Renewable Energy Technology International AB

Renewtec Report 009:2019

LFG Baltic

- Challenges and opportunities with landfill gas in the Baltic Sea Region

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ISSN 2001-6255

Publisher
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Renewable Energy Technology International AB is a private company promoting the transfer to a sustainable and environmentally friendly energy system.

Printed by Serviceförvaltningen/Tryckeriet Lunds kommun, Lund, SWEDEN, 2019
ISSN 2001-6255

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Preface

LFG Baltic has received funding from the Swedish Institute within the framework of its seed funding instrument. This cross boarder project was coordinated by the Baltic Energy Innovation Centre (BEIC) with Gdansk University of Technology and Lithuanian Energy Institute as project partners. The project was conducted during the period of June 2018 to November 2019.

A large number of people have contributed directly or indirectly to this report. The authors would like to thank the project team for their valuable input. A special thank goes to Johan Fagerqvist, the Swedish Waste Management Association for the support with relevant statistics and reports, and to Ole Elmose, Deponigas ApS, Maria Persson and Martin Svensson, MERAB in relation to the nice study tours to Hedeland, Denmark and Rönneholms waste mangement facility, Sweden.

Summary

LFG Baltic stands for "Challenges and opportunities with landfill gas in the Baltic Sea Region."
The work was conducted in close collaboration between the project partners, which covered experiences and results of landfill gas in Lithuania, Poland and Sweden. In addition, a seminar with invited international landfill gas experts was organised in collaboration with 6th International Conference on Renewable Energy Gas Technology, REGATEC 2019, 20-21 May 2019 in Malmö, Sweden. Poster presenters from the Baltic countries and EaP were invited and reimbursed for the conference fee and the hotel and travel costs.

The overall aim of the project is to encourage the use of landfill gas as an energy resource and reduce aggressive greenhouse gas emissions from landfills by cross border knowledge exchange and technology transfer.

The project showed the following:

- All three countries are working actively to fulfil the EU landfill directive in regards to operating permitted landfills and minimising emissions from closed landfills.
- Poland has the highest power production, as expected due to the large population. More unexpected is that Lithuania has a higher landfill gas-based power production than Sweden but it's a consequence of the difference in electricity price and the structure of the power sector in the two countries.
- There are several techniques to produce power from landfill gas with low methane content (<40%), e.g. micro gas turbines, Stirling engines and dual fuel engines.
- There are also techniques to produce heat from landfill gas with very low methane content (~1%), e.g. thermal oxidisers and catalytic oxidisers.
- There is currently no upgrading of landfill gas to natural gas quality in Lithuania, Poland and Sweden.

The close and collaborative effort, conducted during the period of June 2018 to November 2019, resulted in several presentations and conference contributions which can be found on the project website https://lfg-baltic.beic.nu/.

Abbreviations and expressions used in this report

BEIC	Baltic Energy Innovation Centre
BSR	Baltic Sea Region
EaP	Eastern Partnership (Armenia, Azerbaijan, Belarus, Georgia, the republic of Moldova and Ukraine)
EU	European Union
GUT	Gdansk University of Technology
GWP	Global Warming Potential
IPCC	Intergovernmental Panel on Climate Change
LEI	Lithuanian Energy Institute
LFG	Landfill Gas
n.a.	Not available
Nm^3	Normal cubic metre
SI	Swedish Institute

Content

1. Introduction

Methane is one of the most important greenhouse gases and is besides carbon dioxide the gas with the largest impact on the greenhouse effect if water vapor is not included. Methane has a Global Warming Potential (GWP) of 34 on a timespan of 100 years, i.e. methane is 34 times more aggressive greenhouse gas than carbon dioxide according to IPCC's 5th Assessment Report. The concentration of methane in the atmosphere has more than doubled in the last hundred years and landfills are the third largest (16%) emitter of anthropogenic methane after fossil fuel production, distribution and combustion (33%) and livestock farming (27%).

The EU supports the overall objective for reducing global greenhouse gas emissions by 50% up to 2050 in order to meet the 2°C target. Agreement on cutting the EU greenhouse gas emissions to 20% below 1990 levels by 2020 is one of the targets of the Europe 2020 Strategy. In order to achieve these ambitious EU goals, to advance the mainstreaming process in the region and to make the Baltic Sea region more resilient, macro-regional approaches to a low-emission development are needed.

