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What is the resource of second generation gaseous transport biofuels based on pig slurries in Spain?

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HIGHLIGHTS

- Biomethane from pig slurry and residues is mooted as a gaseous biofuel.
- This is preferable to drying of slurries using natural gas as employed in Spain.
- Co-digestion of slurry with glycerine from biodiesel and food waste is suggested.
- The resource satisfies 28% of the renewable energy in transport target.
- The resource may fuel 15,300 buses or supply renewable heat to 8.7% of houses.

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ABSTRACT

Biomethane produced through anaerobic digestion of residues is classified as a second generation gaseous biofuel. A technique employed in Spain to deal with pig slurry is drying, using the heat from natural gas combined heat and power (CHP) systems. This paper examines production of biomethane from pig slurry. Two scenarios are investigated: co-digestion of pig slurry with glycerine (a by-product of biodiesel production) and co-digestion of pig slurry with the organic fraction of municipal solid waste (OFMSW). Both scenarios include for ca. 10 Mt of pig slurry each year. A combination of the two scenarios is sufficient to provide for 1.4% of energy in transport by 2020. The EU Renewable Energy Directive allows a double weighting to biofuels produced from residues when assessing renewable energy supply in transport (RES-T) targets for 2020. Thus the scenarios allow for 2.8% RES-T. The biomethane is sufficient to run 15,300 city buses or substitute for natural gas in 632,000 houses (8.7% of houses connected to the gas grid). The proposed biomethane industry would generate a fuel of similar sale price as diesel, allow for savings in the range 1046–1272 kt CO_{2eq} in transport fuel emissions and create more than 6000 jobs.

1. Introduction

1.1. Renewable energy targets for Spain

At present, 11.1% of primary energy and nearly one third of electricity consumption in Spain is supplied by Renewable Energy Sources (RESs) [1]. The Spanish Renewable Energy Plan 2011–2020 [2] establishes a roadmap for the renewable energy sector until 2020 in accordance with the targets set by the Renewable Energy Directive [3]. The final energy consumption forecast for 2020 is 4122 PJ. Transport is the dominant sector, with 32.8% of the final energy consumption (Table 1). Austerity however may lead to a reduction in this prediction. The predicted economic growth of 2–2.5% per annum until 2020 is unlikely to be achieved. Final energy consumption in 2011 was 3904 PJ, a decrease of 4.4% over 2010 [1].

According to the Renewable Energy Plan [2] (Table 2) the contribution of renewable energy to energy consumption in Spain will be 859 PJ (20.8% of final energy consumption). Renewable Energy Sources in Transport (RES-T) will be 11.3% calculated using the methodology outlined in the Renewable Energy Directive [3].

In the biogas sector, the targets for 2020 are 400 MW_e of installed power with an annual electricity production of 2600 GW_e h (9.36 PJ). In the thermal sector biogas is targeted to supply 4.2 PJ (1167 GW h) per annum by 2020.

1.2. Biogas sector in Spain

The biogas sector in Spain is under developed when compared with other renewable energy sources. The previous Renewable

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Table 1
Gross final energy consumption forecast for 2020 [2].

Energy consumption forecast (2020)	PJ	%
Thermal energy (heating and cooling)	1295	31.4
Electricity	1338	32.5
Transport (road and rail)[a]	1352	32.8
Final energy consumption[b,c]	4122	100

[a] Transport consumption includes road and rail calculation according to article 3.4 of Directive 2009/28/EC.
[b] Several parameters are used to calculate the gross final energy consumption, thus this parameter does not coincide with the addition of thermal energy, electricity and transport.
[c] Including the deduction for aviation included in the article. 5.6 of Directive 2009/28/EC (10 PJ).

Table 2
Renewable energy targets for 2020 [2].

Renewable energy targets for 2020 Renewable Energy Plan (REP)	PJ	%
Heating/cooling using renewable energy (RE) sources	224	17.3
Electricity consumption from renewable sources	521	38.9
Energy in transport[a]	153	11.3
Total energy consumption from renewable sources	859[b]	20.8

[a] Renewable energy in transport (135 PJ) used to calculate % of RES-T is modified to include weighting for biofuels from residues (weighting of 2) and electricity in road transport (weighting of 2.5). The total weighted energy in transport is 153 PJ which is 11.3% RES-T.
[b] The total energy consumption is calculated subtracting electricity in transport (21.1 PJ) to avoid double counting in transport and electricity.

Energy Plan (2006–2010) set a biogas target of 235 MW_e for 2010. Only159 MW_e was installed, with an annual production of 600 GW_e h. About 78% of this production comes from landfill gas (115 MW_e). The rest of the biogas is produced from [2]:

- Organic fraction of municipal solid waste (OFMSW; 19 MW_e)
- Agro-industrial wastes (14 MW_e) and
- Wastewater treatment plants (WWTP; 11 MWe).

