LCA and simulation of a bioethanol process technology in development

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Outline

High-gravity production of biofuels

- Second generation biofuels using wood and wheat straw
- Economically feasible process → High gravity fermentation
  - Lower water use
  - Difficulties with mixing
  - High concentrations of end products and inhibitors

High-gravity production of biofuels

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- Economically feasible process $\rightarrow$ High gravity fermentation
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  - Difficulties with mixing
  - High concentrations of end products and inhibitors
- Use LCA along the process development path
  - To improve and/or optimize the process from an environmental life cycle point-of-view
  - To help guide the technology development by providing stakeholders the environmental hotspots during all stages

Technology development and scale

- Development "stages" with respect to system boundaries[1]
  - Process step → Scale-up of equipment
  - Process complex → Optimization of the complete process
  - Value chain → Inclusion of the upstream and downstream processes

[1] M. Shibasaki and S. Albrecht. *Proceedings of European Congress of Chemical Engineering (ECCE-6)*. 2007, p. 5.

Technology development and scale

- Development "stages" with respect to system boundaries[1]
  - Process step → Scale-up of equipment
  - Process complex → Optimization of the complete process
  - Value chain → Inclusion of the upstream and downstream processes
- Time and scale in technology LCA[2]
  - Shifting time frame → Room for technical development, affects performance data, perhaps functional unit
  - Change in background system related to time and scale of penetration

[1] M. Shibasaki and S. Albrecht. *Proceedings of European Congress of Chemical Engineering (ECCE-6)*. 2007, p. 5.
[2] K. M. Hillman and B. A. Sandén. *Int. J. Altern. Propul.* 2.1 (2008), pp. 1–12.

Process base case and alternatives

- Inbicon's IBUS process[3] in Kalundborg, Denmark
  - Feedstock is wheat straw
  - Hydrothermal pretreatment

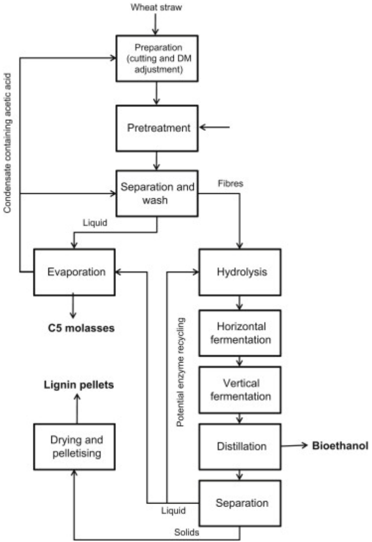
[3] J. Larsen, M. Østergaard Haven, and L. Thirup. *Biomass Bioenergy* 46 (2012), pp. 36–45.

Process base case and alternatives

- Inbicon's IBUS process[3] in Kalundborg, Denmark
  - Feedstock is wheat straw
  - Hydrothermal pretreatment
- Industrial-scale evaluation using raw lab data
  - Process calculations done in spreadsheet
  - Experimental set-up → 33 process options
    - Type of enzyme
    - Process configurations
    - Enzyme load
    - Solids content in the reactor
    - Additive to increase enzyme activity

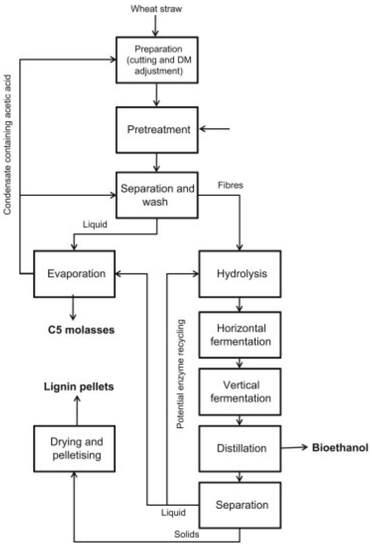
[3] J. Larsen, M. Østergaard Haven, and L. Thirup. *Biomass Bioenergy* 46 (2012), pp. 36–45.

