Utilisation of Landfill gas for Energy Production – Operational Experience from a 13.8 MW_e Power Plant

*G. Skodras\textsuperscript{1,2,3}, P.S. Amarantos\textsuperscript{1}, E. Papadopoulou\textsuperscript{1}, E. Kakaras\textsuperscript{1,4}

\textsuperscript{1}Centre for Research and Technology Hellas, Institute for Solid Fuels Technology and Applications, Ptolemais – Greece  
\textsuperscript{2}Centre for Research and Technology Hellas, Chemical Process Engineering Research Institute, Thessaloniki – Greece  
\textsuperscript{3}Chemical Process Engineering Lab., Aristotle University of Thessaloniki, Thessaloniki – Greece  
\textsuperscript{4}Lab of Steam Boilers, National Technical University of Athens, Athens – Greece

\textsuperscript{*}P.O. Box 1520, 54006 Thessaloniki – Greece  
Tel: +30 – 2310 – 995.918, Fax: +30 – 2310 – 996.168  
E-mail: skodras@vergina.eng.auth.gr

Abstract

In accordance to the European Union energy policy that promotes Renewable Energy Sources utilisation and Combined Heat and Power (CHP) projects, a cogeneration plant has been implemented in Ano Liosia landfill, 7 km from the city of Athens. Construction and operation of the CHP plant is included in a series of rehabilitation measures that have been taken for the specific landfill. Produced biogas from the landfill is being utilised in heat and power production. Landfill gas is entrapped by a collection system consisting of vertical wells and horizontal pipes grid that transfers gas to the CHP plant, where it is converted to enough power to cover the needs of a town of 15,000 inhabitants. Plant operation started in 2001 and it consists of eleven mobile cogeneration modules. The cogeneration plant has a total of 13.8 MW\textsubscript{e} installed capacity. Approximately 110 GWh of electricity are annually produced and they are supplied to the electricity utility distribution grid. Moreover, steam and hot water are produced by heat recovery from the flue gases. Annual total heat production capacity is about 16.5 MW\textsubscript{th}. In this work, operation experience from the Ano Liosia CHP plant is presented.
1. Introduction

During the last years, the Greek government supported significant efforts that have been made by the municipalities in cooperation with the private sector for the development of appropriate Municipal Solid Wastes (MSW) management systems. The main objectives are to overcome lack of organisation in the fields of waste collection and disposal, to maximise material and human resources utilisation, and to establish rational energy utilisation. Moreover, promotion of cogeneration is among main EU targets for improving energy efficiency and reducing production of greenhouse gases. Earlier studies indicated that Combined Heat and Power (CHP) plants could supply 40% of the EU electricity. Therefore, wastes exploitation in energy production fulfils both the above-mentioned objectives of MSW management systems and EU directives in energy production.

Produced wastes are eventually disposed in landfills where organic matter is decomposed by anaerobic microorganisms producing landfill gas. When released into the atmosphere, landfill gas can be identified by its bad odour, since it contains hydrogen sulphide and mercaptanes, while it contributes to local smog and is an explosive hazard. Moreover, landfill gas is rich in greenhouse gases, specifically carbon dioxide and methane. The latter, about 50% contained in landfill gas, is regarded as a major contributor to global climate change. Pound for pound, methane has been found to be over 21 times more effective at trapping heat in the earth's atmosphere than carbon dioxide. On the other hand, produced methane can be utilised in energy production, constituting landfill gas a renewable energy source, that otherwise is wasted [1].

The objective of landfill gas-to-electricity projects is to exploit produced landfill gas in heat and power production. Such projects offer environmental and safety benefits, since they minimise landfill gas emissions to the atmosphere and its migration to nearby residential areas. Power production units are designed for continuous, unattended or minimally manned operation. Landfill gas entrapment is achieved by a collection system consisting of vertical wells and horizontal pipes grid. Partial vacuum created in the piping
system causes the landfill gas to move towards the wells. Once collected, the gas can either be flared to the atmosphere or combusted for energy production, figure 1.

Power production from landfill gas is a mature technology and is regarded as one of the most successful implementations for exploitation of renewable energy sources. Many countries offer significant tax incentives to companies undertaking landfill gas utilisation projects. Since conventional energy production costs are expected to increase, landfill gas employment in electricity generation projects are becoming more economically attractive.

