# Designing of Circular Economy solutions and sustainability of agricultural products with life cycle assessment

Tomasz Nitkiewicz

[1] *Department of Business Informatics and Ecosystems, Częstochowa University of Technology, tomasz.nitkiewicz@pcz.pl*

## Introduction

Circular Economy practices can offer opportunities for reducing emissions and waste generation in the agricultural sector through the circulation of raw materials, agricultural waste, and manure (Jurgilevich et al., 2016). The agricultural sector is particularly concerned by CE, as current food production and consumption habits are unsustainable (Barros et al., 2020; Donner, Verniquet, Broeze, Kayser, & De Vries, 2021; Jurgilevich et al., 2016). The European Circular Economy Action Plan has defined food waste as a priority area of developing CE (EC, 2015). Food is wasted all along the food supply chain, in Europe mostly at the consumption stage (FUSIONS, 2016), but for some groups of agricultural products also in primary production or processing and manufacturing stages (Caldeira, De Laurentiis, Corrado, van Holsteijn, & Sala, 2019). In this context, the CE represents a promising strategy for saving relevant resources and reducing agricultural activities' negative environmental impacts while improving economic and preferably social performance (Kuisma & Kahiluoto, 2017; Stegmann, Londo, & Junginger, 2020; Velasco-Muñoz, Mendoza, Aznar-Sánchez, & Gallego-Schmid, 2021).

## Research case

Figure 2 presents simplified life cycle scenario of waste rapeseed oil to P(3HB) biopolymer. Life cycle could be divided into two different phases: rapeseed oil life cycle and its end-of-life processing to get P(3HB) biopolymer. This latter phase is crucial for closing the loop by using waste oil it as by-product. The objective here is to recover its value from used oil and direct the life cycle towards circularity. Additionally, this scenario could provide economically, socially and environmentally sound solutions to match CE requirements. It is important to mention that there are multiple possibilities in end-of-life processing of used oil and not all of them are considered here. *The functional unit* for the study is defined as **a life cycle 1 kg of P(3HB) biopolymer produced from used rapeseed oil in an experimental manufacturing process**. In order to give full coverage for possible life cycle impacts and include global as well as European perspective the ReCiPe method is used for the assessment. The impacts are calculated with SimaPro software and the endpoint variant of ReCiPe (H) V1.08 indicator (Figure 1).

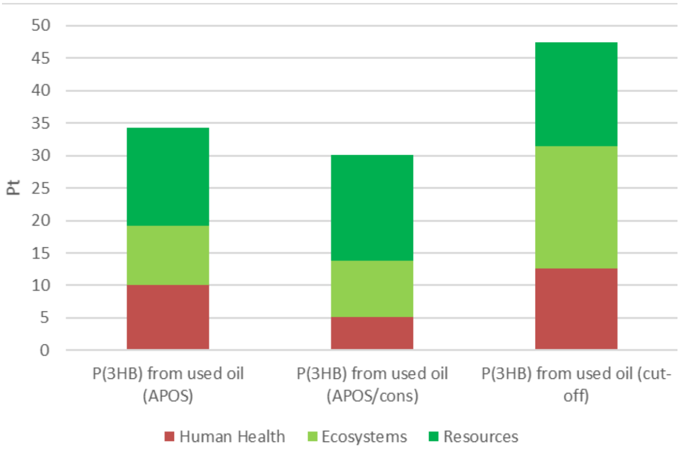


*Figure 1. Weighted ReCiPe damage category endpoint indicators for P(3HB) calculation approaches*

The key factor of life cycle modelling of CE solutions is related to allocation process in LCA that could take form of one of the following:

- **"cut-off" approach**, where end-of-life and side-product processes are excluded from the assessment,
- **allocation at the point of substitution**, where all the end-of-life processes are included in the assessment,
- small scale and long-term **consequential approach**, where the allocation at the point of substitution approach is used but system boundaries are extended to cover indirect impacts as well.

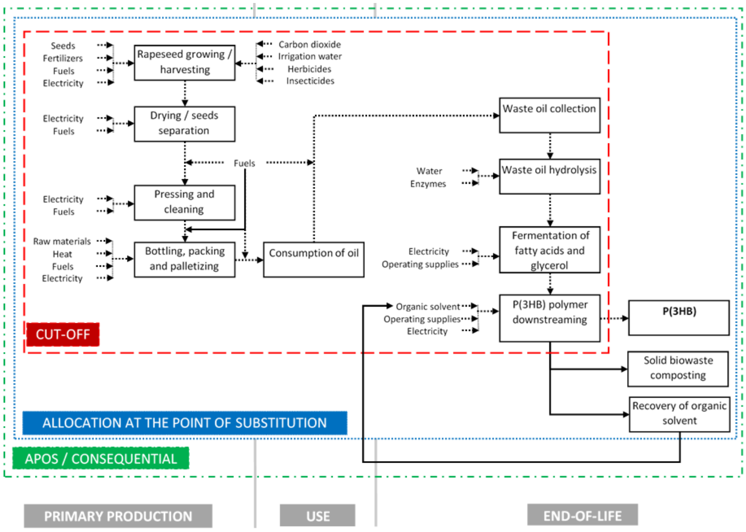


*Figure 2. Schematic presentation of waste oil to P(3HB) life cycle with regard to different allocation approaches*

Comparing the results of different calculation set-ups that are included in the study brings out significant differences. Cut-off scenario does not include the possible environmental benefits from recovering biopolymers (only impact of its processing are included) and, therefore are the worst scenarios while environmental impacts are concerned. The difference between the scores of cut-off and two remaining scenarios is quite significant. The difference between APOS and APOS/Consequential scenarios is rather slight and occurs mainly due to attributing all the positive impacts of biopolymers recovery to the LCIA results. Also, the difference occurs with the inclusion of organic solvent recovery, that is attributed only to the APOS/Consequential scenario.

## Conclusions

The main trade-offs to consider with regard to waste oil to P(3HB) biopolymer, that would be raised with LCSA use:

- Considering the alternative scenarios for waste rapeseed oil end-of-life processing (i.e. biofuel),
- Balancing the economic (waste oil collection system), social (attitudes and compensations of waste oil collection) costs with environmental benefits,
- Investigating market response and consumers need on end-of-life side products (i.e. mcl-PHA vs. P(3HB),
- Improving the efficiency of P(3HB) production.

Biopolymer production seems to be one of the key directions of making agricultural economy more circular. Basing on the example of rapeseed oil, the opportunities of closing the life cycle loops with P(3HB) biopolymer production are significant both in a sense of mitigating environmental impacts as well as providing viable economic resources. Using life cycle based methods for its assessment helps in identification of consequences of introducing circular solutions. Additionally, they could provide appropriate framework for complex decision-making while CE is concerned. Nevertheless, relying solely on LCA results could reduce the complexity of decision making process and direct it towards somehow limited options.

LCM 2021