CATFUR: CATalytic conversion of lignocellulose by an Organosolv process into FURan derivatives

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Introduction

The production of transportation fuels and chemicals from lignocellulosic biomass are being considered as promising alternatives to its non-renewable, fossil based counterparts. The use of biomass could have a significant effect in reducing greenhouse gas emissions (GHG) associated with climate change; reducing non-renewable energy use; increasing concerns over security of supply; and meeting a growing demand of consumers for green and bio-based products.

The CATFUR project focuses on the combination of Organsolv and Furanics technologies to produce furan based fuels, such as furfuryl ethyl ether (FEE) and furan based monomers for bio-polymers, such as polyethylene furanoate (PEF).

Process

A conceptual process design is presented of the Organosolv-Furanics biorefinery. Through the Organosolv technology, lignocellulosic biomass is fractionated into its constituents of cellulose, hemicellulose and lignin. The carbohydrates are then converted into furan derivatives through an efficient, low cost catalytic process, followed by a recovery and upgrading section. The feedstock considered in this study is wheat straw. The target intermediates of 5-hydroxymethyl furfural (HMF) and HMF ethers are oxidized to produce 2,5-furandicarboxylic acid (FDCA), which in turn is converted into PEF by polymerization with bio-based ethylene glycol. Furfural is hydrogenated to produce furfuryl alcohol, which in turn is converted into FEE using bio-based ethanol. Any waste streams in the process, such as lignin and carbohydrate derived humins, are led to a CHP for onsite steam and electricity production.

Methodology

The conceptual process design is modeled using the ASPEN Plus software and is based on experimental data. The mass and energy balance data of the design is used to assess the energy and GHG balance performance of the production of PEF and FEE. This assessment is based on the cradle-to-grave approach and considers all flows of materials and energy throughout the PEF and FEE life cycle, where allocation has been performed on mass basis. Bio-based carbon embodied in PEF and FEE is considered neutral and not accounted for in the GHG balance.

Results & conclusions

Due to the chosen allocation method (mass basis), both PEF and FEE have similar impacts in terms of energy use and GHG emissions.

The production of PEF from lignocellulosic biomass results in a combined renewable and non-renewable energy use of 66.91 GJ/tonne PEF, of which 96% is bio-based (the calorific energy content of PEF and the process energy provided by the CHP, represented by the green bars in figure 3). The production of FEE results in a combined renewable and non-renewable energy use of 54.46 GJ/tonne FEE, of which 92% is bio-based. The CHP provides more energy than can be used onsite and this excess is converted into electricity and sold to the grid and a credit is given (represented by the blue bars in figure 3).

The production of PEF and FEE from lignocellulosic biomass can bring about significant reductions in non-renewable energy use and GHG emissions.

Further research

Further research will include a detailed economic analysis, followed by a complete life cycle assessment (LCA) study, including land use change (direct and indirect) and other environmental impact categories, such as eutrophication, acidification and human toxicity.

