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EVALUATION OF BIOCHAR LIFECYCLE PROCESSES AND RELATED LIFECYCLE ASSESSMENTS

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Abstract

In the case of lifecycle analyses, pyrolysis biochar systems have all integrated treatment and usage systems for any products resulting from the carbonisation of biomass. These systems require biomass ingredients as an input material source, which is a fuel available in many forms, f.e. forestry by-products, sewage waste, animal manure, etc. These materials are put into the pyrolysis process, where the produced biochar (active coal) is fed into the soil, where the circulation of the coal restarts. The biochar system is a complex system which requires multiple components and details to be taken into consideration to allow for a proper lifecycle assessment, in order to make the proper decisions.

Keywords

biochar, lifecycle assessment, pyrolysis, biomass,

1. Introduction

Environment protection and environment-friendly production is becoming a central element of our lives nowadays. The need for methods which reduce the effects produced and consumed products may possibly have on the environment, and which try to prevent these effects is on the rise. One of the most widely used special process of these methods is the lifecycle assessment, or lifecycle analysis (LCA).

During the lifecycle assessment, various environmental factors and potential environmental effects are unearthed, and are evaluated for various products and services from the cradle to the grave. Conducting a lifecycle assessment provides the opportunity to examine the entire life of the product. The usage of resources, and the effects endangering human health and ecological balance are some of the evaluated areas.

The lifecycle assessment may help in:

- understanding the opportunities of improving the various products' environmental factors, at the various different stages of the product's lifecycle,
- decision-making for the industrial sector, the government, and the non-governmental organisations (strategic planning, defining priorities, process planning),
- choosing the appropriate indicators and methods for environmental performance.

Our study aimed to compare LCA-s related to producing biochar using pyrolysis, during which we evaluated the 'best practices' which our current literature describes. According to the definition of Lehman et al. [1], biochar is the fine-grain material produced during the relatively low-temperature thermo-chemical disintegration of biomass, which has low oxygen content, high carbon content, and is porous. Manyá [2] describe it as the charcoal used for environment protection and agriculture.

Biochar is a very versatile, natural material which has many advantageous biological and chemical attributes. It improves the composition of soil, and decreases the GHG emission of the soil due to its physical attributes [3].

2. Discussion

ISO 14040:2006 standard for lifecycle

Both in Hungary and internationally, the usage of the ISO 14040:2006 standard [4] is the most widespread, and most accommodated nowadays. The standard defines the main routes and parameters of conducting a lifecycle assessment and registry, using which we can construct the properly detailed and quality analysis and evaluation of various products or services.

The MSZ EN ISO 14040 standard series related to evaluating the lifecycle lists all the goals, tools, and processes used to identify environmental factors and effects related to the various products, using the lifecycle evaluation. This international standard describes the basics and boundaries of conducting a lifecycle evaluation study, and a report of its findings, and lists some requirements as well.

The lifecycle assessment has four different phases:

1. Phase of designating the goals of the LCA, and the areas of the evaluation
2. Phase of the lifecycle registry
3. Effect analysis
4. Interpretation

The actual topic of the lifecycle assessment, the pre-determined boundaries, and the level of detail we wish to conduct the analysis is usually dependent on the goals we wish to achieve, and the usage of the results we achieved during the research. Depending on the goals, the depth of various lifecycle assessments may vary.

The lifecycle registry is the second phase of the analysis, during which we register the input materials entering the system, and the output materials leaving it.

During the effect analysis phase, we conduct the evaluation of the input and output energies' environmental effects, and the final phase is the interpretation and recording of the results yielded by the evaluation phases. In this final phase, we summarise and evaluate the relations and data unearthed during the lifecycle assessment, using which we define advisory remarks, draw final conclusions in accordance with the LCA goals, and aid the process of decision-making.

The lifecycle assessment has to include the boundaries of the goals and topics, the lifecycle registry evaluation, the effect analysis, and the evaluation of the results achieved, according to Figure 1.

