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Life cycle assessment of biomass production from drained wetlands areas for composite briquettes fabrication

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Abstract

The area of wetlands after peat mining in Belarus is about 190,000 hectares and once peat harvesting has ceased it is impossible to grow any cultural plants for some years. One of the perspective directions is rewetting wetlands after peat extraction that stimulate vegetation of natural grass, like reed, rush and others which are growing in natural conditions. The grass biomass may be used for energy purpose, in particular for composite briquettes fabrication, which contents in 50 % from grass and 50 % from peat. The LCA method based on the standards series ISO 14040 was used for evaluation of environmental impact of growing and production of composite briquettes from wetland biomass. The goal of LCA was comparison two scenarios of biomass production for composite briquettes. Product system B (PSB) based on biomass harvesting with simultaneous shredding and product system A (PSA) based on biomass mowing, raking for drying and bailing. The basic LCA impact categories were: climate change, acidification, photo oxidant formation, eco toxicity and human toxicity. The product system A (mowing and baling biomass) achieved better results in 3 categories out of 5, and especially eco toxicity and human toxicity. And if for climate change the indicator results for both systems were close, for acidification, eco toxicity and human toxicity PSB systems impact was significantly higher to compare to PSA. It may be explained by peat using for biomass drying in product system B. The contents of SO_2 and Hg in the peat in several times higher to compare to diesel and gas, while PCB and GCB are contained only in the peat.

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Keywords: wetland; biomass; bioenergy; composite briquettes; life cycle assessment

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1. Introduction

Peatlands cover 3 % of the world's area but contain 30 % of the soil organic carbon. About 15 % of the world's peatlands have been drained for different human purposes, mostly for agriculture, forestry and peat extraction [1]. Drainage has a negative effect for the functioning of global wetlands and their services including flood protection, water purification, biodiversity and carbon (C) sequestration [2]. Drainage of these systems has resulted in strong degradation by oxygen intrusion, enhancing aerobic decomposition of organic matter and carbon emission. Together with compaction and consolidation, this has caused fast land subsidence. In Republic of Belarus wetlands formerly covered about 15 % of country area, extending to almost three million hectares [3]. Approximately 1.5 million hectares have now been drained and mostly used for agriculture, forestry and peat extraction. The area of wetlands after peat mining in Belarus is about 190,000 hectares [4]. A soil condition after peat mining are not favorable and once peat harvesting has ceased it is impossible to grow any cultural plants for some years, with the most critical period being the time after planting [5]. These areas are used for several purposes, such as forestation, flooding and fishing, growing cranberries and others. One of the perspective directions is rewetting of post-mining peatlands that stimulate vegetation of wetlands grass, like reed, rush and others are growing in natural conditions. There is special term – paludiculture in nowadays practice (latin 'palus'= swamp), that means land management techniques for biomass cultivation from wet and rewetted peatlands [6, 7]. Common Reed it is dominated specie on drained wetlands areas. It is a tall, thin, highly productive grass which was mostly distributed in Europe and nowadays efforts to rewet and restore drained wetlands increased the reed growing area [8]. Common reed and other grasses it is perspective sources of bioenergy from wetland areas that not require new arable lands, but it is necessary to estimate and environmental aspects for grounding of best practical methods of using biomass.

LCA methodology provides a comprehensive systems-based analysis of the energy and environmental performance of a product system based on the standards series ISO 14040 [9]. LCA it is method that is used for environmental impact assessment of various types of bioenergy. For instance, a lot of LCA devoted to assessment of diesel and biodiesel production [10–14]. The significant interest for LCA analyzing has ethanol, which may be produced from different type of feedstock. A number of LCA developed for ethanol production from different type of crops and it's biomass (residues and straw) [15, 16]. LCA is also used for improving of environmental impact [17, 18].

There are some publications concerning LCA of biomass production on the base of reed and other grasses. Most of them devoted to giant reed, sorghum, or tall fescue that produced as normal agricultural crops on arable lands [19–22]. Nevertheless, in several publications the LCA of natural grasses were investigated. Such, LCA of common read for bioethanol production was fulfilled in China [23]. Atmospheric impact of bioenergy based on reed canary grass on a drained boreal organic soil on the base of LCA was investigated in Finland [24]. It was found that, on an average, this system produces 40 % less CO_2-equivalents per MWh of energy in comparison with a conventional energy source such as coal. Other article devoted to reed production from abandoned peat extraction areas that close to conditions of our experiments [25]. The results indicate that, from the perspective of atmospheric impact, the most suitable is cultivation of reed canary grass to compare to other crops.

