Sustainability and lifecycle assessment of pyrolysis oil production and applications

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BTG is actively developing different applications of pyrolysis oil, such as small residential heat boilers, diesel engine based CHP, co-refining, and the production of bio-based products from pyrolysis oil fractions. Along with the technical development work, the consultancy unit of BTG carries out detailed sustainability assessments and lifecycle assessments (LCA) to obtain insight in the sustainability risks and environmental performance of fast pyrolysis oil production and its applications.

Sustainability assessment

Sustainability means that the needs of the present generation are met without compromising the ability of future generations to meet their own needs. The concept of sustainability is made tangible by definition of sustainability principles, criteria and measurable indicators. If bioliquids like pyrolysis liquid and biofuels (e.g. pyrolysis oil derived diesel) are counted towards European renewable energy targets and/or receive renewable energy subsidies, they need to comply with a minimum set of European sustainability criteria as defined in the Renewable Energy Directive (RED). Verification takes place by voluntary sustainability schemes that have been recognised by the European Commission. BTG (2013) has screened the available schemes and concluded that the Roundtable on Sustainable Biomaterials (RSB), the International Sustainability and Carbon Certification (ISCC) and the Better Biomass (NTA8080) are suitable schemes for pyrolysis oil certification. Empyro received the Better Biomass certification for the production of pyrolysis oil, whereas FrieslandCampina received this certificate for the use of pyrolysis oil in their boiler.

In several projects BTG has assessed the RED greenhouse gas emissions

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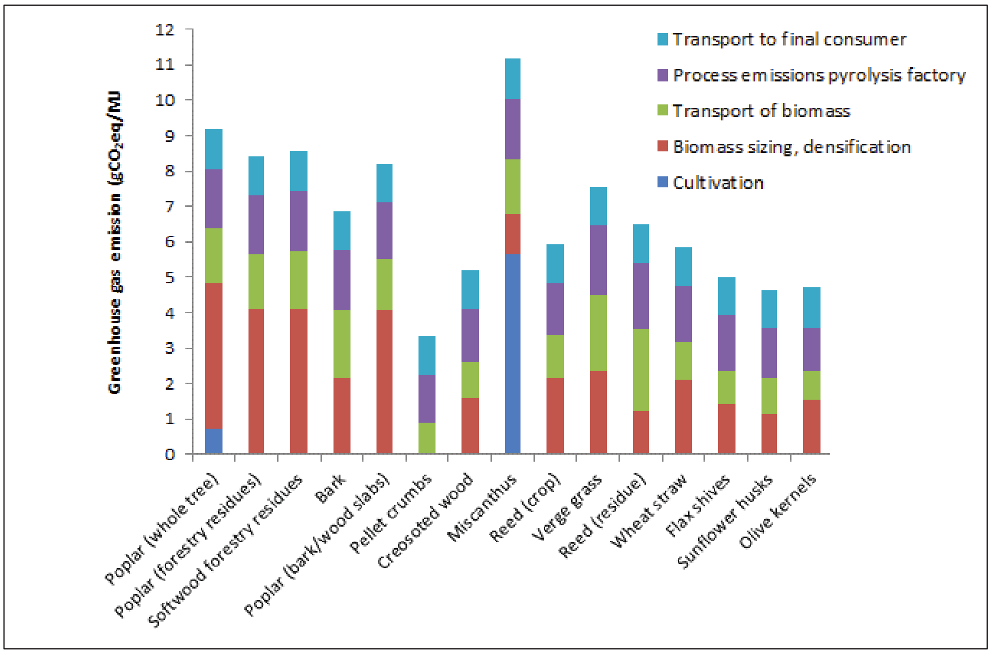

Figure 1: Greenhouse gas emissions from the production of pyrolysis oil using different feedstocks.

