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Economic analysis of anaerobic digestion—A case of Green power biogas plant in The Netherlands

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ABSTRACT

One of the key concerns of biogas plants is the disposal of comparatively large amounts of digestates in an economically and environmentally sustainable manner. This paper analyses the economic performance of anaerobic digestion of a given biogas plant based on net present value (NPV) and internal rate of return (IRR) concepts. A scenario analysis is carried out based on a linear programming model to identify feedstocks that optimize electricity production and to determine the optimal application of digestate. In addition to a default scenario, management and policy scenarios were investigated. Economic evaluations of all scenarios, except no subsidy scenario, show positive NPV. The highest NPV and IRR values are observed under reverse osmosis (RO) as a green fertilizer scenario. Our findings show that treating RO as a green fertilizer, as opposed to manure (default scenario), is not only lucrative for the plant but also lessens environmental burden of long distance transportation of concentrates. This paper also concludes that given the uncertainty of regulations concerning RO and the currently low values of digestate and heat, high investment and operating costs limit feasibility of anaerobic digestion of wastes of farm origin and other co-substrates unless subsidies are provided.

1. Introduction

Manure residues from livestock industries have long been identified as a major source of environmental pollution. Traditionally, these wastes have been disposed of, directly or after composting, as soil amendments in the agricultural industry. Since this practice has resulted in degradation of air, soil, and water resources, new regulations for protecting the environment have been promulgated to control land application of animal manure [1]. The nitrate-directive, 91/676/EEC [2], regulates input of nitrate on farmland, aiming to protect ground and surface water environments from nitrate pollution, and includes rules for the use of animal manure and chemical fertilizers [3]. In principle, not more than 170 kg of animal manure N may be applied per ha per year, as long as this is not in conflict with application standard for total P [4]. Implementation of these environmental measures entails a high cost of manure disposal for livestock farmers, which impairs profitability of farming. As such, livestock industries and regulatory agencies are seeking alternatives for managing manure residues in an economically feasible and environmentally friendly manner. Several studies have shown that anaerobic digestion (AD) of organic wastes has the potential to manage these problems in a cost effective and environmentally sustainable manner [10,11,16,20].

Interest has recently been growing in using the AD of organic waste of farm origin, such as manure, crop residues and organic residues from food and agro-industries, to generate renewable energy [5,6]. Processing manure to biogas through AD recovers energy that contributes no net carbon to the atmosphere [7] and reduces the risk from pathogens from land spreading, as thermophilic or mesophilic AD with a sanitization step destroys all or virtually all pathogens [8].

Besides biogas, AD produces digestate, which consists of a mixture of liquid and solid fractions. Applying digestate to land is the most attractive option in terms of environmental issues, because it allows nutrients to be recovered and reduces loss of organic matter suffered by soils under agricultural exploitation [9]. A reliable and generally accepted means of disposing of the comparatively large amounts of digestate produced is of crucial importance for the economic and environmental viability of a biogas plant [10]. Murphy and Power [11] investigated biogas production utilizing three different crop rotations to optimize energy production and performed a sensitivity analysis for a change in price of digestate. Georgakakis et al. [12] developed an economic evaluation model based on the concept of NPV to

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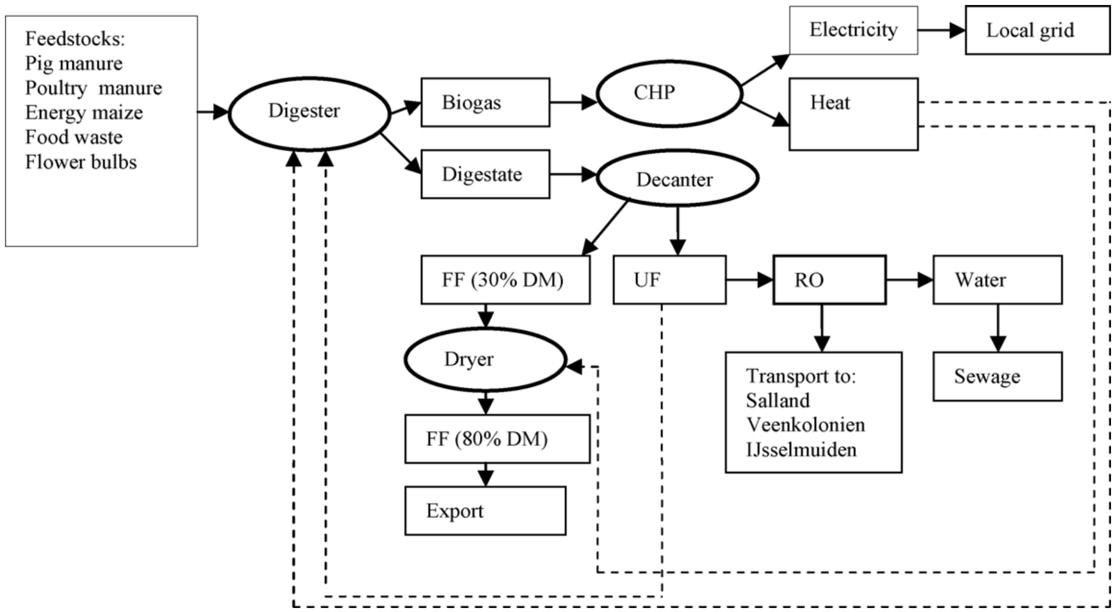

