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A case study of renewable natural gas production at a cattle feedlot in Alberta: environmental, technical and policy analysis

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Summary

The overarching objective of the study is to evaluate the technical feasibility of a renewable natural gas (RNG) production facility in Alberta using co-digested cattle manure. The research adopts a case study approach and focuses on a typical cattle feedlot in Alberta. The study endeavours to find ways to optimize renewable production and reduce greenhouse gas (GHG) emissions. GHG emissions from feedlot operations were calculated for high and low-emission scenarios. Additionally, the study evaluates the technical aspects of RNG production, as well as the potential environmental impact on nearby traditional Indigenous lands. Finally, we performed a comprehensive policy review to evaluate the viability of producing RNG from cattle manure in Alberta.

Introduction

Canada Energy Regulator predicts that the national demand for natural gas will increase by nearly 8% by 2040 to nearly 4 600 petajoules whereas Alberta will remain the largest consumer of natural gas in Canada (Canada, 2019; Stephen et al., 2020). At the same time, the Canadian government has set a goal to achieve GHG net-zero emissions by 2050 (Canadian Net-Zero Emissions Accountability Act, 2021). One potential gas production option which can help to reduce the carbon intensity of fossil fuels produced in Canada is RNG. RNG is produced from organic waste materials and represents upgraded gas with a quality similar to fossil natural gas.

RNG production from manure is a promising example of a sustainable biomass and circular economy system (Fagerström et al., 2018). Given that Canada's total livestock production generated around 21 million tons of dry manure, there is significant potential for RNG production from this source (Stephen et al., 2020). However, RNG production from manure presents various challenges, such as manure collection, anaerobic digester selection, and plant construction costs (Liebetrau et al., 2021). This study evaluated the feasibility of RNG production from co-digested cattle manure at the Cattleland Feedyard Ltd, a feedlot in Alberta, taking into consideration existing government policies, and proposes possible solutions to these challenges. The feedlot has a 25,000-head capacity (Canadian Cattlemen, 2022) and is located 50 km north of the Siksika Reserve. The energy transition towards renewable sources is also considered as a potential pathway to reconciliation (Scott, 2020).

Results

Technical challenges

The production of RNG is highly dependent on the manure-gathering process (Tullo et al., 2019). Usually, the frequency of manure collection for a feedlot is twice a year (McGinn and Flesch, 2018). Normally, feedlots are placed just above the soil and collected manure contains dust, sand, and gravel. These immatures impede manure pre-treatment for RNG production and negatively affect the operation of an RNG plant (LPE learn center, 2017, Khoshnevisan et al., 2021). In this research, a feedlot pen design was proposed for the cattle manure collection to minimize the presence of soil in the collected manure (Fig. 1). Additionally, it mitigates the risk of water contamination (Watts et al., 2016).

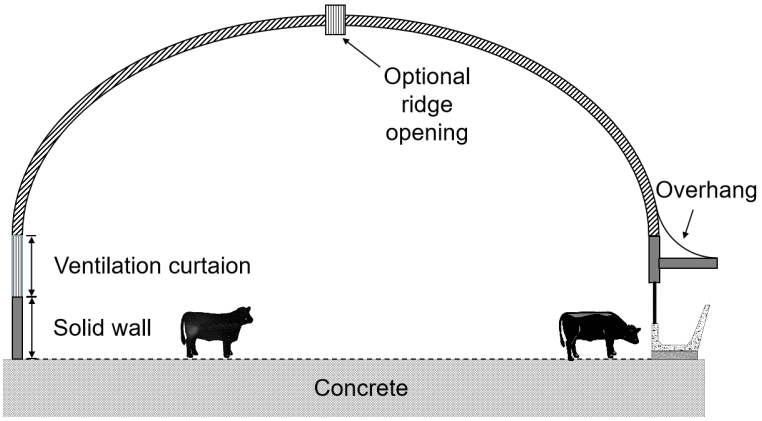

Fig. 1. Proposed feedlot pen design (modified from Honeyman et al., 2008).

The design includes a concrete foundation to decrease the presence of soil in the collected manure. The proposed modifications are expected to enhance the quality of the collected manure and increase the efficiency of renewable natural gas production.

The amount and quality of the biogas produced from cattle manure depend not only on the manure composition but also on a used anaerobic digester (Li et al., 2015). Based on the feedstock type and its amount, co-digest organic sources, energy recovery, costs, environmental impact, and regulations (Wilkie, 2005; Stephen, et al., 2020; Liebetrau et al., 2021), we proposed a complete mix anaerobic digester for RNG production in the considered feedlot. The amount of produced biogas and RNG then was evaluated based on the volume of biogas produced per unit of volatile solids in the cattle manure (AgSTAR Project Development Handbook, 2020).