Acknowledgements

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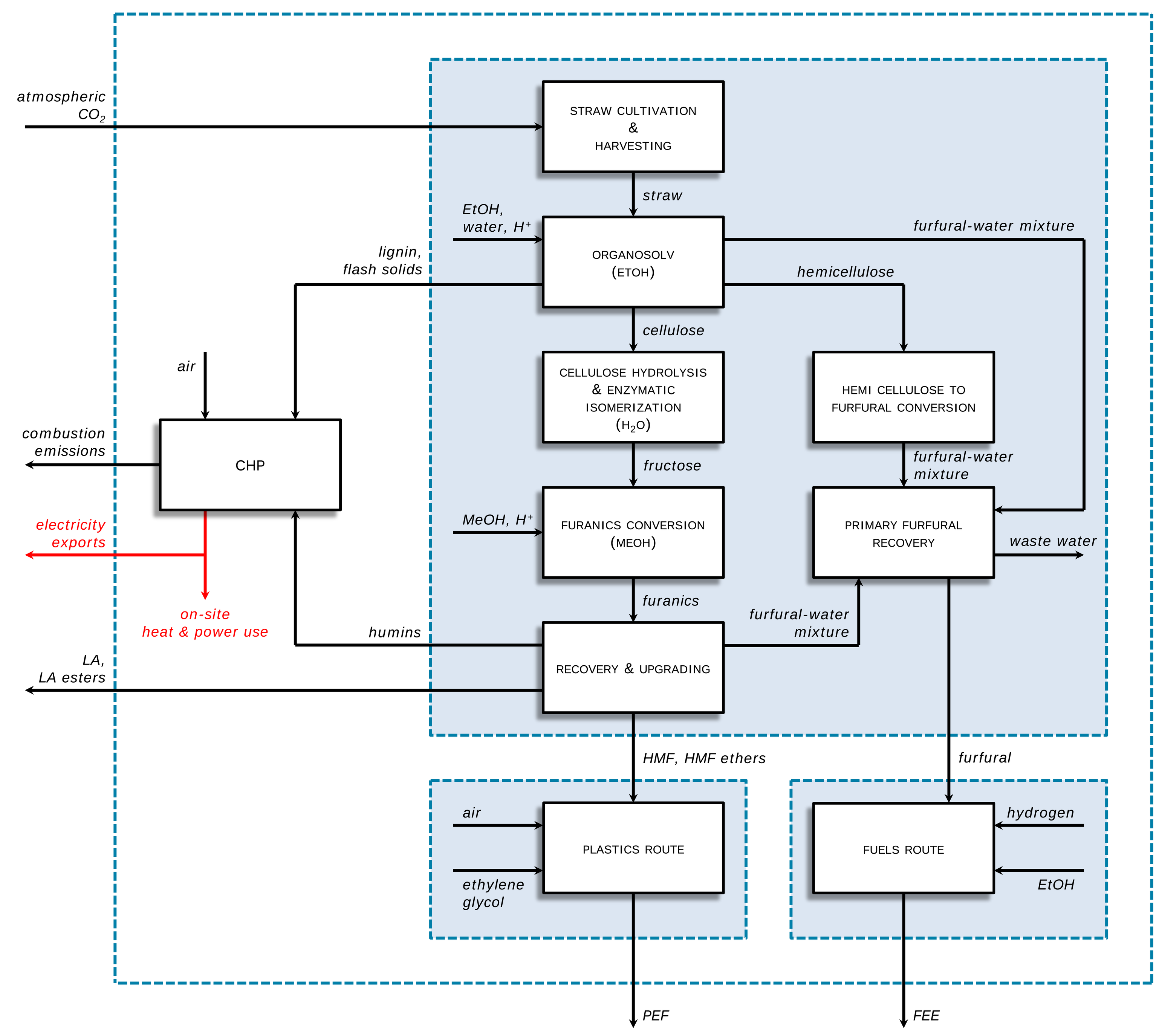