Inventory analysis for straw-based ethanol production



Cultivation and harvest

Inventory analysis for straw-based ethanol production

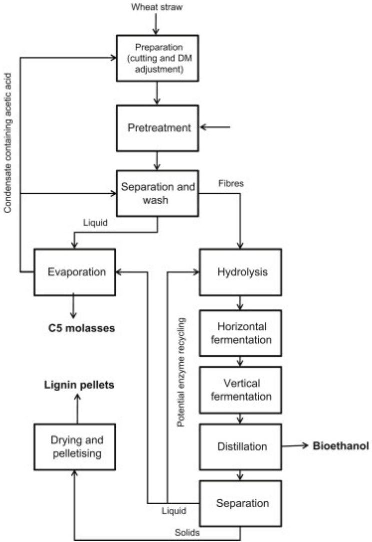


Cultivation and harvest

Preparation and pretreatment

- Conditions: p=15 bar, T=195 °C
- Lignin used as energy source

Inventory analysis for straw-based ethanol production



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Hydrolysis & fermentation

- Differences in conversion efficiency
- Yield as basis for mass balance

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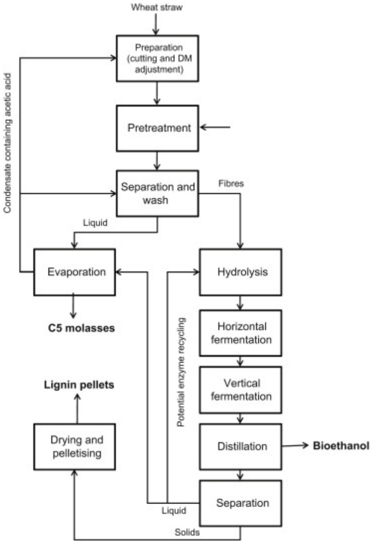

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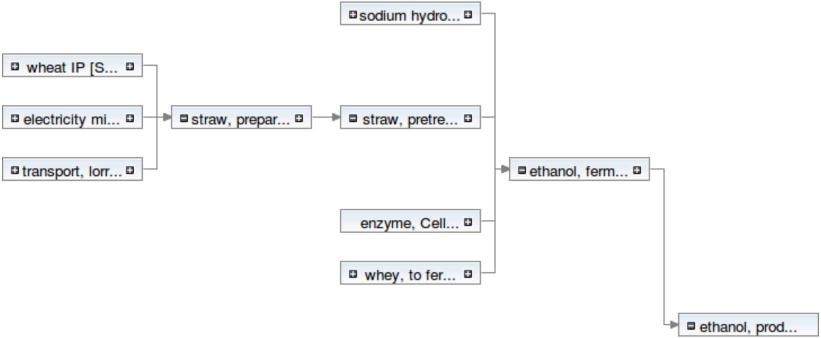
Downstream processing

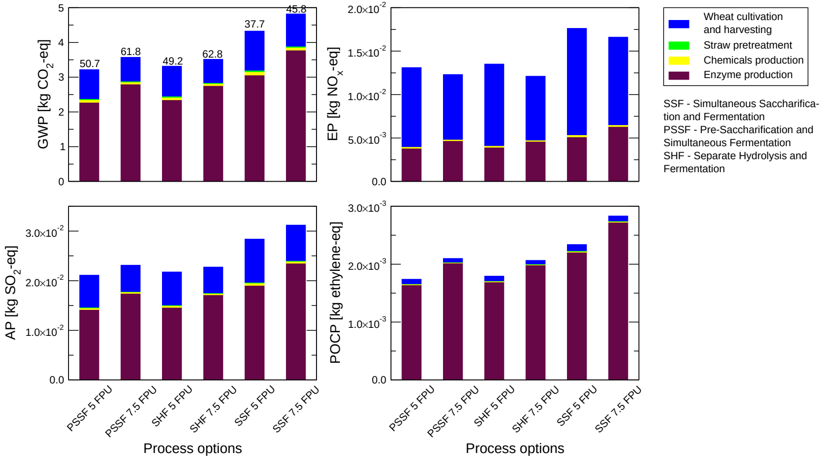
- Heat duty in distillation varies little at higher ethanol concentration
- Lignin used as energy source