![Landfill Gas Collection System](image)

**Figure 1**: Typical landfill gas collection system [2]

In Greece, there are official estimates for as many as 24 existing landfills where landfill gas exploitation projects are feasible. As sanitary landfill management is assigned to municipal authorities, municipalities are expected to contribute in distributed energy production [3].

2. **Project description**

The Ano Liosia landfill is located at approximately 7 kilometres from Athens, nearby a residential area. Since landfill management has been assigned to Association of Attica Municipalities and Communities (ESDKNA), municipalities of South Athens area
operate the Ano Liosia landfill. Municipal Solid Wastes are being disposed in the landfill for about 20 years [4], figure 2.

During the last decade, Greek government in cooperation with major municipalities introduced measures for proper wastes management and rehabilitation of existing landfills [5]. In accordance to the 1994 EU Packaging and Packaging Waste Directive, the Greek Ministry of the Environment introduced legislation aiming to recover and recycle a major part of the 750,000 tons of packaging material, such as glass, plastics, metals and paper, that was previously disposed in landfills annually. Goals laid down by the EU Directive should be achieved by the year 2006, while the Greek Ministry’s plan calls for the recovery of 50 to 65% and the recycling of 25 to 45% of the current output by the year 2005. According to official estimates, packaging material recovery and recycling will result in about M€ 6.5 annual savings. The programme is co-funded by the EU to the amount of M€ 293, in the Framework of the 3rd EU Support [3]. Moreover, Athens municipality and the Association of Attica Municipalities and Communities (ESDKNA) have launched a waste processing and recycling campaign aiming to utilise most of the approximately 5,500 tons of wastes collected from the Athens area daily [4].

![Figure 2. The Ano Liosia landfill](image)

In the framework of the above, a series of rehabilitation measures have been taken for the Ano Liosia landfill, figure 3. The first step was the construction of a landfill gas
collection and flaring system that minimised odour complaints by the inhabitants of the expanding residential area South of the landfill site. Additionally, facilities nearby the landfill have been constructed, utilising about 1,500 tons of wastes daily for the production of compost and Refused Derived Fuel (RDF) [4]. Finally, produced biogas from the landfill has been exploited in electricity generation. Biogas is transferred through a network of pipes to a 13.8 MW_e plant, where it is converted to enough power to cover the needs of a town of 15,000 inhabitants [6].

Figure 3. Ano Liosia landfill project [6]

Landfill gas exploitation is feasible if specific conditions are satisfied, such as proper gas quality (technological conditions), sufficient quantity (economic conditions) and know-how acquirement (implementation conditions). Therefore, in order to evaluate potential utilisation of biogas, analyses of leaking gas from the landfill surface and process simulation via mathematical models have been performed, followed by detection drillings and two months pumping tests. The Ano Liosia biogas is composed of about equal quantities of methane and carbon dioxide, figure 4. Annual biogas production has been estimated at 4.5 m³/t wastes, while mean energy content is about 5 –6 kWh/Nm³ of biogas. Total energy production, however, is time dependent.
The plant started its operation in March 2001. Landfill gas is extracted from the landfill site, processed to remove moisture and particulate matter and utilised as fuel for power generation. The gas collection system includes gas entrapment wells drilled into the landfill. The wells are fitted with wellheads comprising valves and flow meters to control the flow from each well. Biogas is transported via an underground pipeline network that connects the wells. Gas blowers maintain vacuum throughout the pipe grid and compress the gas to the pressure required for supply to the production plant. The energy production plant consists of eleven mobile cogeneration modules, figure 5. Each module includes a gas-engine electricity generator of 1.255 MW\(_e\) capacity that is fuelled with about 700 m\(^3\)/h. The plant is interconnected to the public utility distribution grid at 20,000 volts. Produced electricity is supplied to the electricity utility distribution grid for a return of €0.06 per kWh.
The cogeneration plant has a total of 13.8 MW\textsubscript{e} installed capacity. Approximately 110 GWh of electricity are annually produced. Moreover, the remaining thermal energy of the flue gases is utilised in heat recovery for steam and hot water production, figures 6&7. Total heat production capacity is about 16.5 MW\textsubscript{th}. The produced steam may be either traded as commodity or employed in landfill leachates processing. In Ano Liosia landfill steam corresponding to 6 MW\textsubscript{th} is utilised in leachates drying, figure 8.
An integrated control system has been installed to meet the variations of the biogas quality and production rate in each landfill sector, and to achieve optimum plant operation. According to gas characteristics, specific landfill areas that no longer produce exploitable biogas can be isolated from the energy production system and gas originating
from such areas can be flared to atmosphere. Moreover, construction of gas transfer lines from the wells to the energy production units realises safety maximisation, cost and losses minimisation.

