**Application**

This research could drive important progress in renewable energy and sustainable agriculture by demonstrating the economic potential of anaerobic digestion (AD) of livestock slurry and grass silage. Insights from this study may guide policy and funding strategies to encourage sustainable farming, reduce greenhouse gas (GHG) emissions and support rural economies by creating new revenue streams for grassland farmers.

**Introduction**

Anaerobic digestion of livestock slurry is an effective approach to reduce GHG emissions from slurry management, while generating valuable products such as energy and organic fertilizer, through biomethane and digestate, respectively. Available AD feedstocks in Ireland, where pasture-based livestock systems predominate, include cattle slurry and grass silage. However, there is little knowledge about the economic implications of integrating AD and livestock farms and the financial support required to make biomethane from agricultural feedstocks profitable. This study aimed to (1) assess the economic impact of integrating AD and livestock farms and determine the AD silage price needed to make this activity competitive with beef production, (2) carry out a cost-benefit analysis of a 40 GWh biomethane plant, and (3) determine the adequate support schemes needed to ensure the economic viability of producing biomethane from the co-digestion of cattle slurry and grass silage.

**Materials and Methods**

*Farm scale*

The farm-level model implemented was the Grange Dairy Beef System Model (GDBSM), which allows the evaluation of biophysical, economic and GHG outputs from pasture-based dairy-beef production systems (Kearney et al., 2022). This model was augmented with an AD submodel (Tisocco et al., 2024) to simulate the biomethane production using cattle slurry and grass-based feedstocks supplied from dairy-beef farms. The grass-based dairy-beef system modelled assumed a 50 ha farm stocked with February-born early-maturing progeny of dairy cows which were slaughtered at 24 months of age (Kearney et al., 2022). To provide the feedstock demand for a 40 GWh AD plant (43019 tonnes (t) of grass silage and 50042 m3 of cattle slurry annually), 130 farms were required with 85% of each farm (42.5 ha) allocated for growing grass for livestock use, and the remaining 15% (7.5 ha) allocated to produce AD silage (Tisocco et al., 2024). The AD silage crop comprised a mixture of perennial ryegrass and red clover with a total annual yield of 14.2 t dry matter (DM)/ha and 22% losses. The gross margin of the livestock area was determined by considering revenue from animal sales and direct expenses such as concentrate feeds, milk replacer and fertilizers. Silage production costs were obtained from the Grange Feed Cost Model (Finneran et al., 2010). The total price of AD silage included production costs and an additional amount to offset the partial displacement (15%) of livestock, calculated based on the revenue generated from an equivalent area of a dairy-beef system.

*Supply chain scale*

The capital and operational expenditures of a 40 GWh biomethane plant were calculated, and a 20-year net present value (NPV) analysis was conducted to assess profitability. Two scenarios, reflecting current financial support structures, were evaluated: (1) a baseline scenario, which included the biomethane certificate price (€0.098/kWh) in addition to the prevailing market price for gas (€0.04/kWh), and (2) a grants scenario, which also incorporated AD plant grants (covering 20% of capital costs and 30% of gas grid connection costs) along with an AD silage establishment grant (€60/ha/year). Additionally, the maximum price that the AD plant could afford for AD silage in order to achieve a payback period of 8 years was determined for each scenario. The required AD farm subsidy was determined by the price gap between the farm’s AD silage price and the maximum price the AD plant could afford.

**Results**

Results indicated that dairy-beef farms providing feedstock for AD reduced direct costs by 4% compared to conventional dairy-beef farms due to lower chemical fertilizers used, as the digestate (616.5 m³/farm) provided more nutrients and had a higher volume than the slurry produced (454.2 m³/farm). Consequently, the gross margin per hectare for dairy-beef farms integrated with AD was 5% higher than conventional dairy-beef farms. However, livestock gross margin per farm (50 ha) was 11% lower due to the allocation of 7.5 ha for AD silage cultivation. A total AD silage price of €245/t DM was required to cover the production cost and to compensate for the reduced gross margin per farm. For the baseline scenario, the 20-year NPV was -€2.4 106, indicating that a biomethane certificate price of €0.098/kWh was insufficient for financial competitiveness. Incorporating grants and the AD silage establishment grant in the analysis resulted in a 20-year NPV of €645013 (Figure 1a). For the baseline and grants scenarios, the AD plant could afford a maximum AD silage price of €134 and €169/t DM, respectively, to achieve an 8-year payback period. Consequently, price gaps of €111/t DM and €76/t DM would demand AD farm subsidies of €1229/ha and €840/ha, respectively (Figure 1b).

![A graph of different colored lines

Description automatically generated with medium confidence]()

**Figure 1.** (a) Net present value analysis over 20 years for the baseline and grants scenarios; (b) Maximum AD silage price paid by the AD plant to achieve an 8-year payback period and minimum farm subsidy required to bridge the price gap.

**Conclusions**

Results indicated that a price of €245/t DM is needed to attain gross margin comparable to beef production. For the AD plant to fully cover this cost and remain profitable, a minimum biomethane price of €0.12/kWh is required, along with grants covering 20% of capital costs and 30% of gas grid connection costs. At current biomethane prices and grants, the plant could only afford a silage price of €169/t DM, necessitating AD farm subsidies of €840/ha. These findings highlight key economic thresholds for Irish farmers, policymakers, and industries to ensure the viability of AD systems, emphasizing the need for targeted subsidies and grants. The results also provide a transferable framework for bioenergy development in similar agricultural contexts globally.

**References**

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