Utilising landfill gas for energy purposes provides several benefits for the Baltic Sea region and the EU's Eastern Partnership. The emissions from the landfills are reduced, the extracted landfill gas replaces fossil fuels and indigenous low quality waste is transformed into a high quality fuel contributing to the security of supply and diversification of the energy system.

The EU Landfill Directive (1999/31/EC) provides regulatory direction to member states in operating permitted landfills, with gas control in particular, a key area requiring stringent operating conditions to minimise emissions and the risks to human health and the environment.[1]

1.1 Background

The progress and advances in landfill gas technology differs in the Baltic Sea Region due to varying conditions, policies and associated instruments. In Sweden there is a landfill ban on organic waste since January 2005 and the waste is now diverted to energy production (incineration) and material and organic recycling (compost or other biological treatment, such as biogas production). However, the organic material landfilled until 2005 continues to decay and it will produce methane an additional 20-30 years. Landfill gas is extracted from 51 sites[2] and used mainly for heat and combined heat and power production. In Lithuania there are 19[a] and in Poland 91 landfills where the landfill gas is extracted and used for power or combined heat and power production. Much knowledge, experience and results have been accumulated that could be transferred to other landfills in the Baltic Sea region and the EU's Eastern Partnership. Ukraine for instance has more than 4,500 landfills where this technology could be implemented and hence

[a] There are 11 new active landfills with the possibility to extract landfill gas. However, due to technical, economical, infrastructural, terrain or gas quality and amount barriers, gas extraction in some of the newly operated landfills are still pending or limited. In addition there are 8 closed landfills where landfill gas is extracted and used for electricity production.

reduce the annual methane emissions corresponding to 16 million tons of carbon dioxide equvialents according to the Gas Institute of National Academy of Sciences of Ukraine. If the extracted landfill gas replaces fossil fuels for power production the reduction is even greater. There are also interesting technical development involving landfill gas as fuel in gas turbines and Stirling engines that potentially could improve the economy and/or the energy efficiency. Interestingly enough the Gas Institute in Ukraine has developed an upgrading technology for landfill gas to obtain a gas quality suitable as vehicle fuel or for injection into the natural gas grid, which is of great interest for the BSR and EaP in general, and for countries like Sweden where upgraded biogas is used in the transportation sector, in particular. The differences implies a strong transnational added value since the whole region as such can learn from each other and take advantage of the technological advances, experiences, innovations and results from the different areas within the Baltic Sea region as well as within the EaP.

Utilisation of landfill gas contributes to a low-emission development by eliminating the spontaneous emissions of methane that is formed when the organic material in the landfills is degraded. Furthermore, when the extracted landfill gas is used to off-set fossil fuels in the heating and power sector as well as in the transportation sector additional greenhouse gas reduction is obtained. Utilisation of landfill gas is also one step closer to a circular economy as the energy content in the waste is recovered. By exchanging best available data and approaches a climate-resilient and resource efficient solution is promoted.

Landfill gas utilisation contributes to the security of supply and increased share of renewable energy. Since it's a gaseous fuel it can be used with high efficiency and low emissions in gas engines and gas turbines for CHP production. If upgraded it can be injected into the gas grid and/or used as a transportation fuel. In the project knowledge and experiences of deployment of best available technology for landfill gas extraction, purification and utilisation will be compiled and disseminated contributing to technology transfer and exchange of best practice and lessons learned.

1.2 Objectives

The objectives of this project were to

- Raise awareness of the possibilities with landfill gas utilisation as an energy resource and means to reduce aggressive greenhouse gas emissions from landfills
- Promote climate-resilient and resource efficient solutions through exchanging best practice and lessons learned related to landfill gas extraction and utilisation
- Accelerate the transition to a circular economy by dissemination of knowledge and deployment of best available technologies and lessons learned related to landfill gas extraction and utilisation

The quantitative targets were among others to

- Arrange a seminar with invited national and international experts in collaboration with 6th International Conference on Renewable Energy Gas Technology
- Give researchers and experts from the Baltic countries and EU's Eastern partnership the possibility to present advances in landfill gas technology at the seminar
- Compile an ISSN numbered report on experiences and results from landfill gas in Lithuania, Poland and Sweden

1.3 Methodology

The information was gathered through literature studies, interviews and meetings with trade organisations, waste management companies and landfill gas experts, and visits at landfill gas sites in Lithuania, Poland and Sweden.
The gathered information was presented at the LFG Baltic seminar organised in collaboration with 6th International Conference on Renewable Energy Gas Technology, REGATEC 2019 where international experts were invited.