Figure 1: conceptual process design of the CATFUR biorefinery

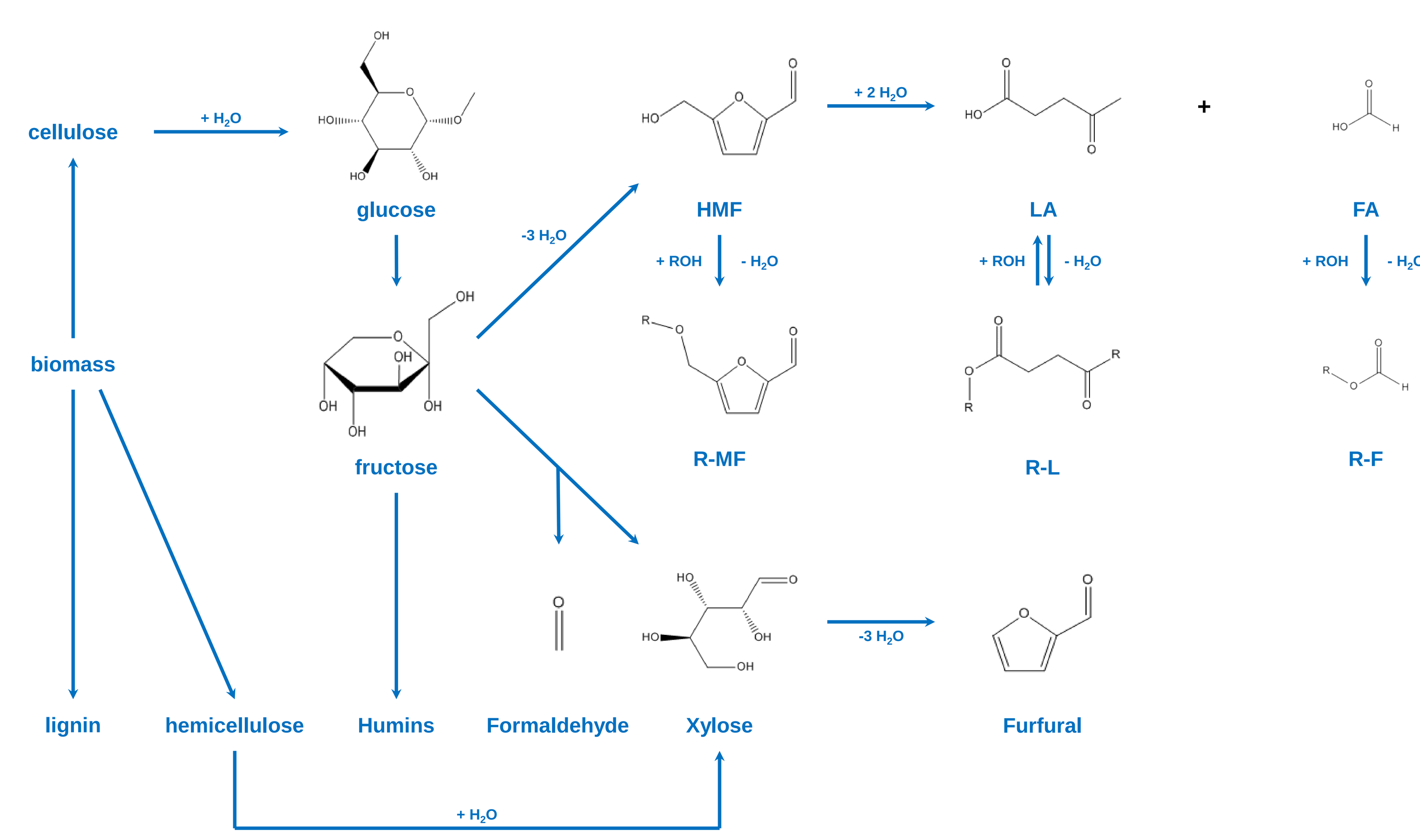

Figure 2: graphical representation of the reactions involved to produce HMF, HMF ethers and furfural from lignocellulose