There are some directions of energy production from biomass, such as direct firing, bioethanol production, fabrication of pellets and briquettes. The purpose of our investigation was comparison of different scenarios of wetland biomass production for composite briquettes manufacturing on the base LCA.

2. Materials and methods

Our experiments were fulfilled on post-mining peaty soils in Grodno region, Lida district, close to the Lida peat Factory (LPF), the biggest peat briquette company production in the region. The degraded peaty soils are very heterogenic with different contains of nutrients, different decomposition depth of peat layer and level of peat decomposition, water regime and underground water level [26]. As the result, it is necessary to apply different kind of agricultural practice more suitable for concrete type of peaty soil and conditions of area flooding. The prevailing grasses on experimental lands were common reed and canary. LCA of 2 basic scenarios of biomass production was estimated in depends of soil conditions and water regime (Fig. 1):

- Harvesting by mower with following drying and baling biomass in field, with transportation for briquette production (scenario A);
- Harvesting biomass by chopper with uploading, transportation and drying to the factory (scenario B).

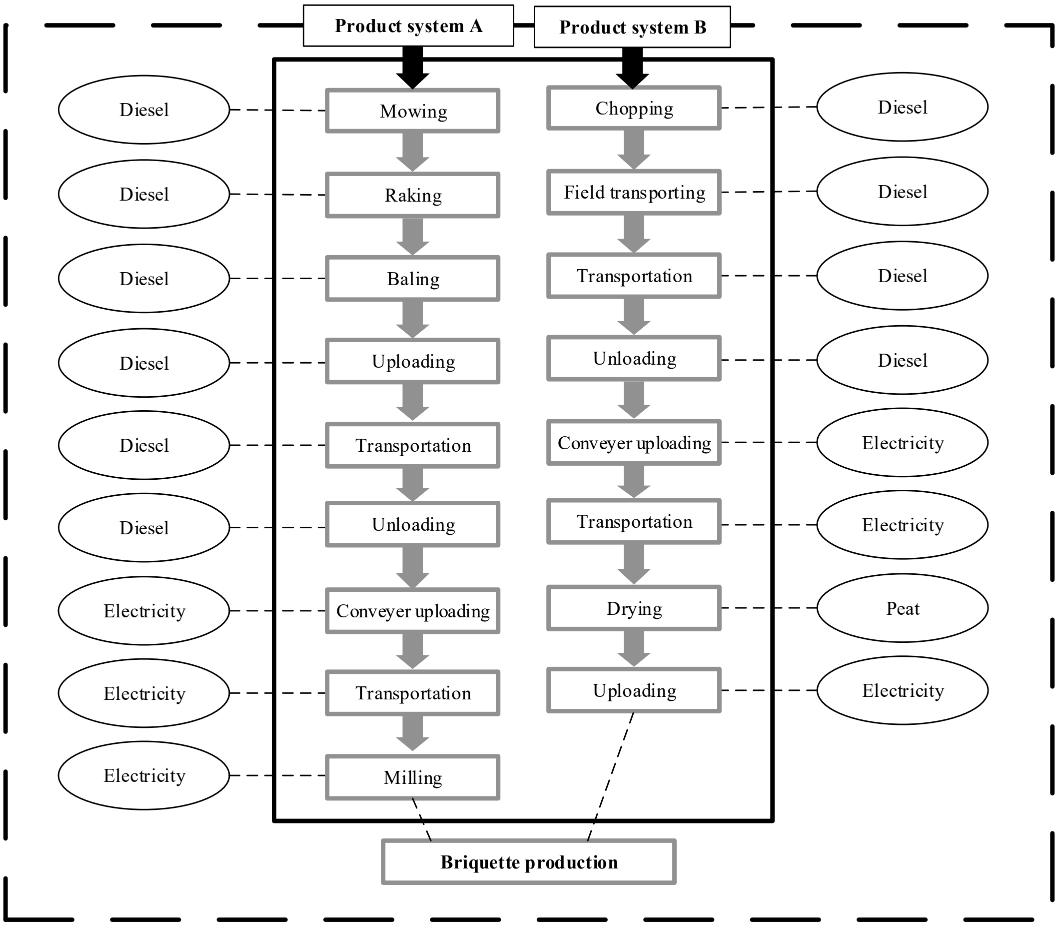

Fig. 1. Product systems and boundaries.

