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Relation between greenhouse gas emissions and economic profit for different configurations of biogas value chains: A case study on different levels of sector integration

Kari-Anne Lyng [a, b, *], Aina Elstad Stensgård [a], Ole Jørgen Hanssen [a, b], Ingunn Saur Modahl [a]

[a] Ostfold Research, Stadion 4, 1671 Kråkerøy, Norway
[b] The Faculty of Environmental Sciences and Natural Resource Management (MINA), Norwegian University of Life Sciences (NMBU), Ås, Norway

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ABSTRACT

Biogas production through anaerobic digestion of organic waste and manure can potentially reduce greenhouse gas emissions in several sectors such as the waste, transport, energy and agricultural sector. The aim of this paper is to study the effect of different levels of sector integration in biogas value chains, and to discuss how different policy measures and regulations influence the reduction of greenhouse gases.

Environmental impacts and economic profit were calculated for four different biogas value chain configurations in Norway. Further, the most profitable scenario was used as a reference to calculate the economic incentives needed to make the other scenarios as profitable as the reference.

The results show that a broad integration of sectors is beneficial in terms of reduction of greenhouse gases. There is, however, a negative coherency between reduction of greenhouse gases and economic profitability when it comes to different levels of sector integration. The calculations showed that only a small increase in economic incentives are necessary to make biomethane for transport purposes as profitable as the reference. Inclusion of the agricultural sector into waste-based biogas value chains appears to be challenging and is likely to require greater incentives.

1. Introduction

Biogas value chains can span across several sectors and contribute to the reduction of environmental impacts in many ways, e.g. by substituting fossil alternatives in vehicles and in the energy system, reduction of greenhouse gases (GHG) from manure handling and recycling of nutrients from organic waste. The cross-sectoral nature does, however, represent a challenge when it comes to developing policies. Huttunen et al. (2014a) found that for biogas value chains in Finland, supportive policies in one sector were made inefficient by unsupported policies, instruments and practices in others. Nilsson et al. (2012) assessed policy coherence on a general level in a European Union (EU) setting, and found that policies are often coherent at the level of objectives, but associated instruments and implementation practices causes concern for policy conflict.

Economic profit is a requirement for sustainable value chains. As a consequence, many countries have implemented economic instruments to facilitate biogas production to obtain political environmental goals. Several studies have been performed to map the environmental and economic performance of biogas value chains. Existing papers discuss different challenges such as mix of substrates (e.g. Boldrin et al., 2016), biogas used in the transport sector (e.g. Cong et al., 2017) and pre-treatment technology of organic waste (e.g. Carlsson et al., 2015).

Few studies have been done on cross-sectoral challenges for biogas as a GHG mitigation strategy. According to Hjalmarsson (2015), biogas function as a boundary object and has contributed to high policy integration between the waste and energy sector in the Stockholm region. Between the energy and the transport sector, however, Hjalmarsson (2015) found little policy integration. The agricultural sector was not a part of this study.

There is a need to better understand the effect of integration of sectors in biogas value chains: the implications in terms of reduced

* Corresponding author. Ostfold Research, Stadion 4, 1671 Kråkerøy, Norway.
E-mail address: kari-anne@ostfoldforskning.no (K.-A. Lyng).

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GHG emissions and the economic consequences for the actors that makes the decisions on how value chains are designed. This information is helpful for policymakers on a regional and national level, when evaluating which instruments to introduce to reach political environmental goals.

1.1. Goal and scope of the study

The main objective of this paper is to study the economic and environmental implications of different configurations of biogas value chains, by looking at the level of involvement of several sectors (waste, agriculture and transport). The environmental impact assessment was limited to climate change for the scope of this paper, but the methodology applied may be used to include other environmental impact categories in the future.

The study aims at addressing the following four research questions: (a) What is the environmental performance of biogas value chains with different level of involvement of sectors? (b) What is the economic profit of the biogas plant for the different value chain configurations? (c) What is the relation between environmental performance and economic profit? (d) What types of incentives are necessary to make the scenario with the best environmental performance economically favorable?

A case study of four different biogas value chain configurations in Norway was performed. Like many other European countries, the Norwegian government has stated a goal of increasing the amount of manure to biogas production (The Norwegian Department of Agriculture and food, 2009). In 2014 a cross sectoral biogas strategy was published to increase biogas production (Norwegian Ministry of Climate and Environment, 2014). Norway is not a member of the EU, but has committed to the EU target of reducing at least 40% of GHG emissions by 2030.