Greenhouse gas emissions

Livestock production is responsible for nearly 18% of all GHG emissions (Steinfeld et al., 2006). There are various methods to measure the greenhouse gas emissions from cattle manure, but a commonly used approach was proposed by Intergovernmental Panel on Climate Change guidelines (IPCC, 2006; Chen et al., 2020). Based on this method, GHG emissions from the cattle manure in the Cattleland Feedyard Ltd. were quantified for baseline (high-emissions) and alternative (low-emission) scenarios. Figure 2 shows the GHG emissions considering the one-year period.

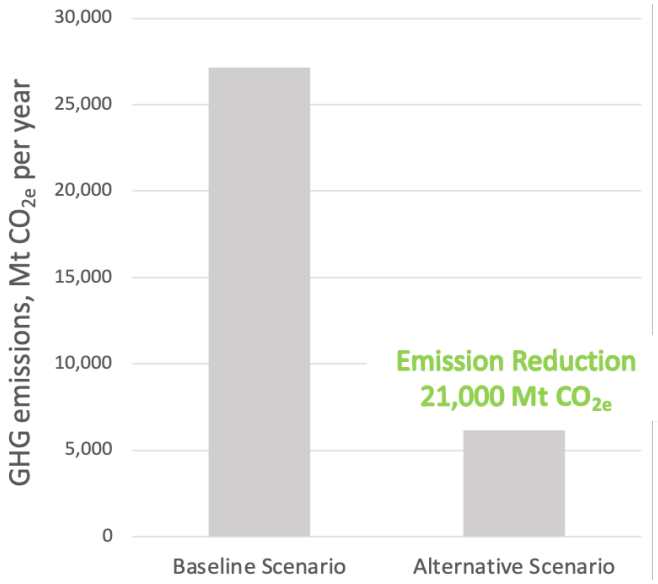

Fig. 2. GHG emissions generated from cattle manure in the Cattleland Feedyard Ltd for baseline (high-emissions) and alternative (low-emission) scenarios per year.

In the baseline scenario, manure is not processed to RNG and is left in the feedlot. The annual amount of GHG emission in this scenario accounted for 27,000 Mt CO_{2e} per year. An alternative scenario proposes RNG production with a regular gathering of cattle manure in a feedlot which decreases the harmful impact on the environment. The total emission reduction is 21,000 Mt CO_{2e} per year and approximately $3*10^6$ Mt CO_{2e} for a period of 150 years. Other studies also confirm that RNG production from cattle manure extremely reduces the amount of GHG emissions (Liebetrau et al., 2021; Tallou et al., 2020).

Water contamination reduction

The high density of feedlot operations in northern Alberta has led to growing public concern about the potential pollution of the environment due to the concentration of manure in specific areas (Whalen and Chang, 2001; Mayer et al., 2004). These operations also produce large quantities of manure that are applied as fertilizer, which can be significant sources of nutrients, bacteria, and pathogens to waters when applied in excess of crop requirements (Mayer et al., 2004). According to a recent study (Sinnatamby et al., 2020), the Bow River which falls on traditional Treaty Land and winds through Siksika Reserve Settlement has anthropogenic threats conditioned by agricultural practices including livestock operations. Its water has elevated concentrations of manure-derived nutrients from agricultural return flows. It is well known that RNG production from cattle manure using anaerobic digestion can significantly decrease water contamination occurring from feedlot operations as well as increase local air quality by decreasing emissions (Tullo et al., 2019).

Policy gaps

Alberta does not currently have a legislative framework that is specific to RNG projects and therefore the relevant requirements of the applicable legislation for industrial facilities, environmental assessments and water use in Alberta will apply to the project (White et al., 2022). The lack of a specific regulatory framework for RNG projects in Alberta raises important questions

about the need for policy interventions and regulatory support to encourage the adoption of RNG and other renewable energy sources in Canada. Without dedicated RNG policies or specific support for RNG production and use the development of manure-based systems will likely be confined to large farms (Liebetrau et al., 2021). The existing market for carbon credits is also challenging in terms of potential revenue, therefore, there should be clarity on how the pricing and carbon credit of methane generation will be regulated in Alberta.

Conclusion

This study assessed the technical feasibility of producing RNG from co-digested cattle manure at a typical feedlot in Alberta. The study aimed to find ways to optimize RNG production and reduce greenhouse gas emissions, while also evaluating the technical aspect of RNG production and the potential environmental impact on nearby traditional Indigenous lands. The study proposes a feedlot pen design for collecting manure, which can minimize the presence of soil in manure and a complete mix anaerobic digester for RNG production. GHG emissions from feedlot operations were calculated for high and low-emission scenarios over a 150-year period, and the study found that RNG production can significantly reduce emissions. The result indicated that nearly 80% of GHG emissions obtained during feedlot operation will be avoided. However, the absence of a specific legislative framework for RNG projects in Alberta remains a major obstacle. This study contributes to the ongoing efforts to reduce the carbon intensity of fossil fuels produced in Canada and to achieve net-zero emissions by 2050.

Further research should be addressed to the efficiency determination of a proposed pen design in real-world conditions as well as more sophisticated estimations of GHG emissions and produced RNG amount using experimental data from the feedlot for the characterization of manure.

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