Taking into account the feedback from these experts this report was compiled. Extended abstracts from the presentations at the LFG Baltic seminar were published in the ISBN numbered REGATEC 2019 conference proceedings ensuring a long-lasting value far beyond the project lifetime.

As a result of the LFG Baltic seminar two relevant technologies developed in Denmark and Iceland have also been included in this report. A study tour to Denmark was undertaken in order to gather information on dual fuel engines able to operate on low calorific landfill gas and visit a reference facility.

1.4 Limitations and assumptions

This report deals mainly with technologies able to convert landfill gas to useful products such as heat and power. Passive or active systems that merely convert methane to carbon dioxide without the use of the energy are not considered. Examples of such systems are flares, bio-filters and bio-covers. Geographically the report is covering landfill gas utilisation in Lithuania, Poland and Sweden but two innovative technologies developed in Denmark (dual fuel engines) and Iceland (monitoring by drones) are included as well.

2. Landfill gas in Lithuania

Lithuania	
Population	2.8 million inhabitants
Area	65,300 km^2
Source: Wikipedia	

Number of landfills

According to statistics there are more than 800 closed or still in exploitation landfills of different size[3]. In 1998 various type of waste was disposed in 314 landfills. However, waste disposal in the small landfills did not get into the statistics and therefore, the number of landfills in Lithuania might be much higher as expected. The situation has changed significantly after Lithuania became a member of the Europe Union in 2004.

Number of active landfills

So far, there are newly installed 14 modern active landfills: 11 regional landfills for non-hazardous (household) waste, 1 for hazardous waste, and 2 for construction waste[4]. All landfills have been installed and maintained according to strict EU requirements.

Number of covered landfills

-

Number of landfills where the landfill gas is extracted

There are 11 new active landfills with the possibility to extract landfill gas. However, due to technical, economical, infrastructural, terrain or gas quality and amount barriers, gas extraction in some of the newly operated landfills are still pending or limited. In addition there are 8 closed landfills where landfill gas is extracted and used for electricity production (Table 1).

Table 1. Landfills where landfill gas is extracted and used for energy production.

Region, name of facility	Installed power		
	Total, kW	kW$_e$	kW$_{th}$
Vilnius, Kariotiškių	500	500	n.a.
Vilnius, Kazokiškės	1600	800	800
Kaunas, Lapių (in operation)	2700	1200	1500
Klaipėda, Glaudėnų	1640	1640	n.a.
Marijampolės	480	480	n.a.
Panevėžys	819	400	419
Šiauliai, Kairiai	1200	600	600
Alytus (in operation)	450	450	n.a.
Total	**9389**	**6070**	**3319**

Use of the extracted landfill gas

Mostly the extracted landfill gas is used for electricity or combined heat and power (CHP) production. The produced energy (heat and electricity) in the operated landfills is mostly consumed in the internal technological process, except for the case of the Alytus regional landfill where around 38% of the produced electricity was sold to electric grids in 2017. The obtained tariff depends on the installed power production capacity.

Currently, the cost of electricity produced from landfill gas exceeds the tariffs of 8.6 euro cent/kWh (>500 kW), 10.6 euro cent/kWh (10-500 kW) and 11.1 euro cent/kWh (<10 kW). At such tariffs, only 10–12 larger size landfills in Lithuania are of some interest for the investors to invest in and make profit. In case of increased subsidies per kilowatt-hour for electricity production from landfill gas, smaller size landfills might also be profitable and attractive for the investors.

Policy framework

In Lithuania exists 10 regional waste management centres (Figure 1). In 2005 the association, uniting all 10 centres, was established, which annually reports the summary of the achievements of all the members. As of year of 2017, total amount of waste managed in these centres exceeded 1,291,406 tonnes[5]. Municipal waste generated in 2017 was 455 kg per capita (EU-28 487 kg), which comprises quite the same amount of totally managed waste[6].

Figure 1. Regional Waste Management Centres (RWMC) in Lithuania.

