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Author(s)	島畑, 淳史
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博士（環境科学）

氏 名 島畑 淳史

学 位 論 文 題 名

Assessment of the potential to adopt biogas plants in Hokkaido
and the environmental and economic benefits based on dairy farmers' willingness
(酪農家の意思を踏まえた北海道におけるバイオガスパラントの導入可能性
及び環境的・経済的便益の評価)

Intensification of the livestock industry has become environmentally problematic due to the uncontrolled treatment of large amounts of watery manure. One solution is the anaerobic digestion (AD) in biogas plants (BGPs). Many studies have already stated that BGPs offer environmental and economic benefits. Hokkaido, Japan, has significant potential for BGP adoption, however, BGP adoption has also been influenced by national policies such as subsidy and energy policy, and the large financial investments and lack of grid space for selling electricity are barriers.

To enhance BGPs, it is important to realize efficient support from the national government. And the accurate potential to adopt BGP and the expected benefits of BGPs are need to be assessed. Thus this study aimed to investigate the farmers' willingness and farming planning to estimate the more realistic potential. Also I clarified the current farming situation and the issues expected to be resolved by BGPs, and assessed the environmental benefits such as reduction of GHG emission and economic benefits by adopted BGPs.

Concerning the BGP adoption potential, there have been several studies investigating the potential by using statistical data. However, there was no study that confirmed the farmers' willingness and reflected it to estimate the potential in the world. To clarify the potential based on the farmers' willingness, this study conducted a questionnaire and an interview surveys of 268 dairy farmers who did not adopt BGPs in nine municipalities in Hokkaido. The result indicated that 119 dairy farmers (41.6% of the surveyed farmers) showed willingness to adopt BGPs, and the average number of dairy cows in each household was 146.4 head (milking cow equivalent). The rate of change for next 10 years was 22.3% to 46.3%, and the amount of manure to be treated in BGPs was 86.8%. Therefore, 2,484 dairy farmers having 385,856 to 461,342 dairy cows might adopt BGPs in Hokkaido, and 25,081 to 29,987 tons of manure would be treated in one day in the future.

This study investigated the farmers' current farming situation such as the farm scale, future plans and existence of issues to treat dairy manure. The farmers who have willingness to adopt BGPs were likely to be large-scale farmers, particularly those with more than 100 mature cows, and expand their businesses in the future, while farmers who planned to downsize their businesses did not exhibit strong willingness to adopt BGPs was found. This result also showed that the farmers willing to adopt BGPs thought BGPs would help solve problems with manure treatment.

This study indicated that BGPs was expected to reduce GHG emission by replacing fossil fuels to produce energy, and by reducing emission in the process of reference manure treatment. In addition, this study estimated economic benefits by the GHG reduction. The expected 25,081 to 29,987 tons of manure per day could produce electricity in BGPs up to 3,673 MWh per day, which would be supplied to 314,866 households, covering 11.3% of the total in Hokkaido. Additionally, BGPs simultaneously generated heat energy, which would cover 0.58% of the heat energy consumed annually in Hokkaido. Assuming that currently all the heat energy was produced by kerosene, BGPs could reduce annual imports of kerosene by 151 ML from overseas. Regarding the GHG emission in the process of manure treatment (pilling and forced composting that many dairy farmers currently implemented), the emission of methane (CH₄) and nitrous oxide (N₂O) was estimated, and the change due to adoption of BGPs were compared to assess the impact of BGPs. Ultimately, the leakage of 2% of produced biogas from BGPs was also estimated. The result showed that BGPs could replace energy from fossil fuels, resulting in the maximum annual reduction of 1,237,350 t CO₂-eq. Also, GHGs emitted annually from pilling and forced composting were estimated to be 585,095 t CO₂-eq and 27,740 t CO₂-eq, respectively. Thus, the shift of manure treatment method could reduce up to 1,591,400 t CO₂-eq of annual GHGs emission, which was equivalent to 2.2% of GHG emission of Hokkaido at the level of 2016, required to stop the emission until 2050.

The expected economic effect of the adoption of the BGPs was also calculated as the revenue from the sale of electricity, the reduction of kerosene consumption, and the expected revenue from the sale of Japan Credit (J-Credit). The annual revenue was estimated to be 52.2 billion JPY when the sales price of electricity was 39 JPY kWh⁻¹ under the Feed-in-Tariff (FIT) system, 12.1 billion JPY when the price of kerosene was 80.1 JPY L⁻¹, and 3 billion JPY when the price of J-Credit was 1,887 JPY (t CO₂-eq)⁻¹. The total economic impact was 67.3 billion JPY year⁻¹. Thus BGPs would offer a total annual economic benefits of 67.3 billion JPY.

This study assessed the potential to adopt BGPs in Hokkaido with farmers' perspective and expected both environmental and economic benefits on the viewpoint of GHG reduction. As the results, 2,484 dairy farmers would continue farming with the improved farming environment by BGPs, and the farmers are expected to play an important role in enhancing local industries in each region of Hokkaido. From the points, BGPs would also be a tool to achieve sustainable development goals (SDGs), especially SDG Goals 7, 8, 12, and 13. And to enhance BGPs, it is expected to obtain financial mechanism such as Environment, Society, and Governance (ESG) investment and Japan credit (J-credit) system certifying GHG emission reduction.