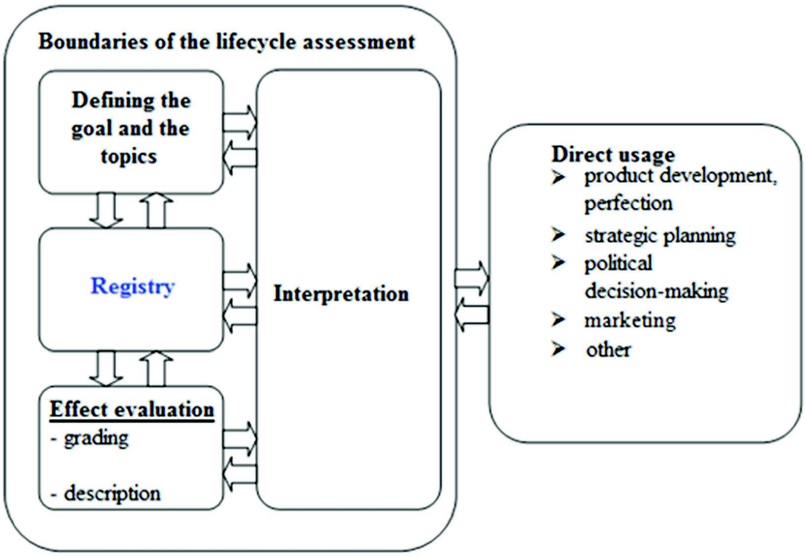

Figure 1. Boundaries of the LCA

ISO 14040 standard

The context and boundaries of the assessment is defined during the definition of goals and topics phase. Defining the unity of functions is also important, since the results of the assessment won't cover that (f.e. 1 kWh, 1 ton of biochar). Every material- and energy flow must be present in the registry phase. The input and output flows have to be precisely defined for all steps of the LCA. These may be products, base materials, in-between products, or emissions.

Quality of data

During conducting LCAs, the condition systems related to the quality criteria of data has to be handled especially carefully. In the case of biochar projects, one of the most significant problem is the bad availability of data required for lifecycle assessments. Since biochar projects don't exactly have a long history, only some reliable data sources are at hand, f.e. related to special biochar production units, and the usage of biochar. Missing values are usually filled in by estimations, or collecting data from literature.

Biochar LCAs in international literature

Multiple biochar LCAs are in the various literature sources, but these may differ significantly. Most of them are introduced in this study, but the simplest LCA model can be seen on Figure 2.

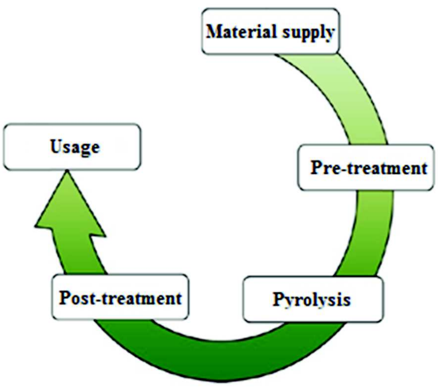

Figure 2. Basic diagram of biochar lifecycle [5]

Currently, due to the availability of data, the most problematic steps of the biochar LCA are usage and pyrolysis.

Two more significant complete LCA analyses were published specifically for biochar production, but both yielded substantially different results. These are the Gaunt and Lehmann [6], and the McCarl assessments.

Gaunt and Lehmann compared the slow pyrolysis biochar process to the slow pyrolysis process optimised for energy production. Their results were that slow pyrolysis optimised for biochar output, and feeding the biochar into the soil yields twice-thrice as much carbon efficiency, when compared to pyrolysis optimised for energy production. They conducted a limited economic analysis as well, which concluded with a 47 USD of biochar price needed to compensate for the missing profits compared to the version optimised for energy production. Their LCA also includes various uncertainty factors, like the specific parameter system of the pyrolysis process, and that the assumed outputs aren't at hand during the assessment, or that there are no data available. Bruce McCarl evaluated the economic condition system of biochar production in more detail, and analysed two big pyrolysis machines, both of which have an annual capacity of 70.000 tonnes. They analysed slow pyrolysis used for energy production, and fast pyrolysis using corn remains as basic material, optimised for energy production. McCarl and company included several steps in the lifecycle assessment, and relied on more conservative estimations in case an uncertainty in data came up [7].

Dutta and Raghwan [8] conducted their research in 2014, during which they highlighted the significance of LCA used for estimating the total GHG emission and the economic implementation possibilities during the complete lifecycle of biochar systems. Their analysis was conducted along optimised pyrolysis parameters for agricultural wastes, corn remains and forestry by-products. Their analysis yielded the results that both corn remains and forestry by-products avoided GHG emission. In our case, the stabilised carbon content of biochar significantly aided emission rate decrease. They constructed their lifecycle assessment as follows (Figure 3).

