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Bioenergy production from roadside grass: A case study of the feasibility of using roadside grass for biogas production in Denmark

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ABSTRACT

This paper presents a study of the feasibility of utilising roadside vegetation for biogas production in Denmark. The potential biomass yield, methane yields, and the energy balances of using roadside grass for biogas production was investigated based on spatial analysis. The results show that the potential annual yield of biomass obtainable from roadside verges varies widely depending on the local conditions. The net energy gain (NEG) from harvest, collection, transport, storage and digestion of roadside vegetation was estimated to range from 60,126–121,476 GJ, corresponding to 1.5–3.0% of the present national energy production based on biogas. The estimated values for the energy return on invested energy (EROEI) was found to range from 2.17 to 2.88. The measured contents of heavy metals in the roadside vegetation was seen not to exceed the legislative levels for what can be applied as fertilizer on agricultural land, neither does it reach levels considered as inhibitory for the anaerobic fermentation process. From a practical point of view, few challenges were identified related to the acquisition and processing of the roadside vegetation. Considering the positive net energy gains, further energy investments for management of these challenges can be made. Despite the somewhat low EROEI values, the use of this resource could however result in other positive externalities, such as improved biodiversity of the verges and recycling of nutrients.

1. Introduction

Research into alternative biomass sources (and production areas) which could mitigate environmental and economic issues related to conventional energy crops, while sustaining and improving bioenergy production has been increasingly investigated. A potential source which could meet this goal but has only been sparsely examined in the literature is vegetation from roadside verges. Roadside verges currently represent unutilised areas (with regard to food production), which could provide a beneficial feedstock for use in biogas systems.

Investigations and reports on the use of vegetation sourced from roadside verges were found to be quite limited, with roadside biomass research mainly concentrated on its use to monitor and evaluate heavy metals and organic pollutants emanating from road transport (Ho and Tai 1988; Garcia and Millán, 1998). However a few European reports and papers on this topic were identified having quite different views and conclusions related to the possibilities of utilising roadside vegetation for bioenergy production. Pick et al. (2012) concluded that the utilisation of roadside grass in biogas plants in Schwäbisch Hall County, Germany, was unfavourable due to the potential content of pollutants and waste in the roadside vegetation. Furthermore, the authors argue that the costs, associated with the biomass harvest and collection, were unfeasible. Durling and Jacobsen (2000) conducted a study in Sweden assessing the energy consumption and the costs per tonne of roadside grass when used for anaerobic digestion, composting, or combustion. The results show that anaerobic digestion and combustion of the roadside vegetation gives a positive net energy production, indicating that the utilisation is feasible from an energetic point of view. The "Living Highways Project" (Delafield, 2006) conducted trials harvesting roadside vegetation with a specialised harvesting machine in the region of Powys, Wales. The harvest machinery was evaluated to work effectively and no concerns related to waste in the harvested grass were reported. Based on the results for the harvest yields in this study, Salter et al. (2007) set up a model to determine the energy efficiency and surplus energy yield of using roadside vegetation as feedstock for biogas production in the UK. The results from this study are promising, indicating that the

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biogas quantity produced from roadside vegetation (harvested in a radius of 20 and 45 km from a biogas plant) is sufficient to cover the energy demand for harvesting, transport and biogas production processes. A common finding from most of the previous studies related to roadside biomass extraction and use was that the harvest and collection of roadside vegetation created positive impacts in the flora and fauna of the roadsides. This finding is further supported in the literature, where increases in the species richness of the roadsides have been documented when the grass cuttings are removed after harvest (Noordijk et al., 2009; Parr and Way, 1988).

The motivation behind this study stems from a recent change in the overall legislative frame conditions for the Danish bioenergy sector. Under the new conditions, the Danish biogas sector is subject to legislation that limits the quantity of purposely grown energy crops that can be used in biogas plants to 25% (weight based, % of total biomass digested) by 2017 with further reduction to 12% by 2020 (The Danish Energy Agency, 2012). At the same time the national energy policy aims to increase the share of energy produced from renewable resources in Denmark to 35% by 2020. It is therefore expected that the demand for alternative biomass will increase; hence the use of non-purposely grown energy crops and the possibilities of roadside grass use for energy production becomes increasingly relevant. No studies on the feasibility of using roadside vegetation for biogas production in Denmark was identified by the authors in the literature, despite the fact that such alternative substrates will be needed if the biogas sector is to expand as according to the national energy policy.