In our agricultural practice the special machines and equipment were used which designed and adopted for wetlands area. For instance, unique tractor МТЗ-952 and harvester FORTSCHRITTE 281 with double wheels which let cross area of wetlands and water and to overcome obstacles as hills, ditches, pits and so on. Biomass has been used for composite briquettes fabrication, which contents in 50 % from grass and 50 % from peat. Composite briquettes are partly renewable local energy source with improved characteristics. For inventory analysis of LCA the original data were collected in the frame of every unit process during three years. For estimation of wetlands biomass 5 more typical plots were choosing in the frame of experimental field. The yield was calculated by weighting in the field on the base of 4 replications after manual mowing. Moisture contents and calorific value of biomass were estimated in the laboratory. LCA was based on the standards series ISO 14040 [9] and especially 14047 [27]. LCA system boundary was limited by wetland area and peat factory and unit process of briquette composite production was not included. Functional unit of LCA was quantity of biomass from 1.5 hectare of wetland area.

3. Results

The results of inventory analyze for product systems A and B, presented in the Table 1 and Table 2. The environment impact of PSA was mostly connected with fossil fuel using. Diesel was used as fuel for agricultural machine and electricity for milling of biomass after mowing and drying. The biomass water content for composite briquettes production should not be more than 12–14 %. The required humidity of PSA biomass was provided by multiple raking in the field without additional drying.

Table 1. Summarizing of inventory analysis. Product system A.

Input	Diesel, l	Electricity, kW/h
Biomass, t (30 % humidity)		
Mowing	4.9	
Raking	5.4	
Baling	6.2	
Loading	15.9	
Transporting	52.0	4.9
Milling		1149.0
Total	84.9	1154.9
Output		
Biomass, t	19.7, humidity 14 %	
Emission to air	CO_2, CO, CH, NO_2, SO_2, SS, VOC (CH), B(a)P, HM and str.	
Impact to soil	Compression of agricultural machines – 5 passages	

Table 2. Summarizing of inventory analysis. Product system B.

Input	Diesel, l	Electricity, kW/h	Peat, t
Biomass, t (30 % humidity)		23.5	
Mowing with shredding	14.25		
Transporting	39.95		
Transporting		5.8	
Drying		34.8	0.194
Total	54.2	40.6	0.194
Output			
Biomass, t	19.7 with humidity 14 %		
Emission to air	CO_2, CO, CH, NO_2, SO_2, Hg, PCB, SP, GCB and str.		
Impact to soil	Compression of agricultural machines – 3 passages		

For composite briquette production the ordinary dryer of Lida peat factory had been used. It is barrel-type of dryer with using of electronic device for moving, and as a heat carrier it uses the air after peat burning. The results of emitting assessment after peat firing were included to inventory analyze.

The basic environmental impact in LCA was caused by fossil fuel firing and was connected with air pollutions. The sources of fossil fuel in this LCA are diesel, peat and natural gas. Natural gas it is usual fossil fuel for production of electricity in Belarus and equivalent quality of natural gas environmental impact was estimated. In the LCA we didn't include the impact of electric currency transition from power plant to LPF. The value of emissions of pollutants released into the atmosphere was calculated by multiplying of burned fuel quality on emission factors [28]. Totally 17 basic substances emitted to air were analyzed for PSA and 20 for PSB. The several substances as PCB, GCB and SP were emitted to the air only at the result of peat burning. The impact category for air was: climate change, acidification, photo oxidant formation, eco toxicity and human toxicity. Characterization factors were taking from the following models: climate change (IPCC); acidification (RAINS); photo oxidant formation (UNECE); eco toxicity and human toxicity (USES-LCA) [29–32].

Results of life cycle impact assessment are presented in Fig. 2.

4. Discussion

The search and assessment of new sources of renewable energy it is aspect directly connected with natural conditions of the area. For instance, in dryland of Argentina the perspective energy crop may be Salsola kali [33]. It adapts easily to environments with strong abiotic stresses (hydric, saline and alkaline) and produces large amounts of biomass in drylands. This species is categorized as an important weed in Argentina. In Latvian conditions significant potential has algal biomass which can be utilized for the production of biogas [34]. The most sustainable and feasible scenario was using algae biomass from natural water bodies.

