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Fostering renewable energy provision from manure in Germany – Where to implement GHG emission reduction incentives

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ABSTRACT

Livestock production makes up a major share of agriculture sector and the manure it produces significantly contributes to greenhouse gas emissions. One option to lower these emissions significantly is using the manure to produce biogas which is used to generate power. Our model calculations show, that per kWh power from manure-based biogas –about 1.448 kg of CO_2 eq. of greenhouse gas (GHG) emission can be avoided due to the improved manure management and the substitution of electricity from the grid under actual German conditions. This form of utilization is supported under the German Renewable Energy Act; however, only the minor share of the manure is processed so far. Thus the question arises as to whether instruments in agricultural policy or instruments in energy policy are better to unlock this remaining potential. The elaborated allocation shows, that both sectors cause a comparable amount of GHG emissions reductions, at around 50% each. However, based on expected developments, the relevance of agriculture-related emissions is slated to increase. This leads to the conclusion that implementing instruments in both agricultural and energy policies would make sense.

1. Introduction

Livestock production is a significant sector in German agriculture and makes up 3% of the global production (FAOSTAT, 2016). This production is characterized by a tremendous demand for feedstock and the production of enormous amounts of excrement in the form of liquid or solid manure and slurry - currently estimated at 139 M tons per year (Thrän et al., 2014). This excrement contains significant amounts of nitrogen and other nutrients so that it is typically spread directly on farmland as fertilizer. Excrement is produced on a continuous basis, however, because it can only be re-used as a fertilizer during certain times of the year, large storage capacities for manure are necessary (Verordnung über die Anwendung von Düngemitteln, 2012). These storage facilities are often open silos where the stored manure produces relevant amounts of methane which cause 1% of the overall German GHG emissions (Haenel et al., 2014). There are a few possibilities to reduce these emissions. One of them is producing biogas from manure which can reduce the GHG emissions from manure storage and provide a renewable energy carrier as well. If the renewable energy carrier is used as a substitute for fossil fuels, additional GHG emissions are saved. So far, about 3000 biogas plants have been installed at farm sites in Germany, mainly under the Renewable Energy Act (Scheftelowitz and Thrän, 2016). These biogas plants provide renewable energy and combined heat and power (CHP). Because only about 48% of the animal waste produced nation-wide is currently utilized in biogas plants (Thrän et al., 2014), more than one hundred thousand farms, with varying amounts of livestock (cattle and pigs), provide additional potential for biogas production. There is a clear need to further reduce GHG emissions through manure management as stipulated by the ambitious targets set by the Paris agreements. These aim to reduce national greenhouse gases by 80–95% in Germany by 2050 (in comparison to 1990).

But this requires further incentives and begs the question of how to design these incentives in an appropriate way: Since biogas production from manure supports greenhouse gas emissions reduction in both the energy and in the agriculture sector, the relevance of these two effects needs to be taken as a basis for developing enhanced support instruments.

Against this background, the main research question of this paper is: How many GHG emissions can be reduced through the use of manure for electricity production via biogas? Which sectoral allocation of the reduction effects can be derived from the quantification and in which sector are incentives relevant??

Most studies on the reduction of GHG emissions are concerned either with the mitigation effects of improved manure management, from the point of view of disposal (Riaño and García-González, 2015; Rodhe

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et al., 2015; Costa et al., 2015; Clemens et al., 2006; Kirchmeyr et al., 2015), or with the mitigation effects of electricity production from biogas, from the point of view of substitution (Gronauer and Bachmaier, 2007; Horschig et al., 2016; DBFZ, 2011; Majer et al., 2015). To quantify the mitigation potential, we have merged both effects and we have elaborated on an appropriate method for assessing the GHG emissions from using manure in biogas plants in Germany and the associated GHG mitigation effects under the actual support schemes over the last seven years. We also discuss options for further developing the promotion of biogas plants.

2. Method

To answer the question regarding the GHG emissions from using manure in biogas plants in Germany and the associated GHG mitigation effects, GHG emissions from manure based biogas systems have been analyzed, calculated and assessed with regard to their reduction potential for both farm based manure management and the substitution of fossil fuels for power generation. There are different methodological approaches for the investigation of lifecycle GHG emissions from products or services. The assessment of lifecycle GHG-emissions is often part of a life cycle assessment (LCA). LCA is an appropriate method for evaluating the GHG performance of a manure based biogas system compared to a fossil reference system. Requirements for conducting an LCA are detailed in the international standards ISO 14040 (ISO 0, 1404, 2006) and ISO 14044 (ISO 4, 1404, 2006).