The aim of this paper was to evaluate potential energy yields obtainable and if it is energetically feasible to use roadside grass for biogas production in Denmark. In addition, the following questions of concern related to the biomass use were also investigated:

- What are the obtainable grass yields from the roadsides in Denmark?
- What is the methane yield using this feedstock?
- Does the roadside grass contain concentrations of harmful substances that could potentially inhibit the fermentation process or are above the legislative levels for application as fertilizer on agricultural land?
- What is the size of roadside verges that can be harvested adjacent to existing biogas plants and what corresponding yields of biomass can potentially be obtained?
- What supply challenges can be encountered with the acquisition and use of the roadside grass compared to the current management strategy?

2. Methods

The methods applied in this study consist of field and laboratory experiments, spatial analysis, and literature review.

For characterisation of the roadside grass, laboratory experiments (presented in Section 2.1) were conducted in order to assess the potential achievable yields of grass, the methane yields, and the content of harmful substances in the roadside grass. Section 2.2 presents the methods applied in the spatial analysis. The analysis was performed to the roads in Denmark available and to estimate their length. Furthermore, the distances for the roadside grass transportation were evaluated by assessing locations of existing biogas plants. Based on literature studies, the potential harvestable width of the roadside verges was assessed and three different scenarios were developed for estimating the potential area of roadside verges that can be harvested. Based on this, the total biomass and methane yields were estimated using results from laboratory experiments. Section 2.3 presents the approach used for estimating the energy potential of roadside grass in biogas production. The values for the energy requirements were based on findings from the literature, while the potential obtainable energy yields were estimated using results of the obtainable methane yields.

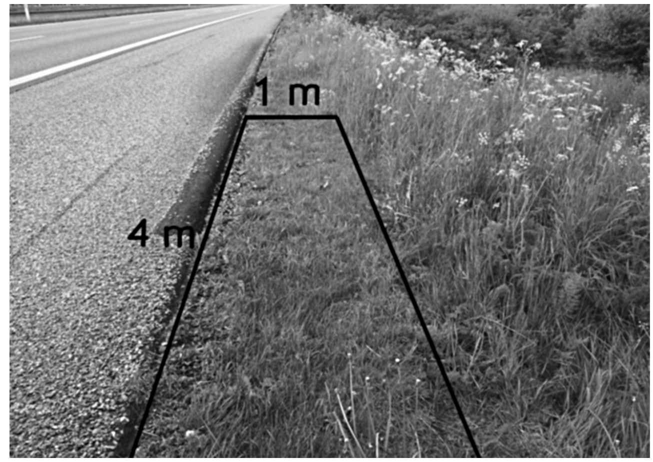

Fig. 1. A pictorial representation of the roadside grass harvesting strategy (spring harvest).

2.1. Characterisation of roadside vegetation in Denmark

A characterisation of roadside vegetation was conducted in order to estimate the potential obtainable biomass yields, methane yields and the potential content of harmful substances. Roadside vegetation harvested in Denmark was applied for this characterisation. The method and materials used for collection of the vegetation is explained in Section 2.1.1. The content of total solids and total volatile solids were analysed as in Section 2.1.2. For assessing the theoretical methane yields, the content of carbon, hydrogen, nitrogen and sulphur was applied (Sections 2.1.3 and 2.1.4). The content of harmful substances were analysed according to the method outlined in Sections 2.1.5 and 2.1.6.

2.1.1. Collection of roadside grass samples

For this study, roadside grass was collected during two sampling periods; May 2012 and in October 2012. Stripes of approximately 1 m width and 4 m length were harvested in both periods (dictated by the current management strategy for the spring season) in order to have a comparable basis (shown in Fig. 1).

The samples were collected from nine locations in Southern Denmark for both sampling periods to facilitate representative samples from a highway, a main road and a minor road. The grass was cut approximately 5 cm from the soil. Grass samples from each location were packed and transported in plastic bags, weighed and stored in a freezer at −18 °C until further analysis were conducted.

2.1.2. Total solids and volatile total solids

From each sample bag, 4 representative samples were extracted after mixing the grass thoroughly. All 36 samples were cut to sizes of ≈0.5–3.0 cm, transferred into porcelain cups, weighed and the total solids (TS) and volatile total solids (VS) contents determined using the standard methods described in APHA (2005).

2.1.3. Sample preparation for further analysis

As preparation for the subsequent experiments on the biomass heavy metals and elemental composition, three representative samples were extracted, and dried for 24 h in porcelain cups at 105 °C. The dried samples were then homogenised in an agate mortar and transferred to plastic containers where they were stored until further analysis were conducted