

# Life Cycle Assessment on a Biorefinery Approach to Pyrolysis Oil for Wood Modification Treatment

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**Table S1.** Midpoint scores for 1 GJ of pyrolysis oil.

Impact category	Unit	Forestry	
		Digestate residues	
Global warming	kg CO <sub>2</sub> eq	12,8	6,02
	kg CFC11 eq		
Stratospheric ozone depletion		8,78E-06	3,03E-06
	kBq Co-60		
Ionizing radiation	eq	0,984	0,567
Ozone formation, Human health	kg NO <sub>x</sub> eq	0,0969	0,0349
Fine particulate matter formation	kg PM <sub>2.5</sub> eq	0,0271	0,00968
Ozone formation, Terrestrial ecosystems	kg NO <sub>x</sub> eq	0,0978	0,0356
Terrestrial acidification	kg SO <sub>2</sub> eq	0,0615	0,0200
Freshwater eutrophication	kg P eq	0,00937	0,00206
Marine eutrophication	kg N eq	0,000403	0,000184
Terrestrial ecotoxicity	kg 1,4-DCB	101	20,5
Freshwater ecotoxicity	kg 1,4-DCB	19,0	0,786
Marine ecotoxicity	kg 1,4-DCB	26,6	1,09
Human carcinogenic toxicity	kg 1,4-DCB	1,30	0,314
Human non-carcinogenic toxicity	kg 1,4-DCB	669	24,0
Land use	M <sup>2</sup> a crop eq	0,663	12,3
Mineral resource scarcity	kg Cu eq	0,0569	0,0191
Fossil resource scarcity	kg oil eq	4,06	1,89
Water consumption	m <sup>3</sup>	0,187	0,0954

**Table S2.** Midpoint scores for 1 m<sup>3</sup>a treated wood pole.

Impact category	Unit	Pyrolytic	
		sugars	Creosotes
Global warming	kg CO <sub>2</sub> eq	1,79	16,4
Stratospheric ozone depletion	kg CFC11 eq	2,89E-06	5,97E-06
	kBq Co-60		
Ionizing radiation	eq	-0,435	0,163
Ozone formation, Human health	kg NO <sub>x</sub> eq	0,0170	0,0649
Fine particulate matter formation	kg PM <sub>2.5</sub> eq	0,00383	0,0287
Ozone formation, Terrestrial ecosystems	kg NO <sub>x</sub> eq	0,0178	0,0877
	kg SO <sub>2</sub> eq		
Terrestrial acidification	kg SO <sub>2</sub> eq	0,00674	0,0382
Freshwater eutrophication	kg P eq	-0,00367	0,00608
Marine eutrophication	kg N eq	-0,000170	0,000495
Terrestrial ecotoxicity	kg 1,4-DCB	17,4	36,3
Freshwater ecotoxicity	kg 1,4-DCB	0,185	16,2
Marine ecotoxicity	kg 1,4-DCB	0,200	5,11
Human carcinogenic toxicity	kg 1,4-DCB	0,0325	5,32
Human non-carcinogenic toxicity	kg 1,4-DCB	10,3	10,3
Land use	m <sup>2</sup> a crop eq	19,9	17,2
Mineral resource scarcity	kg Cu eq	0,0113	0,0115
Fossil resource scarcity	kg oil eq	0,965	7,35
Water consumption	m <sup>2</sup>	0,309	0,333

# Critical review statement of;

## “Life Cycle Assessment (LCA) of Pyrolysis Oil from Digester Waste for the Use of Wood Modification”

### Commissioned by

Biomass Technology Group (BTG)

Authors / LCA practitioners

Dr. J Spekrijse

P.J. Reumerman

M. Vis

### Reviewers

Jasper Scholten (Blonk Consultants), Gouda, the Netherlands

Freija van Holsteijn (Blonk Consultants), Gouda, the Netherlands

This review statement is only valid for this specific report in its final version as received on 26 June 2019.

### Reviewers

ISO 14040 (2006): Environmental Management - Life Cycle Assessment - Principles and Framework

ISO 14044 (2006): Environmental Management - Life Cycle Assessment – Requirements and Guidelines

### Scope of the critical review

The reviewers had the task to assess whether;

- the methods used to carry out the LCA are consistent with the international standards ISO 14040 and ISO 14044,
- the methods used to carry out the LCA are scientifically and technically valid,
- the data used are appropriate and reasonable in relation to the goal of the study, • the interpretations reflect the limitations identified and the goal of the study, and
- the study report is transparent and consistent.

The LCI model and individual datasets were also provided and reviewed.

### Review process

The critical review was performed by two external experts according to paragraph 6.2 of ISO 14044. The study as such is intended to be used for comparative assertions intended to be disclosed to the public. According to the ISO 14044, a panel of interested parties shall conduct critical reviews on LCA studies where the results are intended to be used to support a comparative assertion intended to be disclosed to the public. Only on this point the LCA study is not ISO compliant.

BTG selected Jasper Scholten as external independent expert.

The first draft final report was submitted to the reviewers on 28 February 2019. Reviewer comments were received provided to the LCA practitioners on 26 March 2019. An updated version of the LCA report and the responses on all the review comments was received on 21 May 2019. The reviewers performed a final check and provided on 25 June 2019 minor comments which were correctly adapted in the final report.

## Reviewers

### *Consistency of general structure and methods with ISO 14040/44*

The LCA report and study are consistent with the general structure for LCA in ISO 14040 and the requirements of ISO 14044. The goal and scope are clear, the LCI is relevant and specific to the products being modelled, the Life Cycle Impact Assessment( LCIA) is conducted via a recognised midpoint approach (ReCiPe, 2016), sensitivity analysis relevant to certain data is included with the results and the overall interpretation is consistent with the goal and scope and the technical results.

### *Scientific and technical validity of the methods*

The LCA methods used are appropriate in scientific/technical terms and valid in terms of general LCA practice.

### *Data used appropriate in relation to the goal*

The LCI data are appropriate and of suitable accuracy and detail for the study's goal. There is reasonable primary data. No specific data quality assessment is conducted but the report presents a transparent inventory and justification of the data used for the study. Overall transparency and completeness of the LCI is good.

### *Interpretation reflects limitations and goal of the study*

The interpretation is well-focussed on the goal and scope of the study. The limitations of the study are considered in the sensitivity and uncertainty analysis.

### *Study report is transparent and consistent*

These criteria are met throughout the report.

## Conclusion

**The reviewers concluded that this Comparative Life Cycle Assessment of pyrolysis oil from digester waste for the use of wood modification meets most of the requirements of ISO 14040 and 14044.**

According to the ISO 14044, a panel of interested parties shall conduct critical reviews on LCA studies where the results are intended to be used to support a comparative assertion intended to be disclosed to the public. Only on this point the LCA study is not ISO compliant.

The study is reported in a comprehensive manner including a transparent documentation of its scope, the applied data and the interpretation of the results.

The LCA practitioners have processed the reviewer comments very well by significantly improving the LCA. The result is a report for which the reviewers compliment the authors.

Jasper Scholten

Freija van Holsteijn



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June 2019