Sustainability and lifecycle assessment...continued

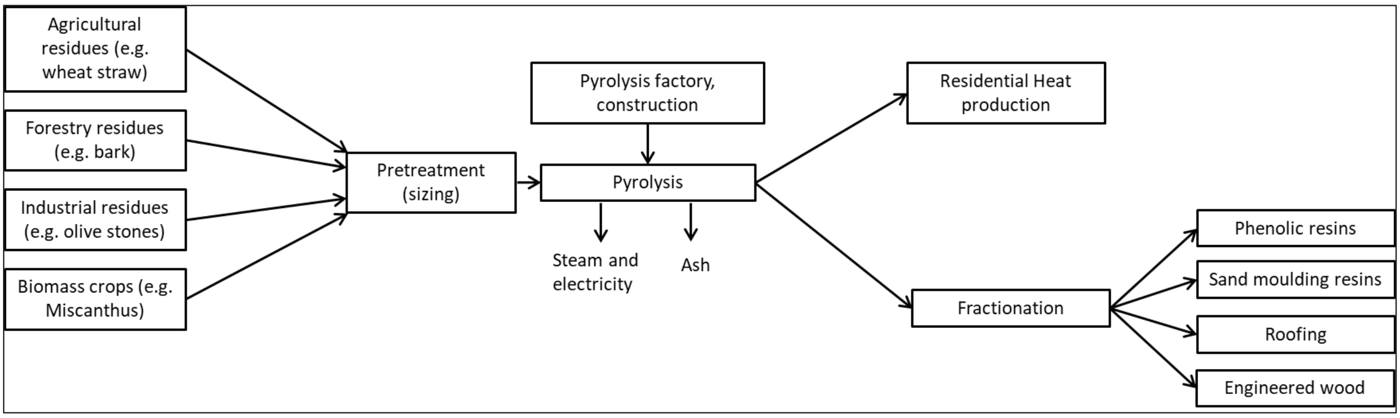

Figure 2: System boundaries of the different LCA's currently being performed by BTG

from production and transport of pyrolysis oils from different biomass feedstocks. An overview of the results is given in Fig. 1.

Cultivation becomes an important factor once artificial fertilisers are applied, like in the case of Miscanthus. Sizing includes chipping and further sizing with a hammer mill or hay buster to obtain a small particle size suitable for pyrolysis oil production. For all feedstocks, the transport distance of biomass to the pyrolysis plant, and of pyrolysis oil to the final consumer were set to 100 km. Transport emissions are relatively high for feedstocks with a low density and LHV such as reed and verge grass. Differences in moisture and ash content between feedstocks impact the pyrolysis oil yield and the amount of surplus energy that can be used for steam generation. Following the RED, energy allocation is applied to divide the upstream emissions between the pyrolysis oil and the generated steam, available for third parties.

In case the pyrolysis oil is used for heat generation, the resulting emission reduction can be estimated by the use of the fossil fuel comparator of heat production of 80 gCO2-eq/MJ, following the methodology of the Renewable Energy Directory. The emission reductions of pyrolysis oil use in heat applications are in the range of 89 to 96%, well above the current minimum required reduction of 60%, as well as the expected future threshold of 70%.

Lifecycle assessment

Lifecycle assessment (LCA) covers the creation of an inventory of flows from and to nature for a product system, and an assessment of their impacts. As an example, in the 'Residue2heat' project BTG has carried out a screening LCA for pyrolysis oil production from forestry residues, bark, wheat straw, and miscanthus followed by the use of the pyrolysis liquid in residential boilers (20-200 kW). In 'Groen Goud' maize silage is evaluated as a potential feedstocks. In 'Bio4Products' the LCA will be extended to upgrading the pyrolysis oil via a fractionation step and the use of the resulting fractions in different bio-based products. Figure 2 shows the system boundaries of the different LCAs that are currently being performed.

Assessment

ReCiPe 2016 was used as impact assessment method, which has a much broader scope than GHG emission reduction. It contains 17 midpoint impact categories that can be merged into three endpoint categories: i) damage to human health, ii) ecosystems and iii) resource availability. ReCiPe 2016 is a commonly used LCA impact assessment method. The method is described in detail by Huijbrechts et al (2016).

Fig. 3 shows the endpoint impacts of 17.8 GJ of heat – the average yearly per capita domestic energy consumption for heating and hot water within the EU – using oil, natural gas, pellets and pyrolysis oil (FPBO) produced from a number of feedstocks. The feedstock "pellet wood," a typical mixture of biomass sources used for the production of pellets, was added to enable a comparison between wood pellets and pyrolysis oil. Bioenergy has a lower impact than fossil fuel heating options with respect to the endpoints 'damage to human health' and 'damage to resources.' Concerning 'damage to ecosystems' bioenergy has a similar impact, either slightly higher or slightly lower, depending on the allocation of the biomass. However, the origin is different: where fossil heating causes damage to the ecosystems by global warming, the bioenergy options have an impact due to the occupation of land by forests and crop land. Overall, the heating options using fast pyrolysis bio-oil score better than the fossil fuel heating options.