3. Landfill gas in Poland

Poland		
Population	38.4 million inhabitants	
Area	312,696 km^2	
Source: Wikipedia		

Number of landfills
According to the National Waste Management Plan (2010), there were 764 landfills for non-hazardous waste and 34 landfills for hazardous waste in Poland. This list includes both closed and still active landfills[7].

Number of active landfills
At the end of 2017, there were 301 active landfills receiving municipal waste. These landfills occupied a total area of 1 741.6 ha. In 2017, about 92.5% of the landfills area was the area of active controlled landfills. The remaining part was the area of the so-called "wild landfills" i.e. places not designated for municipal waste storage. At the end of 2017, there were 1,661 illegal landfills in Poland[8,9].

Number of covered landfills
In 2017, there were 267 landfills equipped with installations for degassing, and they constituted 88.7% of all active landfills on which municipal waste was stored. Figure 2 demonstrates the map of Poland with division into regions where there were landfills with a degassing system and without degassing system[9].

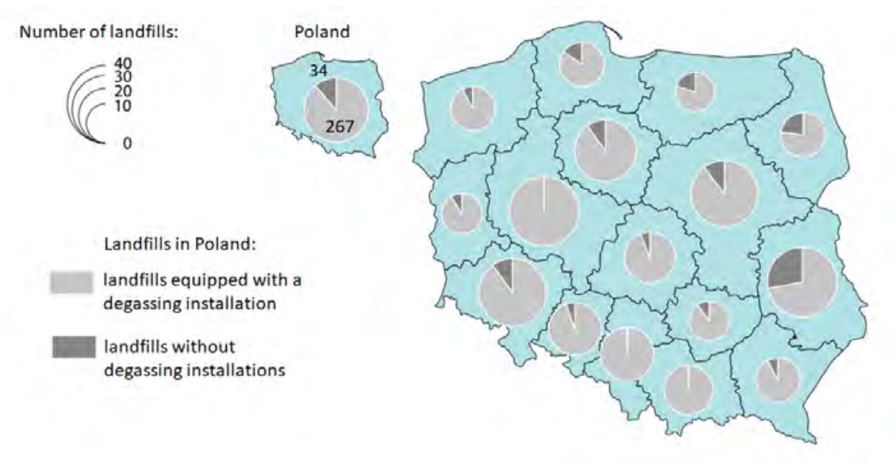

Figure 2. The map of Poland, which contains information on the number of landfills equipped with a degassing installation and without degassing installations[9].

About 37% of installations for degassing were installations with gas escaping directly into the atmosphere, while 6.6% were those where the gas was neutralized with the recovery of thermal energy. About 20.3% of the installations were used to generate electricity from landfill gas. In 2017, as a result of disposal by burning off the landfill gas, about 96,997 thousand MJ thermal energy and about 121,574,000 kWh of electricity were recovered. Almost 2,734.2 thousand tonnes of municipal waste, were allocated for energy recovery[9].

The number of biogas plants in landfills, after Poland's accession to the European Union in 2004, is gradually increasing. In 2012, there were 91 such installations with a total capacity of 54,456 MW. Currently, there are 98 biogas plants in Poland producing landfill biogas (in landfills) with a total capacity of 62.919 MW.
Table 2 presents the number of biogas plants operating in different regions of Poland in 2012. Unfortunately, there are no available data for the current year.

Table 2. Number of installations that convert landfill gas into thermal and electric energy and their power (30.09.2012)[10].

Region	Number of installations	Power [MW]
Dolnośląskie	5	4.345
Kujawsko-pomorskie	8	3.814
Lubelskie	1	0.5
Lubuskie	1	0.5
Łódzkie	5	4.675
Małopolskie	6	2.928
Mazowieckie	21	11.956
Opolskie	1	0.45
Podkarpackie	3	1.511
Podlaskie	1	0.7
Pomorskie	4	3.557
Śląskie	15	11.738
Świętokrzyskie	1	0.36
Warmińsko-mazurskie	2	1.142
Wielkopolskie	7	5.09
Zachodniopomorskie	10	3.19
Total	91	56.456

