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Circular Biogas-Based Economy in a Rural Agricultural Setting

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Abstract

This study investigates the application of a circular economy in a rural agricultural setting in Northern Ireland, centered around a typical anaerobic digestion (AD) plant, showing its potential to provide renewable energy for the electricity and transport fuel needs of an average dairy farm and associated milk processing facilities. It was calculated that a typical AD plant has the potential to fuel 22 average sized dairy farms in Northern Ireland, equating to the production, transport, and processing of 51,986 litres of milk per day. The feedstock needs of the AD plant can be provided by the local farming community.

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Keywords: Circular economy; anaerobic digestion; biogas; biomethane; renewable energy; dairy farming

1. Introduction

1.1. Farming in Northern Ireland

Currently, there are just over 24,500 farms in N Ireland, with dairy, beef and sheep being the largest commodity sectors [1]. In N Ireland, over 47,700 people work on farms [1]; this makes up 9.9% of the overall workforce, which

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is above average compared to the rest of the UK, highlighting the value of agriculture to the country and its economy [2]. Agriculture also supports jobs in other sectors, with a further 22,000 people employed directly within the N Ireland food and drink industry [3]. Farming is very important to the UK as a whole, with the industry making major economic contributions both in its own right and as a key supplier to the agri-food industry. In 2015, agriculture contributed around £24 billion of revenues and around £8.5 billion of Gross Value Added (GVA) to the UK economy, with the ratio of the agricultural industry's benefits to the UK economy to its costs to the UK standing at 7.4:1 [2]. In N Ireland, the GVA produced by agriculture in 2015 was £354 million, 4.2% of the overall value of the N Ireland economy [2]. The agriculture industry also contributes to the wider economy, with £486 million in purchases made from other sectors by farming businesses in N Ireland in 2015 [2].

1.2. Emissions due to agriculture

N Ireland, which accounts for just 2.8% of the population of the UK [4], produced ~20.3 million tonnes of CO_2 equivalent in 2014, 4% of total UK greenhouse gas emissions (GHG) [5]. The agricultural sector is the largest contributor to N Ireland's GHGs, accounting for 28% [5]. Emissions are predominantly from livestock (methane) and soils (nitrous oxide), and N Ireland accounts for 8.1% and 7.9% of the UK's emissions of methane and nitrous oxide respectively [5]. Emissions from energy use (12%) are composed of emissions from stationary combustion (10%) and from off-road machinery (90%) [6]. Due to the relative importance of agriculture to the N Ireland economy, agricultural sources accounted for a higher proportion of emissions here than other parts of the UK [5]. The second largest contributor to N Ireland's GHG emissions is the transport sector, which accounted for 21% in 2014 [5]. Transport is closely linked to agriculture, with heavy duty vehicles used both by farmers and to distribute the wide variety of raw materials and products needed by processors and retailers to meet the demands of customers.

The Renewable Energy Directive requires all EU member states to fulfill at least 20% of their energy needs with renewables by 2020, with at least 10% renewable transport fuels [7]. Revised in 2016, the Directive set a new target for 27% of energy needs from renewables by 2030 [7], and for fuels made from wastes/residues to receive double credits [8]. Exploring alternative, environmentally benign and energy efficient systems is therefore important, particularly in the agricultural and transport sectors; one technology that is receiving increased interest is anaerobic digestion (AD). The share of renewable electricity from AD in the UK rose by 40% between 2014 and 2015 [9].

1.3. Anaerobic digestion in Northern Ireland

AD is a process in which organic matter is broken down by micro-organisms in an oxygen-free environment to form biogas and digestate/biofertiliser. The feedstock (organic matter) can include pig or cattle slurry, poultry litter, energy crops such as grass silage, and food waste. Biogas composition is dependent on the feedstock, but is typically ~60% methane (CH_4) and ~40% carbon dioxide (CO_2), with some minor constituents such as water and hydrogen sulphide (H_2S) [10]. The most common use of biogas is directly for combined heat and power (CHP) generation, with the electricity being used on-site and/or injected into the grid. In Europe in 2013, more than 90% of biogas was used for electricity generation [10]. A growing use of biogas is as a road vehicle fuel, which requires the upgrading [11] of biogas to biomethane (typically >97% CH_4) to remove the CO_2 and impurities and to bring it to the same standard as natural gas; the two fuels can be used interchangeably. Biomethane offers the same benefits as natural gas (lower carbon intensity, reduction in emissions of particulate matter) but has a lower carbon footprint if it is sustainably derived from organic materials. Biomethane from animal slurry, for example, offers 84% GHG savings compared to diesel when used as a transport fuel [12], while biomethane from grass offers 75% savings [13].

To reduce N Ireland's dependence on imported fossil fuels (which account for ~90% of total energy demand [6]), incentives and targets have been put in place to increase the proportion of locally sourced renewable energy, including biogas. Around 40 AD plants are either in operation or under construction in N Ireland [14] and, as of 2013, 91 planning applications had been granted for AD plants [6]. All of the plants are electricity production plants, with two producing heat as well as electricity [14]. The feedstock used is mainly derived from agriculture, with a few plants using commercial and/or industrial waste. For natural gas transport fuels to be feasible in N Ireland, biomethane infrastructure is needed. On the island of Ireland as a whole, the natural gas network is extensive [15], but the current grid does not supply many of the key towns in the west and northwest of N Ireland. There is, however, a £250 million