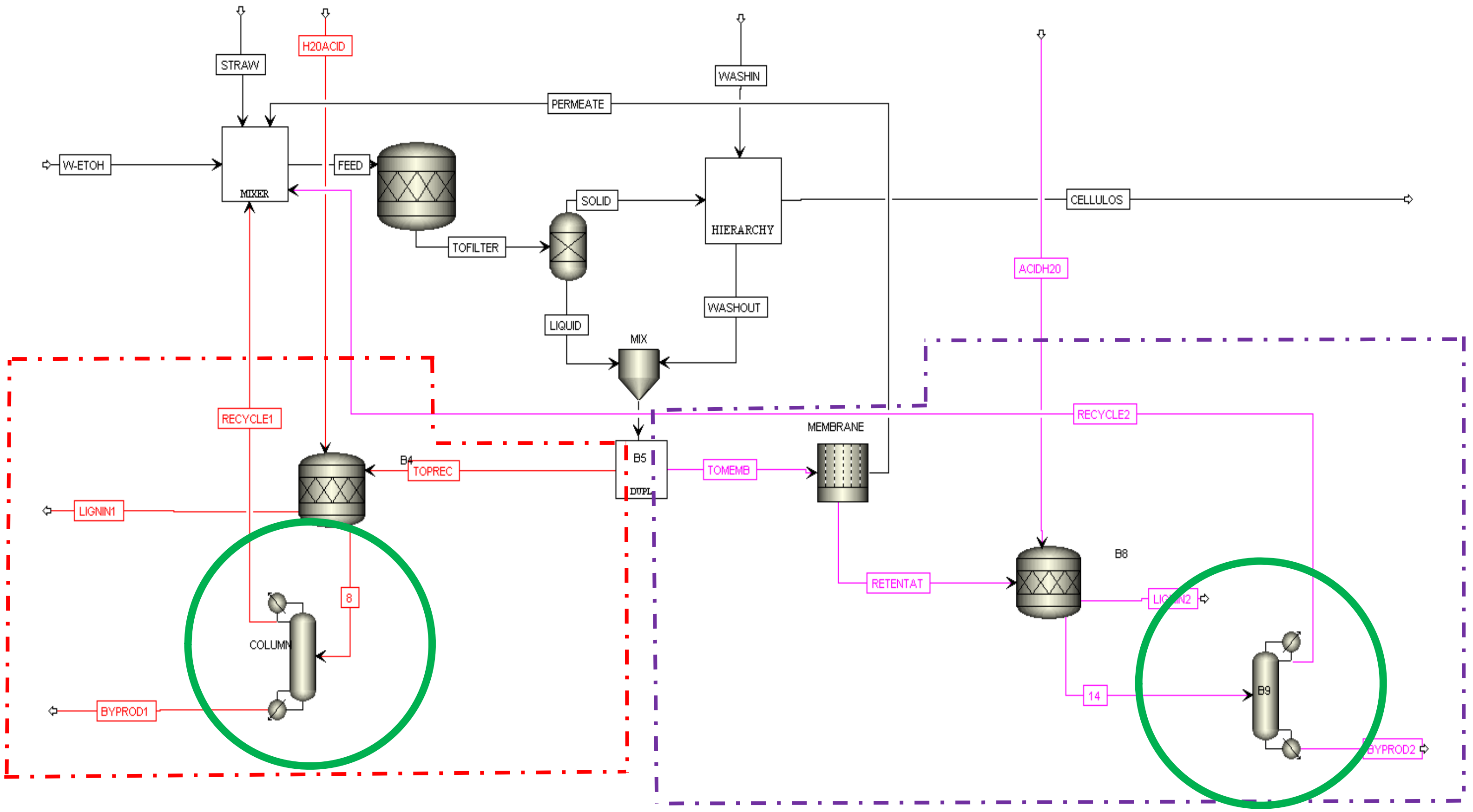


Option I, classical route

Option II, membrane process route

Ref.: Drljo, Wukovits TU-Wien 2012

Process Optimization - Organosolv Prozess



- - - Option I, classical route
- - - Option II, membrane process route

Ref.: Drljo, Wukovits TU-Wien 2012

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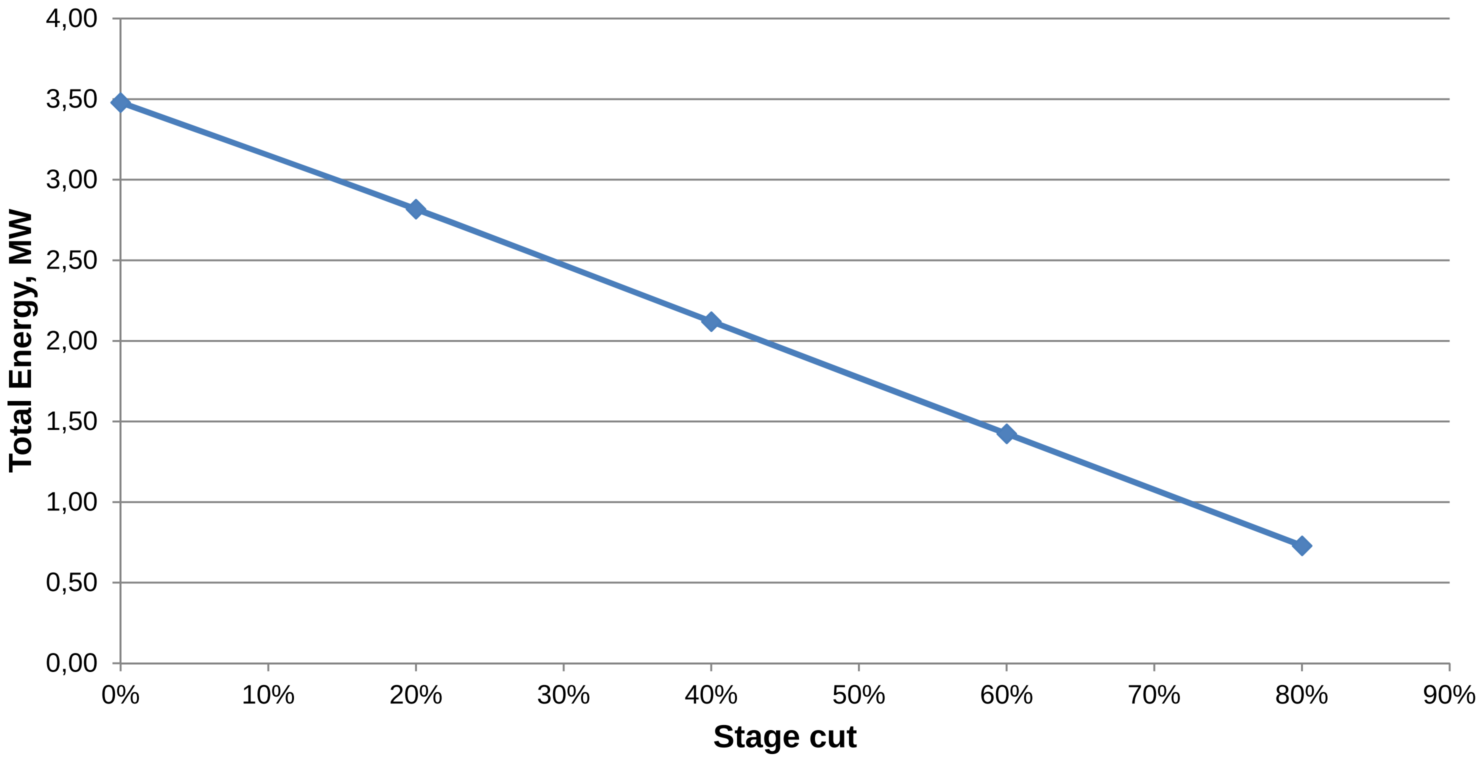
Membrane separation

Stage Cut: Permeate flow / Feed flow



Ref.: Drljo, Wukovits TU-Wien 2012

Summary

- Separation processes and closing cycles of treatment liquors are essential for the development of economical biorefineries.
- Processes simulation can support the optimization of biorefineries.

- For commercial products the product concentration and quality is very important – need for efficient separation and concentration processes (Research tasks)
- Improvement of process efficiency leads to closed process stream cycles and recovery of chemicals as well as process energy (Process development tasks)