According to these standards, the analysis covers the complete product life cycle from the production of the raw material to the final disposal of the product after the use phase, including all pre-products and energy carriers used.

Using the selected LCA-based approach, we were able to extrapolate the mitigation potential for the entire amount of liquid manure used in Germany. This calculation is based on the specific GHG savings from a case study that compared a typical manure based biogas system with reference data on the GHG emissions released as part of conventional electricity production in Germany.

The methodology employed in the evaluation of the GHG emissions is described in the following sections.

2.1. Goal and scope

The first step of the LCA method - the definition of the goal and scope – includes a description of the underlying questions of the case study, the system boundaries under consideration, the definition of the functional unit, the allocation procedures, the life cycle impact assessment (LCIA) and the types of impact (ISO 14040, 2006).

2.1.1. Aim and scope of the study

The principal aim of the study is to estimate the GHG emission mitigation effects associated with use of manure from livestock breeding, with regard to two aspects (i) mitigation of GHG emissions due to an improved manure management and (ii) replacing electricity from the German electricity grid by producing electricity from manure based biogas. To achieve the stated goals a LCA is performed according to the standards ISO 14040 and ISO 14044, using the software Umberto 5.5 and the database Ecoinvent (Ecoinvent v2.1, 2009) for background data. The primary steps by conducting a LCA, the setting of the system boundaries, the definition of the functional unit and the Life Cycle Inventory are described below for the present case of biogas production from manure.

2.1.2. Boundaries

Setting the system boundaries is one of most essential issues for carrying out a life cycle assessment.

The system boundaries define the framework in which the assessment takes place and determine which energy material flows are taken into account in the assessment.

In the present case a ‘cradle to gate’ life cycle has been analyzed. The ‘cradle to gate’ life cycle means that all flows of materials and energy which are necessary for the operation of the biogas plant and the production of electricity from manure based biogas have been taken into account. The assessed life cycle starts with the transport of the manure (in case that the manure is not generated on site) and ends with the transformation of manure based biogas to electricity at the combined heat and power (CHP) plant and the subsequent feed of the produced electricity into the electricity grid. Contrary to the ‘cradle to gate’ life cycle for the biogas processes a ‘gate to gate’ life cycle has been chosen for the provision and use of manure from animal husbandry production. This means that only transport expenditures and direct manure emissions at the biogas plant has been calculated. Whereas upstream processes associated with livestock breeding such as, for example expenditures from crop cultivation for animal feed were not considered. Because the goal of livestock breeding is not the production of excrements (such as manure) but the production of milk and meat, from which the manure results as a waste product. That's why the life cycle emissions of manure are zero until the place of the production. At the same time not included, are on the one hand emissions from the transport and the field application of the digestate. In particular, nitrous oxide emissions from spreading the digestate can have an influence on the GHG balance sheet, the amount of these emissions depends mainly on the method of digestate spreading and on the technique the digestate has been incorporated into the soil. On the other hand, the fertilizing effect of the digestate and the associated substitution of synthetic fertilizer are not taken into account. Climate relevant emissions resulting from the energy-intensive production of synthetic nitrogen fertilizers can be avoided in this manner. This approach seems to contradict the fact that the avoided emissions from the conventional manure storage are included in the life cycle assessment. Since due to the anaerobic digestion of the manure the improved manure management is directly linked to the supply of the manure (the manure is not stored after production, but is placed in the digester in a timely manner), the emissions avoided are to be located within the boundaries of the GHG assessment.

Due to the negligible impact the GHG emissions associated with construction and demolition of the biogas plant and the CHP were not considered.

On the basis of these assumptions, the system boundaries of this assessment include the major stages of the manure based biogas system: (i) manure provision, (ii) the production of biogas by anaerobic digestion of manure, (iii) using the produced biogas in a combined heat and power (CHP) plant to produce electricity and heat and (iv) feed the electricity into the grid (see Fig. 1). These steps are further detailed in the life cycle inventory (LCI) as described in the following chapters.

2.1.3. Function and functional unit

The main objective of this GHG assessment is to calculate the GHG

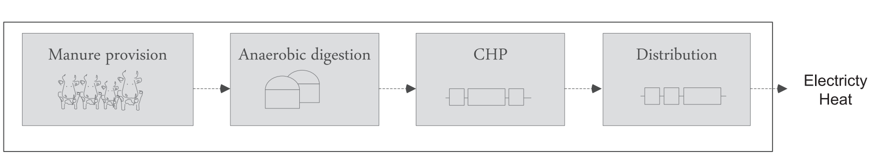

Fig. 1. System boundaries.