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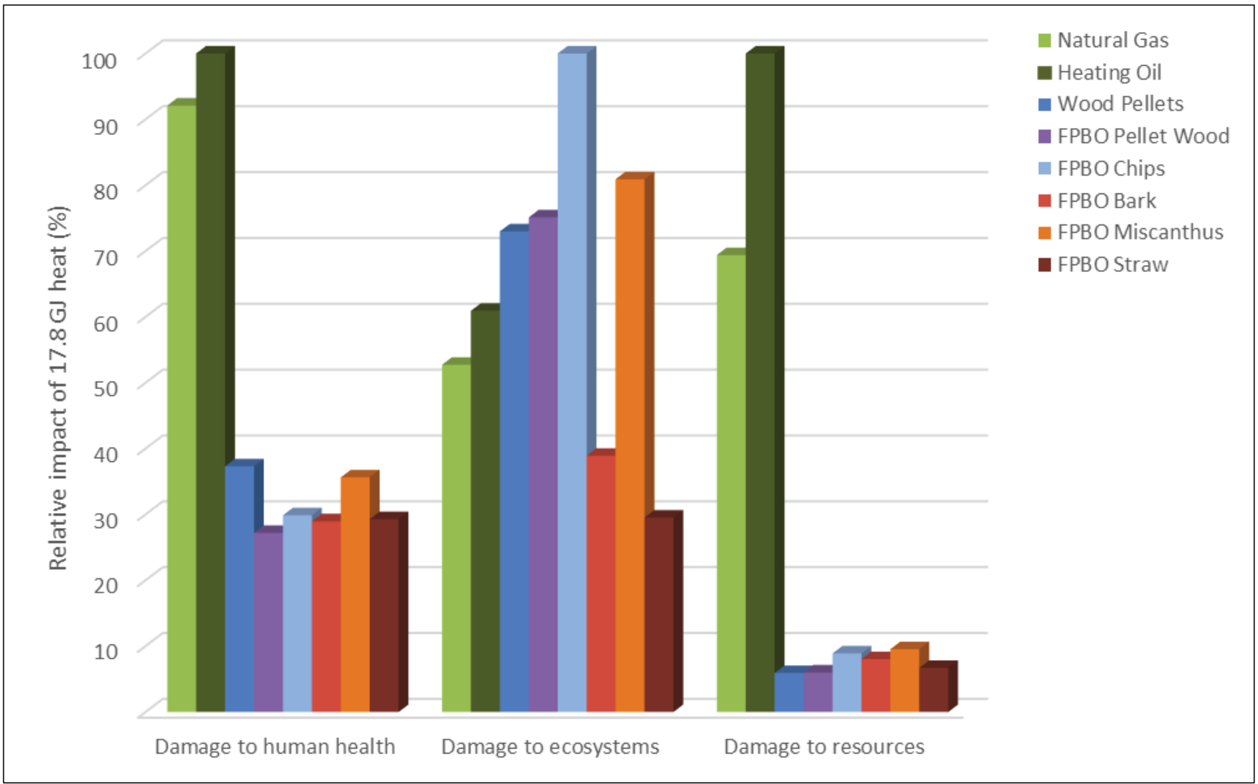

Figure 3: The Endpoint scores of the ReCiPe 2016 impact assessment for the production of 17.8 GJ heat from natural gas, heating oil, wood pellets, and pyrolysis oil from five different biomass sources.

Currently, the use of other biomass feedstocks, as well as the use of pyrolysis oil fractions, is being evaluated in projects like Groen Goud and Bio4Products. These will be full LCAs evaluating the entire value chain (cradle to grave) for a number of potential applications of pyrolysis oil fractions, such as phenolic resins, sand moulding resins, roofing material, and engineered wood. The initial results of these LCAs are promising and demonstrate the sustainability of pyrolysis oil from various biomass feedstocks in a wide range of applications.

References

1. Directive 2009/28/EC of the European Parliament and of the Council of 23 April 2009 on the promotion of the use of energy from renewable sources.
2. See http://www.btgworld.com/en/references/publications/guidelines-pyrolysis-oil-sustainability-certification.pdf.
3. Huijbrechts, M. et al. (2016) ReCiPe 2016, a harmonized lifecycle impact assessment method at midpoint and endpoint level. Report I: characterization.

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