This low level development can be explained by the low feed-in tariffs for electricity produced from biogas. Up until February 2013 the feed in tariff was ca. €0.145/kW_e h for plants less than 500 kW_e. However as of February 2013 there is no subsidy for new biogas plants in Spain, and subsidies have been reduced for those currently in operation (see Section 4.2).

This may be compared with the feed-in tariffs in Germany (up to €0.30/kW_e h) [4]. Implementation of the Landfill Directive [5] will reduce the organic waste sent to landfill which will reduce the landfill gas production while increasing the feedstock available for anaerobic digestion.

Spanish biogas potential is estimated at 75.3 PJ; 78% of the resource is based on agri-food wastes [6]. Thus agriculture, farming, and the food industry are the key sectors in initiation of a biogas industry. Co-digestion of wastes must be undertaken to optimise biogas yields and financial sustainability of the anaerobic digestion (AD) facilities.

1.3. Co-digestion of pig slurry with methane rich substrates

Animal manures and slurries are the largest source of organic waste produced in the EU-27 with more than 1.5 billion tons produced per annum. Anaerobic digestion of these slurries should be a great resource of renewable energy and nutrients for sustainable agriculture [7]. The slurry considered in this paper is typical of the slurry produced in large pig farm with pigs on slatted systems. This slurry has a low solids content (less than 8% dry solids (DSs)) and a low biogas yield (10–20 m^3 CH_4 per ton of wet slurry) [8–11]; thus mono digestion is uneconomic. Co-digestion with substrates that have a high methane production per unit volume and a gate fee is critical for an economically feasible industry [8,12]. Denmark was a pioneer in centralised co-digestion plants, integrating organic waste treatment, renewable energy production and nutrient recycling [7].

1.4. Environmental justification for digestion of pig slurry

The pig industry in Spain is the second biggest in the EU with nearly 25 million pigs and a yearly turnover of €4 billion [13]. Slurry production of 45.9 Mt is generated on intensive pig farming facilities every year [14]. Environmental concerns with this industry include for (greenhouse gas) GHG emissions associated with animal manure management and pollution of water and groundwater due to nutrient leaching. GHG emissions from the farming sector accounts for 10.7% of the total GHG emitted by Spain according to the National GHG Inventory [15]. GHG emissions in the agricultural sector may be broken down as follows:

- 29% from enteric fermentation by cattle;
- 28% from manure management;
- 43% through tillage operations and application of nitrogen fertilizers from both organic and inorganic sources (65% of these emissions are in the form of N_2O).

Conventional management of pig slurries in Spain involves storage in lagoons and subsequent application as fertilizer. This storage generates 8.9 Mt of CO_{2eq} each year, mainly in the form of CH_4; field application of these slurries emits 1.1 Mt CO_{2eq}, mainly N_2O [14]. Anaerobic digestion allows the stabilization of the organic matter and reduces the GHG emissions of manure degradation in storage [12,16]. It also reduces emissions on subsequent land application of digestate as compared to application of raw slurries and mineral fertilizers [17,18]. The Ministry of Agriculture developed the pig slurry bio-digestion plan (PSBP) [14] to achieve digestion of 9.5 Mt of pig slurry whilst saving 1.78 Mt CO_{2eq}.

1.5. Present treatment of pig slurry in Spain

Slurry treatment plants (not involving anaerobic digestion) have been built recently in areas with a high concentration of pig farms, and especially in those zones classified as vulnerable by the Nitrate Directive [19]. The treatment involves separation of the solid and liquor phases of the slurry. Natural gas powered CHP engines are used to produce electricity at a special feed-in tariff of €0.15/kW_e h (February 2013). The heat is used to dry the slurry which is then used as an organic fertiliser. At present there are 27 treatment plants with a generation power of 364 MW_e, treating 2.5 Mt of pig slurry annually. These plants recycle 100,000 t/a of fertilizers and save 700,000 t CO_{2eq} annually [20]. A few plants produce biogas from the pig slurry and combine this with natural gas for CHP production.

1.6. Aims and objectives

The aim of this paper is to explore the potential and merits of an anaerobic digestion industry based on pig slurry. It is suggested by the authors that digestion of slurry is preferable to the practice employed of drying slurry using the heat from natural gas CHP systems. Low levels of subsidy suggest that the produced biogas may be best used as a transport fuel. Upgrading biogas to biomethane allows for a second generation gaseous biofuel system which is encouraged by the Renewable Energy Directive (RED) [3]