WP No 6
Name: Process chain design
Description and progress
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Biosynergy Workshop
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Objectives WP No.6

Identification of the most promising biorefinery chains for the European Union, and for some specific market sectors in terms of:

- Performance as yield and efficiency,
- Energy efficiency,
- Environmental performance as LCA,
- Cost as capital, operating and product costs
- Socioeconomics

Participants: Aston, ECN, IFP, CRES, JR, JRC, Cepsa

Collaboration: ABNT
Methodology

• Construct a comprehensive and representative suite of biorefinery processes

• Evaluate these processes in terms of:
  • Performance in yield and energy balance – this requires mass and energy balances to be constructed, and at least minimal energy integration to be included
  • Cost – the capital and operating costs
  • Environmental performance as LCA and impact assessment
  • Socioeconomic assessment in terms of employment and investment
Evaluation of 27 biorefinery concepts by Performance, Economics, Environment, Social, MCDA
Large number of feedstock, process and product options leads to an even larger number of possible combinations.

Example:

• 2 feedstocks, 4 pre-treatment options, 2 C6 conversion options, 5 C5 conversion options, 4 lignin utilisation options
• Possible combinations = 2 x 4 x 2 x 5 x 4
  = 320

It is clear that there is a requirement for a logical and consistent methodological procedure for generating and comparing biorefinery process chains.
Methodology - overview

Consists of three steps

1. Chain generation (Process Synthesis)

2. Process modelling + data collection
   i. Mass and energy balances
   ii. Cost estimation
   iii. Environmental LCA
   iv. Socioeconomic

3. Chain evaluation and comparison (MCDA)
Mix and match process modules

PRE-TREATMENT
- B1 STEAM EXPLOSION
- B2 AVDEL
- B3 ORGANOSOLV
- B4 MECHANICAL/ALKALINE
- B5 CONC. HCL
- B6 AQUATHERMOLYSIS + FURTHER TREATMENT

C3
- H1 ENZYMATIC HYDROLYSIS + FERMENTATION TO ETHANOL
- H2 FERMENTATION TO ABE
- H3 FDA PRODUCTION

C5 + C6
- K1 ENZYMATIC HYDROLYSIS + FERMENTATION TO ETHANOL
- K2 ABE FERMENTATION

LIGNIN
- L1 FAST PYROLYSIS
- L2 LIGNIN GASIFICATION + GAS CLEANING
- L3 LIGNIN COMBUSTION
- L4 LIGNIN DIRECT RESIN

THERMO-CHEMICAL
- T1 GASIFICATION (for alcohol synthesis)
- T2 GASIFICATION (for FT synthesis)
- L1 FAST PYROLYSIS

SYNTHESIS
- S1 ETHANOL SYNTHESIS
- S2 HYDROCARBON SYNTHESIS
- S3 HYDROTREATING BIO-OIL
- S4 PHENOLIC FRACTIONATION

REFINING
- R1 ETHANOL DISTILLATION
- R2 ABE PERVAPORATION
- R3 MIXED ALCOHOL DISTILLATION
- R4 FURFURAL DISTILLATION

U1 HEAT AND POWER
Methodology - overview

Consists of three steps

1. Chain generation (Process Synthesis)

2. Process modelling + data collection
   i. Mass and energy balances
   ii. Cost estimation
   iii. Environmental LCA
   iv. Socioeconomic

3. Chain evaluation and comparison (MCDA)
Module inputs/outputs
With in-built logic rules
Biorefinery concepts

- 27 complete biorefinery concepts chosen by partners
- Biorefinery concepts using technologies and feedstocks from within the project with a number of other technologies for comparison
- Evaluated in terms of efficiency, cost, environmental and socio-economic performance
- Data provided by project partners or from the literature
- Validation carried out to ensure the accuracy of the models
- Possible with the methodology to investigate many more
Socio-economic assessment

- Employment
  - Direct
  - Induced
- Agriculture and land assessment
  - Consumption as % regional and national production
  - Land required (ha)
  - Land required as % of regional and national agricultural land
- Trade assessment
  - Revenue from traded feedstock and products
  - Revenue from traded feedstock and products as % of national GDP
Life cycle impact assessment

1. **Global Warming Potential** [t CO₂-eq.]
2. **Cumulated Primary Energy Demand** [GJ]
3. **Acidification Potential** [t SO₂-eq.]
4. **Eutrophication Potential** [t P-eq.]
5. **Photochemical Ozone Creation Potential** [t C₂H₄-eq.]
6. Abiotic Depletion
7. **Freshwater Aquatic Ecotoxicity Potential**
8. **Marine Aquatic Ecotoxicity Potential**
9. **Terrestrial Ecotoxicity Potential**
10. **Human Toxicity Potential**
11. **Ozone Layer Depletion Potential**
1) Biomass Feedstock Chains
2) Biorefinery Processes
3) Auxiliary energy/materials Chains
4) Distribution, use and end of life

Reference system
5) Reference Energy Chains
6) Reference Product Chains

Energy services
Product services
Methodology - overview

Consists of three steps

1. Chain generation (Process Synthesis)

2. Process modelling + data collection
   i. Mass and energy balances
   ii. Cost estimation
   iii. Environmental LCA
   iv. Socioeconomic

3. Chain evaluation and comparison (MCDA)
MCDA – Multi Criteria Decision Analysis – was used to compare concepts.

- Provides a technique to measure the extent that each biorefinery achieves desired objectives such as lowest capital cost, highest efficiency, best LCA etc.
- The method considers all criteria.
- The “scores” for each concept come from the modelling processes.
- Each criterion is weighted according to their perceived importance.
- The result is a set of scored concepts ranked according to objective set by weighting.
Chain comparison - criteria

- Which biorefinery
  - Profit/loss
  - Conversion efficiency
  - Environment
  - Socio-economics
    - 8 sub-criteria including GWP
    - 5 sub-criteria including employment
Weighting

- Different weightings applied to criteria according to particular objective
- Examples for this project:
  - Equal weighting
  - Techno-economic weighting
  - Enviro-socio weighting
Conclusions

• Most promising biorefineries:
  • Produce specialty chemicals in addition to ethanol
  • Simple processing routes
  • Those that utilise all fractions of the biomass producing only value added products

• Least promising biorefineries:
  • Poor conversion efficiency combined with -€ loss
  • Those with a high heat and power demand, heat/power provision becomes expensive and biomass requirement too high
  • To produce only heat and power from biomass not cost effective
Overall project results

- Flexible, modular, process synthesis methodology
- Will enable the generation, analysis and comparison of biorefinery process chains
- Result will be the identification of the most promising biorefinery process chains
- Most promising could mean:
  - Most cost effective
  - Most environmentally friendly
  - Highest efficiency
- Provides some clear directions for R&D in short, medium and long term
- The system may be expanded to include many more process options in the future
Thanks for listening!
Questions?