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Recent trends in biogas value chains explained using cooperative game theory

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Abstract

In Denmark, since 2014, it has been possible to upgrade biogas to a gas grid and achieve support in line with biogas-based heat and power production. Since then, most new biogas production plants have chosen to upgrade their biogas. In this study, a mixed integer programming model is used to find the optimal biogas value chain, and cooperative game theory is used to understand real world observations compared to this study's results. Specifically, three profit allocation mechanisms are applied to allocate the profit between the heterogeneous owners in the value chain. It is found that Danish biogas plants should use large shares of manure combined with deep litter. Furthermore, it is found that input suppliers have relatively poor bargaining power in the profit allocation negotiations due to poor alternatives. This may explain why livestock farmers tend to receive little payment for their manure, and why they are hesitant to join biogas projects.

Finally, it is found that biogas plants prefer to upgrade their biogas for several reasons. First, if the natural gas price is expected to be high, it is preferable to upgrade biogas than to use it directly in a local combined heat and power plant (CHP). Second, if the natural gas price is expected to be low, it is preferable to upgrade because the CHPs have better alternatives and therefore better bargaining power before investments (*ex ante*). Third, when the value chain contains an upgrading plant, the biogas plant has a greater bargaining power—in particular *ex post*.

Keywords: Cooperative game theory, Profit allocation, Mixed integer programming, Biogas, Biomethane, Value chain

1. Introduction

Danish biogas production has developed remarkably recently since a change in regulation following the Energy Agreement in 2012 (Danish Government, 2012), where it was agreed that biogas, among other renewable energy sources, should be strengthened economically. Thus, several initiatives began. The probably most important initiative was that, after an EU ratification in 2014, it

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