The first installation using landfill gas to the production heat and electricity energy in Poland was launched in 1995 at the Żółwin landfill near Bydgoszcz. It was equipped with two generating sets with a total power of 200 kW. However, currently the largest landfill biogas processing stations operate in Katowice, Warsaw, Sosnowiec and Olsztyn Łęgajny (in Katowice and Olsztyn, about 500 cubic meters of gas is extracted per hour), where biogas processing equipment with 800 kW and 1200 kW capacity has been installed[10,11,12]. Examples of other, smaller biogas plants in landfills in Poland are listed below:

- Biogas plant at the landfill site in Trzebana – consists of two parts with a total capacity of 966 kW. Biofraction (approximately 70,000 tons per year) is subjected to fermentation, resulting in biogas. The generated electricity is consumed for own needs, and surplus is sold to the grid, whereas heat energy is used to heat utility water and heat the plant[13].
- Biogas plant at the landfill site in Suchy Las - The installation capacity is 1.2 MW, including 2 x 260 kW electric power and 2 x 325 kW thermal power. Thermal energy is used to heat rooms and water in administrative buildings of a landfill, while electricity is used for own needs, and surpluses are purchased by Energetyka Poznańska S.A.[13].
- Biogas plant at the landfill site in Gdańsk – In 2017 and 2018, the 16.6 thousand MWh of electricity and 15.6 thousand GJ heat were produced in the bioelectric plant. In 2018, 7.2 million cubic meters of biogas were extracted and used. Total biogas recovery in 2011-2018 amounted to nearly 42 million cubic meters. The gas extracted in the 40 well system is fed into two gas generating sets with an electric power of 200 kW each. The installation was designed to extract about 1.6 million m3 of gas during the year. Electricity production is about 3 000 MWh per year[14].
- Biogas plant at the Barycz landfill site in Kraków - The biogas extracted from the biogas landfill is transferred to four generating sets, where electricity and heat are generated in combination - this is called cogeneration or CHP (combined heat and power). At the plant, heat is used to heat domestic hot water and to heat the technical facilities. Additionally, the produced electric and thermal energy is used for the operation of the sorting plant and the composting plant[15].
- Biogas plant at the Amest landfill site in Otwock – where 500 m^3 of biogas per hour is utilised in the power generator[16].

Closed landfills where landfill gas is extracted

There is no official information about numbers of closed landfills where landfill gas is extracted. The installation producing thermal and electric energy on the inactive landfill is located, among others in Toruń, where biogas from waste is burned in three co-generators with a total capacity of 1,324 kW. The biogas is taken through 82 biogas wells. In 2011, 5,927 MWh of electricity and 20,454 GJ of heat were generated[13]. The gas landfill is also extracted from closed part of landfill in Opole. The biogas is transformed into electricity that is sold to the grid. Biogas on inactive landfills is also obtained in the Śląskie region. One of the largest is the biogas plant in the Tychy landfill with a capacity of 1.09 MW[13].

Use of the extracted landfill gas

In Poland, biogas is only processed for electricity and heat. This is mainly due to the lack of adequate infrastructure around landfills and the relatively low potential of gas storage sites. In turn, electricity is mainly consumed in the internal technological process, as well as in operation of the sorting plants and the composting plants. However, heat energy is used to heat rooms and water in administrative buildings of a landfill. Only a part of the biogas plant sells the generated electricity to the grid. Most landfills are located far away from cities, therefore the generated heat is very rarely sold for heating water and residential buildings. The transmission of this type of energy is not viable due to the large heat loss during transport[10-17].

Policy framework and regulations

EU policy and legislation on waste:

- Waste Framework Directive (2008/98/EC)
- Landfill Directive (1999/31/EC)
- Packaging and Packaging Waste Directive (94/62/EC)
- Directive on Integrated Pollution Prevention and Control (96/61/EB)
- Directive on the Promotion of electricity produced from renewable energy sources in the internal electricity market (2001/77/EC)

National waste legislation:

- The Act of April 27, 2001. Environmental Protection Law.
- Act on packaging and packaging waste of 11 May 2001.
- Act of 5 July 2002 on the ratification of the Amendment to the Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal.
- The Act on the obligations of entrepreneurs regarding the handling of certain wastes and the production fee and deposit fee of May 11, 2001.
- The Act of 14 December 2012 on waste, Dz. U. z 2013 r. poz. 21, 888, 1238, z 2014 r. poz. 695, 1101. 1322, z 2015 r. poz. 87, 122, 933, 1045.
- Regulation of the Minister of the Environment of 30 April 2013 on landfills, Dz. U. z 2013 r. poz. 21, 888, 1238, z 2014 r. poz. 695, 1101. 1322, z 2015 r. poz. 87, 122, 933, 1045.
- Regulation of the Council of Ministers of 9 November 2004 on the conditions for projects that may significantly affect the environment (Dz. U. z 2004r. No 257, poz. 2573).
- Regulation of the Minister of Economy and Labor of September 7, 2005 on determining the criteria and procedures for the acceptance of waste for landfill for hazardous, neutral, non-hazardous and neutral waste (Dz. U. z 2005r. No 186, poz.1553).
- Regulation of the Minister of Economy and Labor of 9 December 2004 on the detailed scope of the obligation to purchase electricity and heat generated in renewable energy sources.

All Polish laws, along with the regulations issued to them, are in line with EU requirements formulated by the relevant directives.

4. Landfill gas in Sweden

Sweden	
Population	10.2 million inhabitants
Area	450,295 km^2
Source: Wikipedia	

Number of landfills

There is no unambiguous number of landfills but Östman[18] indicates that the number of landfills for household waste can be as high as 8,000 while the Swedish Waste Management Association[19] estimates the number to 4,000. Due to the EU landfill directive and the introduction of a landfill tax many landfills were closed in 2001.

Number of active landfills

2015 there were a total of 265 landfills in operation in Sweden. The number includes also not yet closed facilities with permission to deposit, and not only those where waste is actually deposited. Of these, 60 landfills were for hazardous waste, 133 landfills for non-hazardous waste and 72 landfills for inert waste. All 265 land-fills comply with the EU directive on the landfill of waste.

Number of covered landfills

The landfill covering is ongoing and in 2016 approx. one fourth of the landfill areas were covered[20].

Number of landfills where the landfill gas is extracted

According to the Swedish Energy Agency[21] there were 51 landfills were landfill gas was extracted in 2017. The total production amounted to 145 GWh. A decline with 17% compared to the previous year.

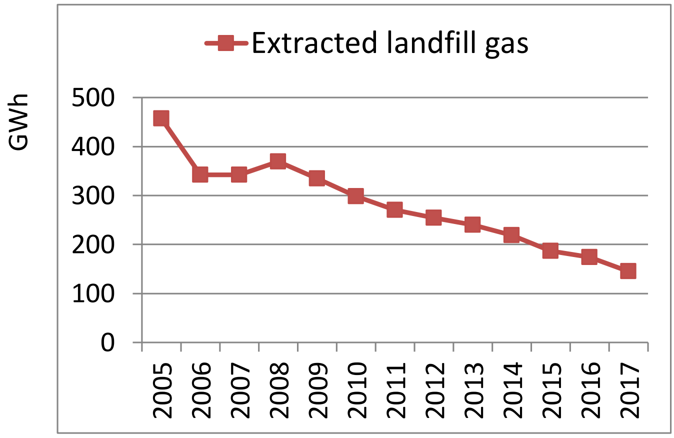

Figure 3. Landfill gas extraction in GWh in Sweden.

In January 2005 a ban to landfill organic material was introduced which has led to declining landfill gas production as seen in Figure 3.

Use of the extracted landfill gas

Most of the landfill gas produced in 2017 was used for heating, 91 GWh. 18 GWh was used for power production and 37 GWh was flared. 18 GWh of electricity corresponds to approx. 2.25 MW and 8,000 operational hours per year. This is significantly lower than the landfill gas-based power production in Poland and Lithuania.

Policy framework

As mentioned above a ban to landfill organic material was introduced in January 2005.

Regulations

To ensure that the EU directive on landfill of waste is implemented several regulations have been incorporated in the Swedish Environmental Code (Miljöbalken).

5. Technologies for landfill gas utilisation (Sweden)

During the last three decades different landfill gas utilisation technologies have been demonstrated and used in Sweden.

5.1 Conversion technologies

As a result of the 1991 Energy Policy Agreement, a support for CHP production with biofuels was launched. A small fraction of the support went to CHP production with gas engines based on landfill gas and biogas. The 24 facilities which received public funding undertook to report practical experiences of operation during a five year period. The electric efficiency ranged from 19% to 37% with an average of 29%. The production cost differed a lot between the different plants depending on the operating and maintenance costs. Problems with siloxanes causing increased engine wear and need for additional maintenance showed up but two out of twelve plants that were investigated in more detail actually produced heat and power at a competitive cost without the public support. The capacity of the gas engines ranged from 10 to 2,000 kW[22].