Flow diagram in openLCA



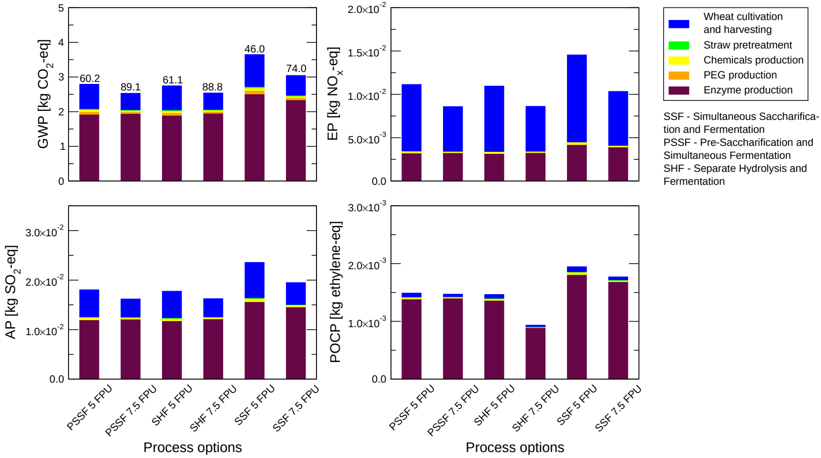
- Impacts calculated for the whole process

Results for 30% dry matter content



SSF - Simultaneous Saccharification and Fermentation
PSSF - Pre-Saccharification and Simultaneous Fermentation
SHF - Separate Hydrolysis and Fermentation

Results for 30% dry matter content, PEG added



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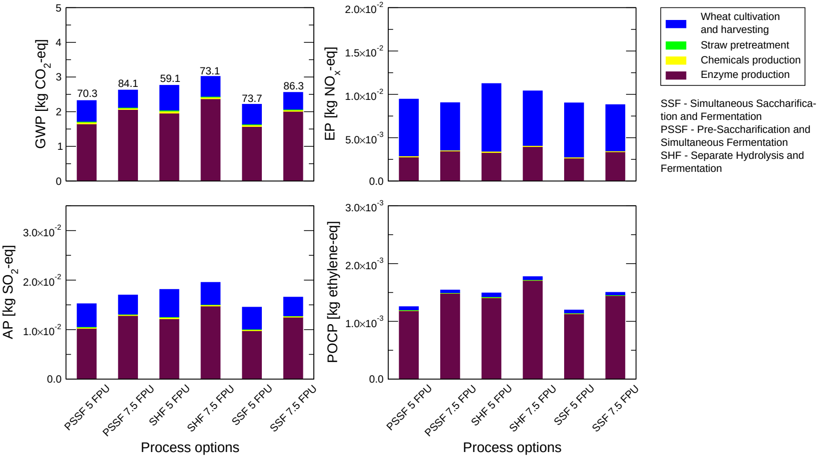
Results for 20% dry matter content



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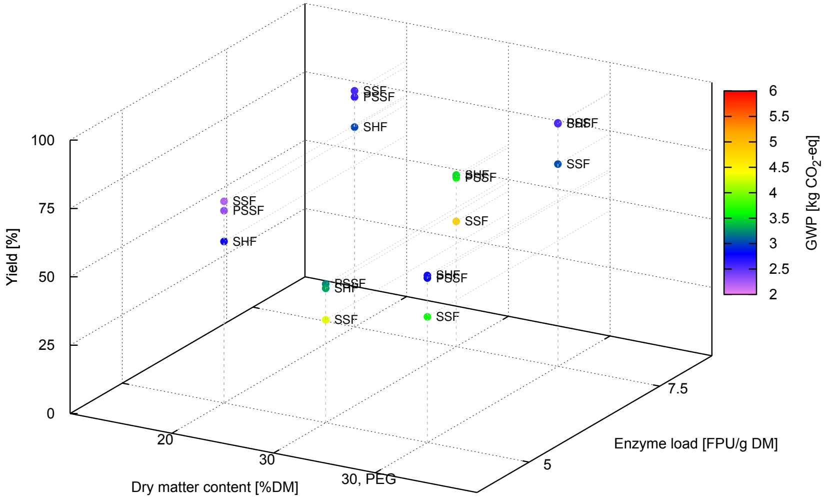
GWP, %DM vs. enzyme load vs. yield



Conclusion

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  - Enzyme use has a significant impact
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  - Enzyme use has a significant impact
  - Several trade-offs can be identified that influence environmental impact
- Related to scale-up
  - Equipment scale-up → Use data of industrial scale processes with similar characteristics
  - Complete system scale-up → Increased use of biomass
  - Level of detail needed at a very early development stage

THANK YOU

Any questions?