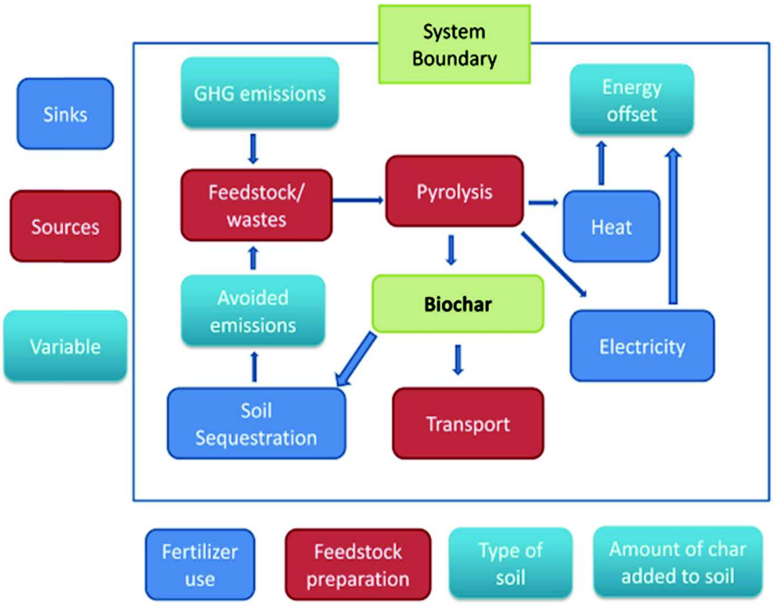

Figure 3. Biochar LCA flow diagram [8]

Biochar systems can also use biomass source materials as input material, or as an energy source [9].

The source of these can be:

- Cellulose-based biomass (timber chips, splinters, tree bark)
- Sewage waste
- Forestry biomass
- Paper production facilities' sludge
- Animal manure

Biochar producting process, the pyrolisys

Pyrolysis is a thermo-chemical disintegration process, during which we convert organic materials into carbon-rich solid products in a no-oxygen environment [10]. When biomass enters the pyrolysis process, biochar and energy are the results. We differentiate between two different types of the process - these are the low-temperature and high-temperature pyrolysis processes. In the case of the former - as its name also suggests - we work on a high temperature (around 500 °C) short gas treatment. In this case, we usually need materials produced from small molecules, and we need to devise a system where the gas can immediately released after the solid product is formed. And in case of the low-temperature pyrolysis, we differentiate between processes producing traditional charcoal, and other, more modern processes. However, the basic characteristics are also determined in this case, according to which the end product is procured on lower temperatures (around 400 °C), and with a longer gas treatment [9]. Though the goal is - again - to produce charcoal, we can also see end products of liquid and gaseous nature as outputs of the procedure. Our research however requires more modern - meaning the end of the 20'th century - processes, since biochar can only be produced using these methods. The process needs a horizontal furnace reminiscent of a pipe, which are further aided by drum furnaces and rotating furnaces in shaping the biomass. The latter were included in the system for the goal of the pyrolysis treatment of the biomass, beyond traditional charcoal production. This aspect has to be stressed because even though processes specialising in these products were in use since quite a while, the method specialising in biochar hasn't gained widespread acclaim in the business world up to now [11]. All in all, though pyrolysis is only one of the technologies producing energy from biomass [12], it differs from other alternative systems producing energy (from biomass), as biochar, a material rich in carbon is also yielded from the pyrolysis process (Figure 4).

In Lehmann's model, bio-energy is also being produced in the form of synthetic gases and bio-oils, apart from biochar, and these can be properly exploited in the following energy production processes. The bio-energy, which is a by-product of the pyrolysis process, similarly to biochar, also offers the opportunity of producing environmentally friendly energy. The technological potential may cause the production to be carbon-negative, which means that each produced or consumed unit of energy may cause GHGs to be removed/grounded from the atmosphere.

Bess-Ouko [13] also got results on sustainable biochar production similar to Lehmann (Figure 5).