Since cogeneration modules operation is influenced by biogas corrosion potential, moisture content is recorded in order to properly specify gas pretreatment requirements. Considerations have also been made for problems resulting from high temperatures occurrence at the landfill site, i.e. during the summer, and solutions have been provided to environmental aspects arising from the landfill management, such as leachates processing.

Successful project implementation has been based on gained experience in biogas exploitation of the parties involved in designing and construction. Proper maintenance scheduling increased plant availability to more than 85%, while personnel selection and training have proven to be decisive in project economic viability.

3. Economics

Cogeneration plant design and construction is a joint venture of the municipality of Ano Liosia, a Greek private construction company, TOMI S.A, and an Australian technology provider. Elaborated detailed technoeconomic study included potential landfill expansion, probable alteration of disposed wastes quantities and composition, and possible financing identification. Construction cost exceeded M€ 19 and the whole project was co-funded by the municipality of Ano Liosia and TOMI S.A. However, investment risk was minimal due to fact that there was a secure market for generated electricity supply [6].
Figure 7. Heat recovery process schematic diagram [6]
Flue gas, 800 kg/hr, 120°C, 6 bars

Steam boiler

Cogeneration Station

Process for initial biological load reduction

Leachates, 200 m³/d, 20°C

Drying Unit

Water, proper for irrigation, 180 m³/d

Residue, 20 m³/d

Figure 8. Steam employment in leachates drying [6]
Decentralised cogeneration units, such as the Ano Liosia energy production plant, constitute an economically attractive way to cover power and heat demands of small-scale industries and nearby communities. Since landfills are usually located far off urban areas, generated electricity can cover power demand of nearby villages, while produced heat may be employed in small district heating systems to cover their heat needs. Such a development will enable full capacity operation of the plant as well, since there will be a secure market for produced energy supply. Therefore, in addition to the environmental benefits, the introduction of energy production from wastes may offer increased power and heat supply reliability, and reduction of imported fuel cost. Moreover, construction and operation of decentralised units increase employment opportunities and contributes to regional economic development.

4. Conclusions

Power production from landfill gas is a mature technology and is regarded as one of the most successful implementations for exploitation of renewable energy sources. Since conventional energy production costs are expected to increase, landfill gas employment in electricity generation projects are becoming more economically attractive. Such projects offer environmental and safety benefits, since they minimise landfill gas emissions to the atmosphere and its migration to nearby residential areas. Landfill gas exploitation is feasible if specific conditions are satisfied, such as proper gas composition (technological conditions), sufficient quantity (economic conditions) and know-how acquirement (implementation conditions). Detailed technoeconomic study elaboration is required that includes potential landfill expansion, probable alteration of disposed wastes quantities and composition, and possible financing identification.

The Ano Liosia landfill CHP plant operates successfully since 2001. It has a total of 13.8 MW_e installed capacity. Approximately 110 GWh of electricity is annually produced, which corresponds to enough power to cover the needs of a town of 15,000 inhabitants. The remaining thermal energy of the flue gases is utilised in heat recovery for steam and hot water production. The former is employed in landfill leachates processing. Total heat
production capacity is about 16.5 MWth. The whole installation has been implemented in a way to maximise operation flexibility. Special attention has been paid to total gas flow to cogeneration modules control, in order to compensate for variations of composition and quantity of biogas produced in each landfill sector. Proper maintenance scheduling increased plant availability to more than 85%, while personnel selection and training have proven to be decisive in project economic viability.

Decentralised CHP plants, such as the Ano Liosia energy production plant, constitute an economically attractive way to cover power and heat demands of small-scale industries and nearby communities, i.e. by employing produced heat in small district heating systems. Therefore, apart from the environmental benefits, the introduction of energy production from wastes may offer increased power and heat supply reliability, reduction of imported fuel cost, while plant construction and operation increase employment opportunities and contributes to regional economic development.

5. References

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