Fig. 1. Schematic overview of Green power anaerobic digestion process. CHP = combined heat–power unit; FF = fixed fraction; DM = dry matter; UF = ultra filtration; RO = reverse osmosis.

assess cost-effectiveness of biogas production systems fed with pig manure. However, a complete economic analysis of AD, incorporating outcomes from production and application of digestates is still lacking.

The aim of this study is to analyze economic performance of AD of a given biogas plant. A scenario analysis is carried out on the basis of a linear programming (LP) model to identify feedstocks that optimize electricity production and to determine optimal application of digestate. Green power biogas plant located in northern part of Netherlands forms the basis for our analysis. The plant is a relatively large plant with an installation capacity of 70,000 tons of input on an annual basis. The plant produces electricity, heat, and three types of digestates, namely fixed fraction (FF), ultra filtration (UF), and reverse osmosis (RO).

The paper is structured as follows. Section 2 introduces case study and will elaborate on general framework, data used, and assumptions made for developing an optimization model. Section 3 will analyze model results and scenarios assessed. The final section contains discussion and major conclusions.

2. Materials and methods

2.1. Case study description

Green power biogas plant was established in 2007 by 50 swine farmers, with an installation capacity of 70,000 tons of input on an annual basis. The important starting point for the plant was its commitment to process a contracted amount of pig manure from its member farmers. The installation, in addition to pig manure, uses other co-digestion materials, such as poultry manure, energy maize, food waste, and flower bulbs. A schematic overview of Green power AD process is given in Fig. 1.

The input materials are mixed, grinded, and pumped to 2 prefomenters of 600 m^3 each. Fermentation starts, and mixture stays a week in these silos. This pre-fermented product flows to main fermentor of 1800 m^3 and stays there for 40 days at 40°. Biogas is burned in a combined heat and power (CHP) unit to generate electric power and heat. Electricity produced is sold to local grid at a market price of €0.06 kwh^{-1}. Additionally, the plant receives an MEP[1] subsidy of €0.097 kwh^{-1} for a duration of 10 years, after which it is estimated that it will receive about half of current tariff (personal communication with plant manager). The plant is limiting electricity production to a total of 2 MW $year^{-1}$, amount for which subsidy is provided.

Market for heat is currently non-existent. Heat is utilized within the plant for heating digester and drying digestate. Besides biogas, the plant produces digestate, which is separated into a solid and a liquid fraction via pressing. Solid fraction (80% dry matter), rich in phosphate, contains NPK of 9.3, 19.2 and 5.9 kg ton^{-1}, respectively and is targeted for export to EU countries with a phosphate deficiency. The plant intends to sell FF concentrate at zero price, but transportation cost will be fully paid by buyers. Ultra filtration is recycled to digestion process, guaranteeing sufficient dilution of substrate fed into digester. Reverse osmosis, also referred to as green fertilizer, contains NPK of 6.8, 0.6 and 11.5 kg ton^{-1}, respectively. It is to be used as a supplement to animal manure on plots with low K qualities. Currently, RO is treated as animal manure, competing with other types of manure with an application rate limited to 170 kg (or 250 kg on grassland) N per ha per year from animal manure. However, pilot projects are underway to test fertilizing value and treatment of RO as a replacement to artificial fertilizer.

For biogas plants, the first consideration in digestate management is adhering to hygiene requirements and certification of digestate. Organic waste can contain infectious matters, which can result in new spreading of pathogens and transmission of disease between animals, humans, and environment. Many countries, therefore, enforce their legislation regarding pathogen control in digestate. At the same time, European Council has implemented rules and regulations that are mandatory for all Member Countries [13]. These regulations include European regulations (EC) No. 208/2006 and (EC) No. 1774/2002. In Netherlands, Food and Consumer Product Safety Authority (VWA) deals with monitoring of the production and certification of digestates.

[1] The MEP (Environmental quality of electricity production) is a kwh subsidy paid to domestic producers of electricity from renewable sources and CHP who feed into the national grid. The state guarantees the subsidy for a maximum of 10 years.