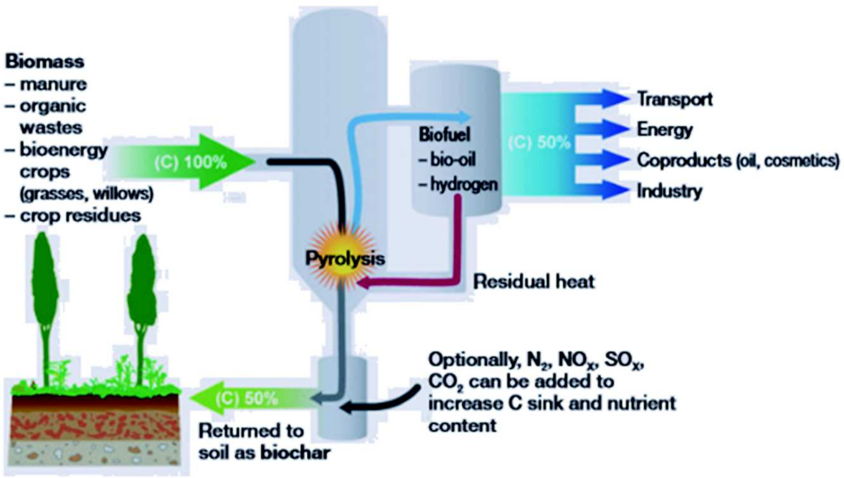

Figure 4. Model of producing biochar using low-temperature pyrolysis process [9]

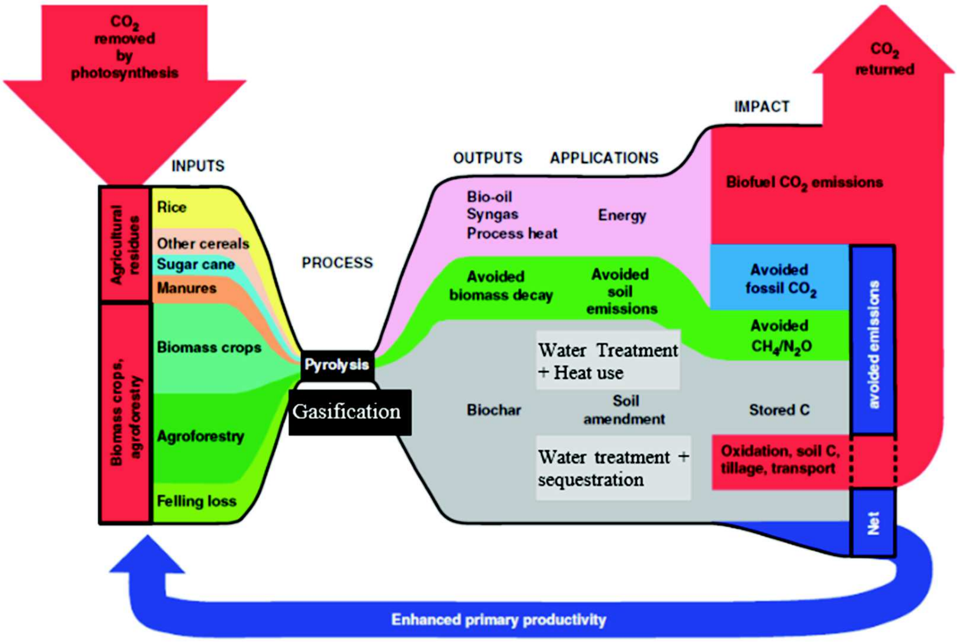

Figure 5. Concept of sustainable biochar production [6, 13]

From the perspective of GHG emission, the process of pyrolysis during biochar production is exceptionally important. The biochar production process has the advantages of carbon grounding, energy production, improving the quality of soil, and waste management. All products resulting from the carbonisation of biomass, f.e. biochar, carbon-monoxide, and bio-oils can be used in following processes.

3. Conclusion

International literature has LCA studies related to biochar, which can be used sufficiently, but can't be adapted as are to domestic biochar plants. Most LCAs base on the ISO 14040 standard as a starting point, but approach the process of biochar production from different perspectives, which is due to the multiple technological solutions and possible input materials. Our study introduced various LCAs, which may serve as a starting point for a facility's specifically tailored LCA, but all cases require the limitation of system elements related to the assessment in order to reach precise results (f.e. in what depth do we want to conduct the LCA in). Various software solutions can be used (Umberto, GaBi, CMLCA), which may aid in the lifecycle assessment. When we create the LCAs related to biochar, we have to take various basic factors into consideration, like the technological solutions at hand, the logistics processes, by-products, processes of handling intermediary products, if we need to introduce a specific pyrolysis unit during the assessment, and if we work with sufficient aggregated values, etc. We might want to introduce a supplementary footprint-calculation method into the analysis, f.e. water footprint, or carbon footprint methodologies. According to the sustainable agricultural methods, we have to offer sufficient development and usage space for biochar in the future.

Acknowledgements

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