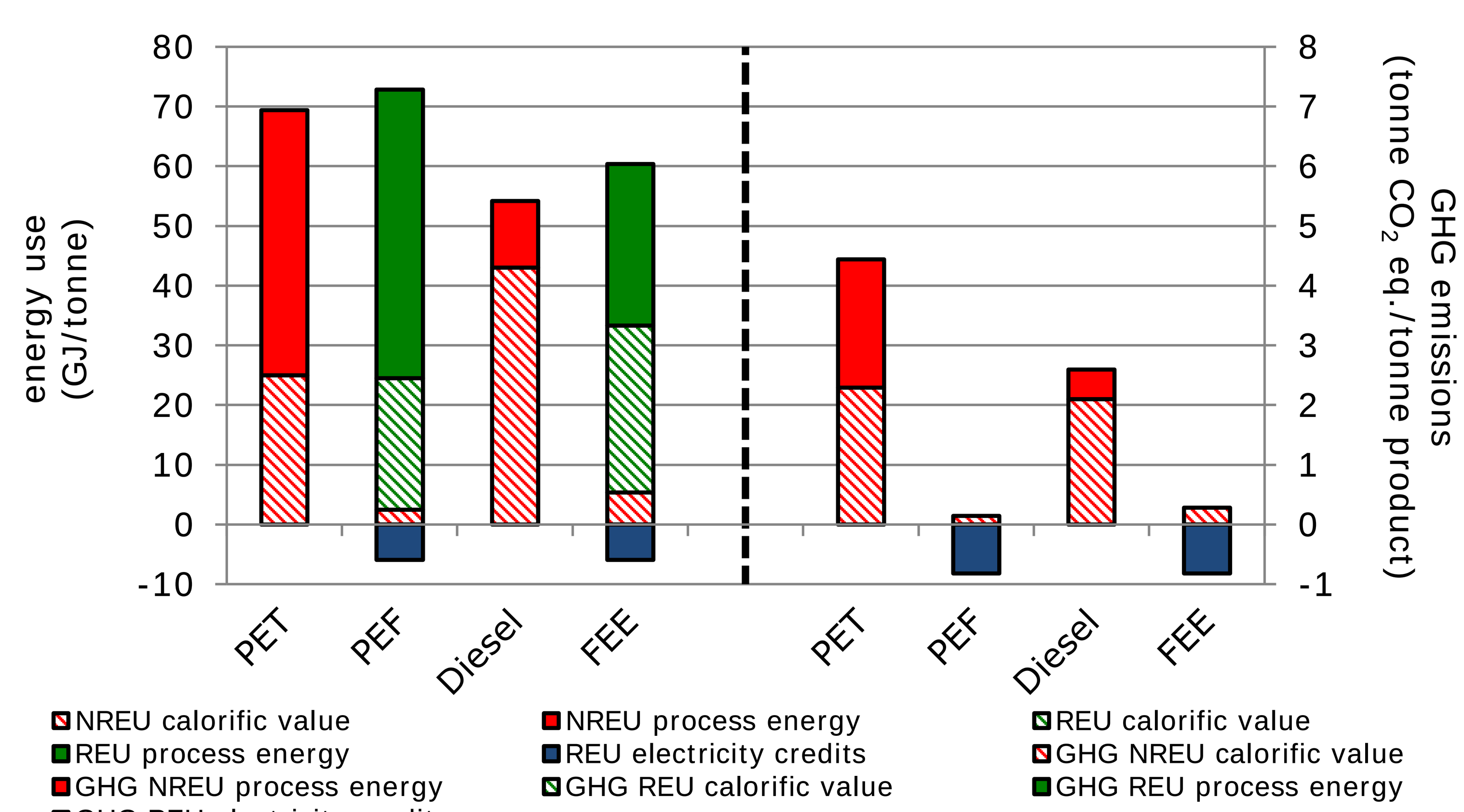

Figure 3: results of the energy use and GHG balance assessment of PEF and FEE vs. its fossil based counterparts PET and diesel

References

A.J.J.E. Eerhart, A.P.C. Faaij & M.K. Patel, *Replacing fossil based PET with biobased PEF; process analysis, energy and GHG balance*, Energy & Environmental Science, 2012, **5**, 6407-6422

G.J.M. Gruter, I. Sipos & M.A. Dam, *Accelerating research into bio-based FDCA-polyesters by using small scale parallel film reactors*, Combinatorial Chemistry & High Throughput Screening, 2012, **15**, 180-188

E. de Jong, T. Vijlbrief, R. Hijkoop, G.J.M. Gruter & J.C. van der Waal, *Promising results with YXY diesel components in an ESC test cycle using a PACCAR diesel engine*, Biomass and Bioenergy, 2012, **36**, 151-159