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Energy production from landfill biogas: An italian case

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ABSTRACT

The study considers the "renovation" (as defined by Italian legislation) of an electricity-generating plant using biogas produced in a managed landfill as the primary energy source. The landfill, located in the Marche region (central Italy), receives about 100 kt y^{-1} of urban and industrial residues. The plant is endowed with two 470 kW (e) internal combustion engines and has been in operation since 1998. At the end of its lifecycle it is scheduled for decommissioning. Public incentives for energy production from renewable sources, which the plant enjoyed in the first eight years of activity, have also expired. The study examines the main legal, technical and economic options available to the landfill management, in particular considering the new Italian and EU incentives for energy generation from renewable sources.

Five configurations are considered for the replacement of the existing engines, three at the original site (a single combustion engine with/without incentives, and a plant with microturbines), and two involving the construction of new plants at a separate site (a cogeneration plant with a combustion engine and one with microturbines).

The study provides data that may be a useful basis for other similar cases and for simulations.

1. Introduction

In 1997 the European Commission published a White Paper on renewable energy [1] where it unveiled a long-term objective to double to 12% the European Union (EU)'s share of renewable energy by 2010. Directive 2001/77/EC [2] subsequently set indicative targets for each Member State that would allow achieving an overall EU share of 21% of electricity produced from renewable energy sources by 2010, while calling for actions to improve the growth and development of and access to renewable energy. It also charged the Commission to publish biannual reports on Member States' progress towards their national targets, on the EU's progress towards its 2010 targets, and in general on the advancement of efforts to develop renewable energies.

The 2007 report [3] highlighted the slow progress Member States were making and the likelihood that the EU as a whole would fail to reach the 2010 target. Although "12% renewables" was a good political target, it was plainly insufficient to stimulate the renewable energy sector, and it appeared evident that the targets needed to be more clearly defined, focused and mandatory to be effective. The Commission therefore adopted an energy and climate change package, the Renewable Energy Roadmap [4], calling on the Council and the European Parliament to approve a mandatory EU target of 20% for energy produced from renewable sources, to be met by 2020. This was laid down in Directive 2009/28/EC [5], which repealed Directive 2001/77/EC and also set mandatory national targets for renewable energy shares to be achieved in gross final energy consumption and transport. The 2009 report

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[6] suggested that meeting the 20% EU-wide target required reaching a renewable energy share of about 33% in the electricity sector. In this context exploitation of landfill biogas for energy production may be both useful and environmentally sound, since a large amount of the residues produced in the EU are still disposed of in landfills.

According to the 2007 report [3] in 2005 almost 210 PJ of biogas for energy uses were produced in the EU, and total biogas resources were about 840 PJ y^{-1} based on waste production figures. About a third of the biogas produced in the EU went into heat production and two thirds into electricity production (14.9 TWh in 2004, half of which from cogeneration plants). The latter sector was developing fast and had grown by 24% in 2002, 13% in 2003, 22% in 2004, and 15% in 2005. Growth was also stimulated by stricter EU environmental regulations in terms of constraints and taxes on landfill disposal.

Another sector where biogas, or liquid biogas [7,8,9] can be used is public transport.

This paper explores the hypothesis of an Italian power plant fuelled by landfill biogas nearing the end of its lifecycle in 2008, and examines the technical and economic convenience of its renewal in the light of subsequent renewable energy legislation.

Section 2 describes the landfill characteristics; Section 3 the existing electricity production plant, and Section 4 the relevant legislation. Section 5 outlines different plant renewal options as of late 2008. Both cogeneration and non-cogeneration solutions, with internal combustion engines (ICEs) and microturbines (MGTs), were considered. In section 6 the results are analysed and the assumptions based on 2008 economic figures tested by making reference to the energy market trends up to the present time. The conclusions are drawn in section 7.

2. The landfill

The biogas-powered electricity production plant is located in Marche, Italy (43°54'04''N, 12°47'40''E), in a managed landfill that receives about 100 kt y^{-1} of municipal solid waste, non-hazardous special waste, and sludge from wastewater treatment plants. The landfill, opened since July 1992, occupies 20 ha, of which 12 ha are taken up by the landfill and 8 ha by plants, offices and unbuilt areas. The landfill is run by the local municipal services company which, besides waste collection and disposal, is also in charge of gas, water and sewage utilities, green spaces and street lighting services.

3. The existing plant

The existing electricity production plant was built from investment made entirely by the municipal services company based on a feasibility study and an assessment of potential biogas production, and has been operating since December 1998. National policies granting incentives for the construction of plants using renewable energy sources, introduced in the early 1990s, strongly influenced investment decisions, since they enhanced profitability.

From the operational point of view the plant can be divided into three main plants:

- biogas capture and extraction system;
- biogas treatment and analysis system;
- electricity production system.

The capture system was in use before the electricity-generating plant was constructed, since the biogas had to be burnt in flares. The system was however considerably modified, as new facilities were added to power the two 470 kW (e) ICEs in the electricity production section. Plant dimensioning was based on biogas production estimates of about 3.15 $hm^3 y^{-1}$, assuming plant operation for 90% of total annual hours and a production capacity of the landfill consistent with an average flow rate of about 400 $m^3 h^{-1}$ (throughout the paper cubic metres are assumed to be at 0 °C and 101 325 Pa). The lower heating value (LHV) of the biogas produced was another critical parameter; since its volumetric methane content is about 53%, the LHV is on average around 18.3 MJ m^{-3}.

4. Reference legislation promoting energy production from renewable sources

4.1. *European legislation*

The European reference legislation is the 2009/28/EC Directive, which encourages renewable energy production in view of a European single market for energy.

Each country can set up its own incentive system that meets Directive guidelines, particularly those regarding the guarantee of origin that the electricity is produced from renewable sources. The relevant certificate is issued by the RECS (Renewable Energy Certificate System) [10]. Two main types of incentive mechanisms have been devised by EU Member States: a type based on a quota exchange system (*trade and quota*) and another based on incentives for end-users (*trade and premium*). In the former systems the government sets production targets for electricity from renewable sources, while the price is set by the market. In *trade and premium* schemes the amount of the incentive is set by the government and the level of electricity production from renewable sources is set by the market. The former schemes are the more suitable for integrating individual national markets into a European single market for energy from renewable sources. The unit on which all such systems are based is the Green Certificate (GC), i.e. the MWh (e) produced from renewable sources.

4.2. *Italian legislation*

Even before Directive 2001/77/EC, Italy had already adopted measures to promote energy production from renewable sources, starting in 1992 [11]. The incentives from which the plant studied in this work benefited were replaced in 2003 by new legislation [12] implementing the European directive 2001/77/CE.

Current laws grant incentives for the construction of plants for electricity production from renewable sources through