Energy and GHG emission balance of Furanics-based biopolyesters †

Universiteit Utrecht
[Faculty of Science
Chemistry]

A.J.J.E. Eerhart ‡, A.P.C. Faaij and M.K. Patel
Dept. Science, Technology and Society (STS), Copernicus Institute - Faculty of Science, Utrecht University
‡ a.eerhart@uu.nl | +31 30 253 5144

♦ Introduction

In 2004, the U.S. Department of Energy identified twelve sugar-based building blocks which hold the greatest potential for the production of biobased chemicals and materials. One of these building blocks is 2,5-furandicarboxylic acid (FDCA), which could play a key role because it could replace petrochemical purified terephthalic acid (PTA). PTA is widely used as the main component in polyesters, such as polyethylene terephthalate (PET) and polybutylene terephthalate (PBT) and typically accounts for 80% of the mass in the polyester.

This study focuses on polyethylene furandicarboxylate (PEF) which is considered as a fully biobased alternative to petrochemical PET. The goal of this study was to determine the non-renewable energy use (NREU) and greenhouse gas (GHG) emissions of partially (only FDCA) and fully biobased PEF, using currently available process information.

♦ Methodology and process overview

The study is based on the cradle-to-grave approach and considers all flows of materials and energy throughout the PEF life cycle, excluding the use phase. The feedstocks considered in this study were corn based fructose and high fructose corn syrup (HFCS). The production of PEF can be divided into four main units (Figure 1).

The production of fructose and HFCS was based on literature, while the conversion of fructose and HFCS to FDCA was modeled using the ASPEN Plus modeling software. The oxidation of Furanics to FDCA and its subsequent polymerization to PEF were estimated by analogy with the conventional petrochemical production of PET from *p*-xylene and PTA.

Next to FDCA, the Furanics conversion process also produces levulinic acid (LA) and LA esters in sufficient quantities to justify recovery. Therefore the need arises to partition (allocate) the NREU and CO_2 emissions to FDCA and to the by-products. This partitioning is done on mass basis.

♦ Results and conclusions

The production of PEF from fructose and HFCS can reduce the NREU and GHG emissions by 51% to 54% when compared to its petrochemical counterpart PET. The NREU and GHG can be further reduced by using biobased ethylene glycol (EG) in the polymerization process. Reduction levels that can be reached then are 63% to 68% for maize based EG and 74% to 76% when using sugar cane based EG (represented by the error bars in PEF+). These high reduction levels are very promising compared to other biobased plastics such as polytrimethyl terephthalate (PTT), polyhydroxyalkanoate (PHA) and poly lactic acid (PLA).

♦ Further research

Next to partitioning based on mass, economic partitioning based on market prices will also be applied. Further research will also include a sensitivity analysis on indirect land-use changes (iLUC) associated with the use of a corn based sugar feedstock and could have a negative influence on the GHG emission reduction levels presented here. Finally, the use of lignocellulosic feedstock for the production of Furanics-based polyester from cellulose, as well as the production of Furanics-based biofuels from hemicellulose will be investigated.