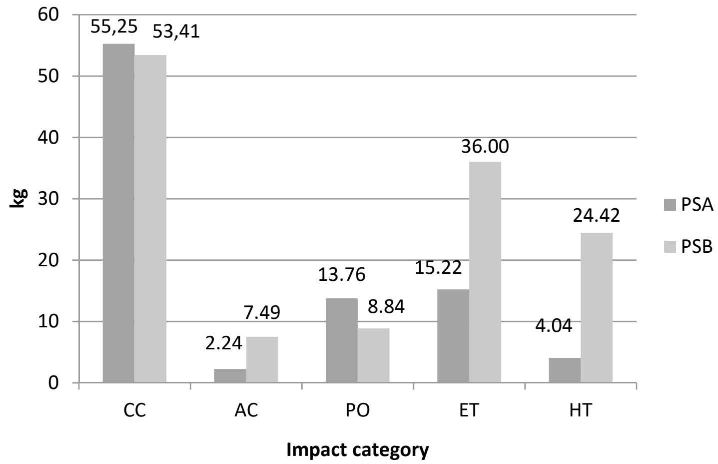

Fig. 2. Life cycle impact assessment. Air pollution. CC – Climate change, eq./kg CO_2*10; AC – Acidification, eq./kg SO_2; PO – Photo oxidant formation – eq/kg ethylene; Eco toxicity – eq/kg (PSA*10-4, PSB*10-3); HT – Human toxicity – eq/kg.

Results of our investigations justify that even from drained wetland it is possible to obtain about 15–18 ton biomass of natural grass per hectare which may be used for energy. The most traditional direction of biomass utilization it is pellet production [35]. Nevertheless, it is important to use fruitfully local potential and from wetlands area that situated near to peat factories biomass may be used for composite briquette fabrication. The technological chain of biomass production in our experiments depended of specific local conditions and the biggest LCIA indicator for both product systems was connected with climate change (534 eq./kg CO_2 for PSB and 552 for PSA). The quantity of biomass in accordance with functional unit in our LCA was 19.7 t and the emission of greenhouse gases was from 27 to 28 gCO_2 eq./kg or 1.7–1.8 gCO_2 eq/MJ. These results were in several times higher to compare with the research conducted in China [23]. In accordance with their results for bioethanol production from common read, the total emitted GHG estimated through the LCA system was 15 gCO_2 eq MJ. Nevertheless, it is necessary to keep in mind that for ethanol LCA unit processes of fermentation and natural gas biorefinery contributed the most (85 %) to the total GHG emission, and the processes of harvest, bale and transport contributed 13 % to the total GHG emission. The adequate unit processes were not estimated in our LCA, and without them GHG emission may be estimates approximately 1.9–2 gCO_2 eq /MJ that competitive with our results.

In research conducted in eastern Finland the total CO_2 emissions associated with crop management of common reed ranged from 160 kg to 249 kg CO_2 ha, that also comparative to our results [24]. These emissions are primarily a function of energy costs in the amount of fertilizers applied (annually) to the crop, harvesting and transport of the seasonal crop yield and amount of lime added.

The amount of GHG emissions for giant reed cultivation was from 2522 kgCO_2eq ha for the fertile soil to 2636 kg CO_2eq ha for the marginal soils [36]. It is in several times more to compare to our results. However giant reed are cultivated as s regular crop and inventory analyze consist from 25 unit process including fertilizer and pesticides application. So, it is the reason of the significant difference of GHG emission between common reed and giant reed.

From other impact categories the most significant were acidification, photo oxidant formation and human toxicity. The product system A (mowing and baling biomass) achieved better results in 3 categories out of 5, and especially eco toxicity and human toxicity. And if for climate change the indicator results for both systems were close, so for acidification, eco toxicity and human toxicity PSB systems impact was significantly higher to compare to PSA. It may be explained by peat using for biomass drying in product system B. The contents of SO_2 and Hg in the peat in several times higher to compare to diesel and gas, but PCB and GCB are contained only in the peat.

In accordance with LCA results, a number of recommendations were prepared for LPF, in order to decrease environmental impact, such as:

- For PSA. It is necessary to take special care and attention for logistic of transportation. One of the opportunities is used local railway of LPF, which let us decrease emission;
- For PSB. It is possible to decrease environmental impact by using drier biomass. It is reasonable to harvest more biomass in cold winter period, in depends of grass species.

5. Conclusion

It is possible to obtain about 15–18 ton biomass of natural grass per hectare of drained wetland which may be used for energy. The results of LCA of biomass production from wetland areas let us conclude that the bigger impact was obtained for product system B, and it is rather unexpected result. For PSA the consumption of fuel and consumption of electricity is bigger to compare to PSB that connected with intensive using of agricultural machines and biomass milling. But for product system B it was necessary to dry biomass by using of fossil fuel and in this case LPF use local recourse (peat). Of course it is cheaper fuel for LPF, but it contents and emits a lot of substances to air, including SO_2, Hg, PCB, SP and GCB. In accordance with LCA results and recommendations were prepared for LPF in order to decrease environmental impact. Such as, for PSA it is necessary to take special care and attention for logistic of transportation and for PSB it is possible to decrease environmental impact by using drier biomass.

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