Although economic profit is important for all actors in the value chain, this study was limited to the profit of the biogas plant. The biogas plant has a central role when it comes to the configuration of the value chain, especially regarding three important decisions: (1) choosing which substrates to use as input (2) what to use the biogas for: whether to produce heat or electricity from the gas, or to invest in upgrading facilities and produce biomethane that can be used as fuel or fed into the natural gas grid (3) how to treat the digestate (co-product from biogas production): whether to supply it to farmers as biofertiliser, or to dewater and compost it and supply it as a soil improvement product.

The main emphasis was on two types of input; source separated food waste from households and manure from cattle and pig. The study focused on large scale (in a Norwegian context) centralised biogas plants (>1 GWh biogas/year). Although a considerable amount of Norwegian biogas plants receives sewage sludge, it was not included as a substrate in this case study. A biogas plant treating sewage sludge would be less relevant when discussing integration of the agricultural sector into the value chain, due to the legal restrictions on the use of digestate produced from sewage sludge.

2. Materials and methods

2.1. Study objects

In Norway, biogas production was initially a waste treatment option for sewage sludge and organic waste from households and industry. Due to low demand for renewable energy caused by a large share of renewable hydropower in the electricity grid, a considerable amount of biogas has been flared or used as heat internally (63% according to Nedland and Ohr, 2010). There has, however, been a shift towards utilizing biogas as a fuel for transport and to use manure as a substrate. Poor utilisation of biogas has also been the case in other European countries, such as Finland, where heat from biogas plants has had a low utilisation factor, especially during summer months (Huttunen et al., 2014b).

The four different biogas value chain configurations assessed in this study with different levels of sector integration, is described below and shown in Fig. 1.

Level 1: Waste sector only. The biogas plant receives food waste from households. Biogas is used for heating purposes at the plant's own facility. The digestate is dewatered and composted and the water is sent to a waste water treatment plant.

Level 2: Waste and transport sector. The biogas plant treats food waste from households. Biogas is upgraded to biomethane and is used as a fuel in bus transport. The digestate is dewatered and composted and the water is sent to a waste water treatment plant.

Level 3: Waste and transport sector, agriculture as consumer. The biogas plant receives food waste from households. Biogas is upgraded to biomethane and is used as a fuel in bus transport. The digestate is transported to surrounding cereal farms and is used as a biofertiliser, as a substitute for mineral fertiliser.

Level 4: Waste and transport sector, agriculture as supplier and consumer. The biogas plant receives manure from cattle and pig farms, and food waste from households. The biogas is upgraded to biomethane and is used as a fuel in bus transport. The digestate is transported to farms producing cereals only, or farms producing cereals in combination with cattle and pig production, and the

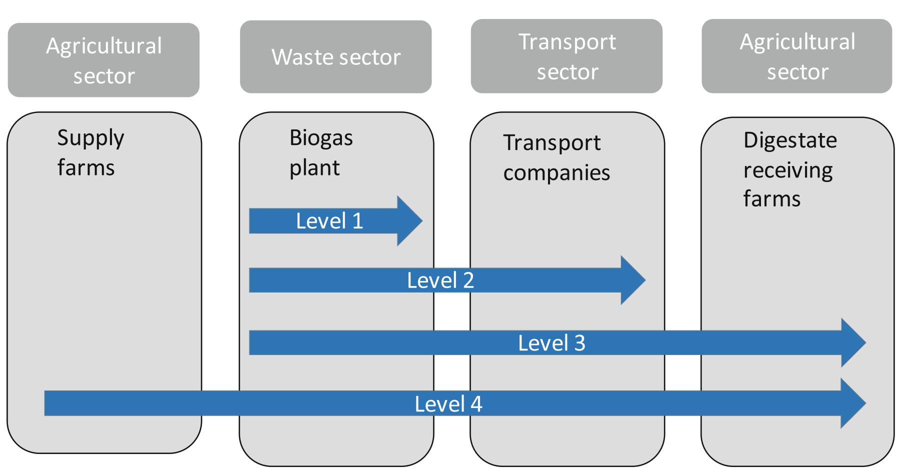

Fig. 1. Inclusions of sectors in the scenarios.