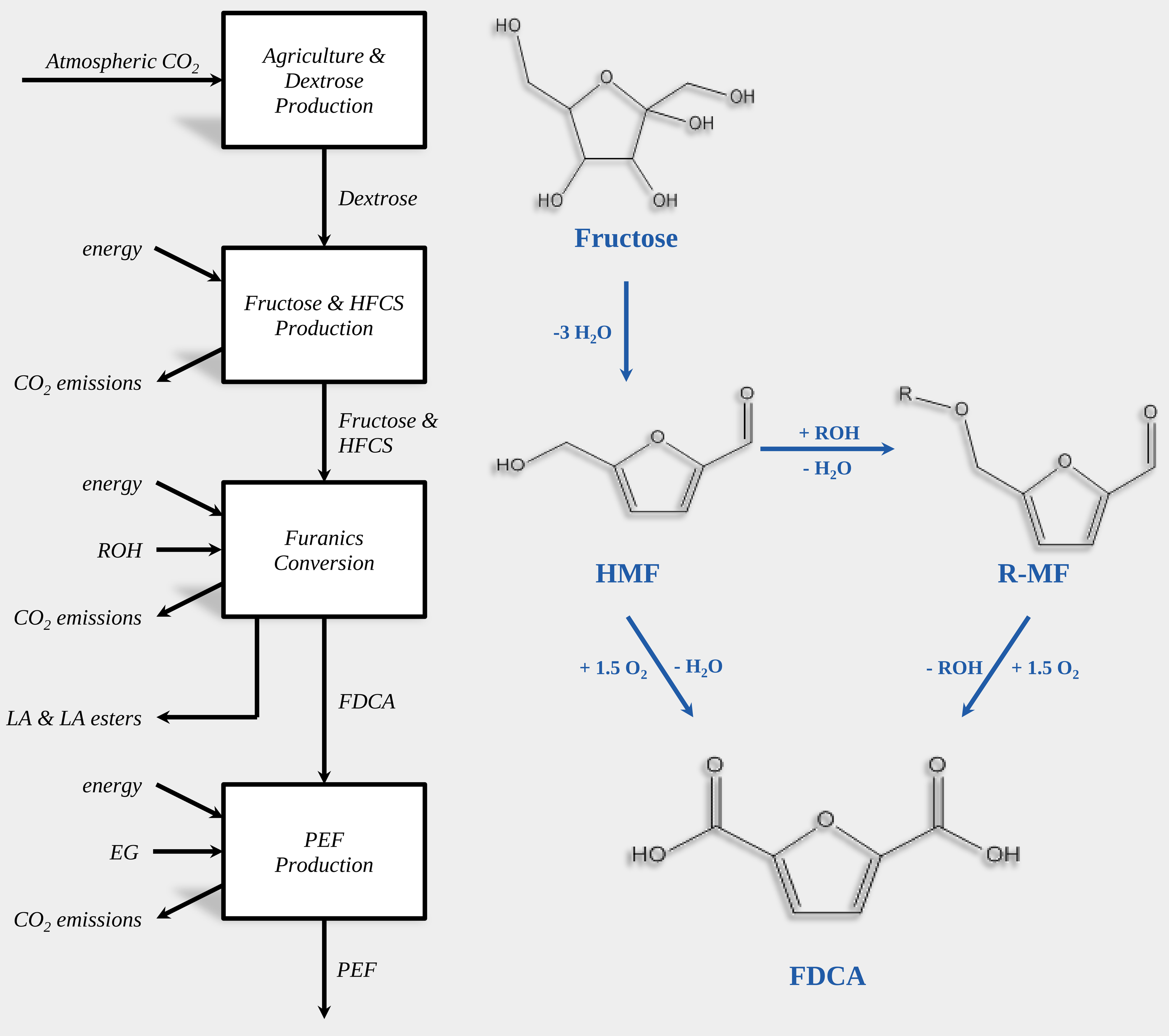

Figure 1: Process overview for the production of PEF

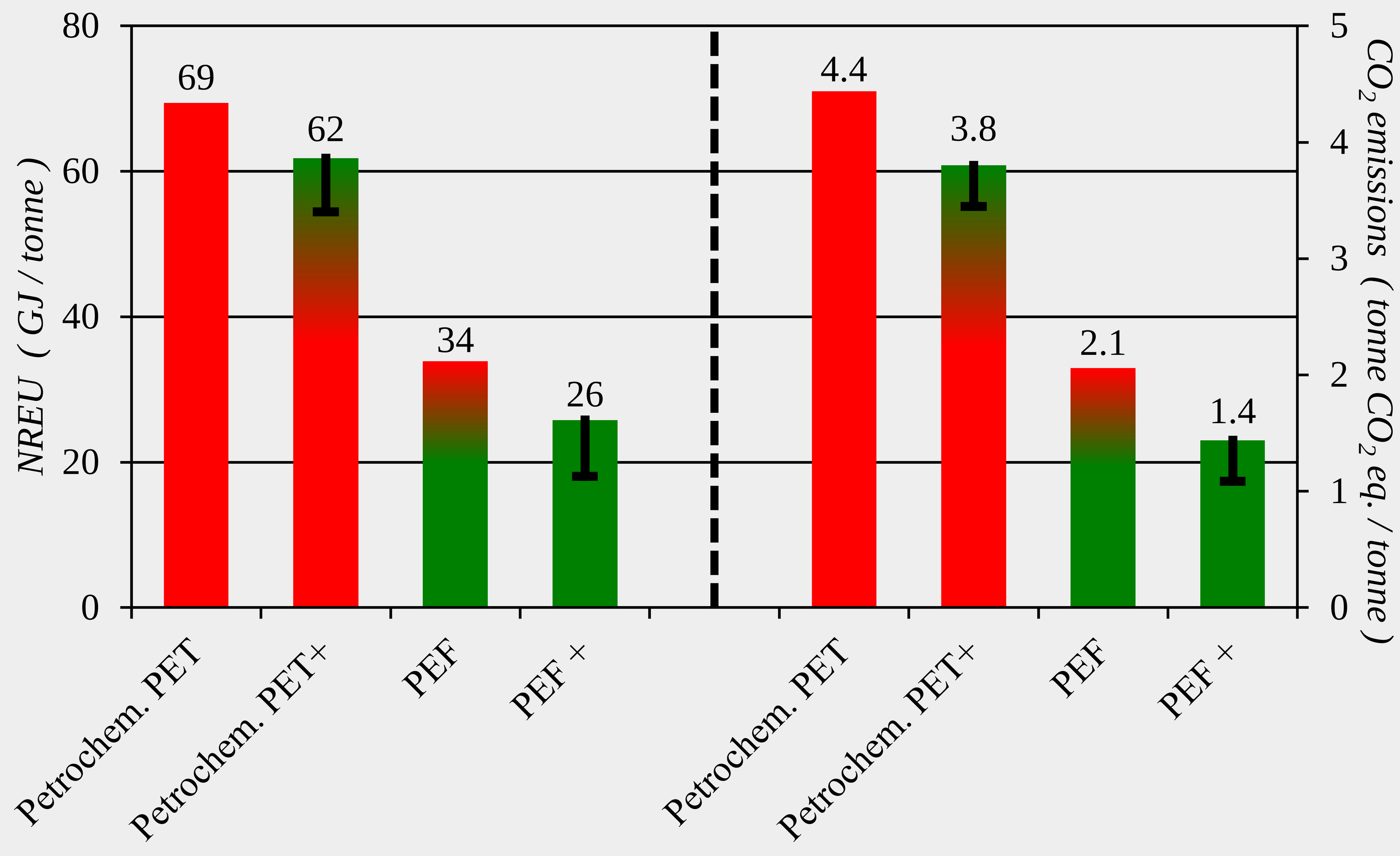

Figure 2: Comparing PEF with PET

| PET = petrochemical PTA and EG | PET + = petrochemical PTA and biobased EG (maize or sugarcane) |
| PEF = biobased FDCA and petrochemical EG | PEF + = biobased FDCA and biobased EG (maize or sugarcane) |
| The production of fructose and HFCS is based on U.S. corn |

♦ Acknowledgements

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