Figure 4. Maria Persson and Martin Svensson, MERAB, standing between the two Stirling engines at Rönneholms waste management facility, Sweden.
Photo: Jörgen Held

Externally fired Stirling engines have also been tested (see Figure 4). At Rönne-holms landfill outside Eslöv, Sweden the methane content had fallen to 25-30% but there was still an ambition to produce power. Two Stirling engines with a capacity of 7 kW[b] each were installed in 2012. During five years the facility has produced 300 MWh electricity, and 800 MWh heat used internally at the waste management facility[23]. The cost for the two Stirling engines was 900 000 SEK (approx. 90 000 EUR) and the whole installation costed 2,000,000 SEK (approx. 200,000 EUR). The Swedish Energy Agency has co-financed the project with 45%.[24]

The Stirling engines at Rönneholm landfill are still in operation (September 2019). They are guaranteed to operate down to a methane content of 20%. The annual maintenance cost is approx. 4,000 EUR.

According to a study conducted by the supplier of the Stirling engines, Clean Energy (now Azelio AB,) it's possible to produce power using landfill gas with methane content down to 15%.[25]

Other technologies for producing power using landfill gas include microscale gas turbines. The Turbec T100 gas turbine has for example been installed at landfills in Filipstad, Skövde and Norrköping[26]. Based on natural gas the gas turbine consumes 333 kW fuel and produces 100 kW electricity plus heat[27].

MEGTEC Systems AB offers flameless thermal regenerative oxidation technology for conversion of landfill gas with methane levels down to 0.15%. The excess heat generated above this concentration limit is recovered in an integrated embedded heat exchanger[28].

5.2 Monitoring technology

In a project, geo-electrical methods for better understanding of the conditions below the surface of the landfill were further developed. The geo-electrical methods used were mainly resistivity and induced polarization (IP). One of the aims was to improve the understanding of the impact of material parameters on sub-surface processes such as movement of gas and water in landfills (e.g. pore pressure, temperature and soil moisture), as well as to characterize the internal content and structure of landfills. The project therefore also aimed for a better exploitation of the energy potential of the landfill gas and a reduction of the leakage of climate gases to the atmosphere[29].

[b] The max capacity is originally 9 kW but from a maintenance perspective 7 kW is more optimal. The change in max capacity is done by changing the pressure of the working fluid (Helium).

6. Other relevant landfill technologies (Denmark and Iceland)

In Denmark another technology to utilise landfill gas with low methane content has been developed. The Danish company, Deponigas ApS provides dual fual engines where low calorific landfill gas with methane content down to ~10% is co-combusted in modified Diesel engines.

Figure 5. Ole Elmose, Managing Director Deponigas ApS besides a Volvo Penta engine modified to operate in dual fuel mode at Hedeland, Denmark.
Photo: Jörgen Held

By operating the engine in dual fuel mode, where Diesel is injected to ignite the lean pre-mixed landfill gas/air mixture, a simple and robust operation is obtained. The engine can run in a wide range of loads but since the Diesel consumption is the same independent of load it's beneficial to operate the engine at as high load as possible to minimise the Diesel consumption in relation to the landfill gas consumption. It would be interesting to try the concept with RME or any other renewable equivalent to eliminate the use of fossil fuel. A John Deere engine in dual fuel mode including generator with a capacity of approx. 40 kW_{el} costs roughly 100,000 SEK (approx. 10,000 EUR)[c].

[c] Personal communication with Ole Elmose in relation to a study tour to Hedeland, Denmark on the 1st of September 2019.

In 2018 Deponigas ApS produced 2.1 million kWh electricity in their 8 landfill gas facilities in Denmark with engines from John Deere, Volvo Penta and Cummins modified to operate in dual fuel mode[30]. Deponigas ApS has also developed a low-cost concept for collection of landfill gas based on more wells but with less diameter and depth.

New technology for landfill monitoring has been developed on Iceland by ReSource International[31]. The Álfsnes landfill outside Reykjavik has been used as a study case. The active landfill is operated by SORPA and landfill gas has been collected since 1996. There are 200 wells in 5 collection lines. 1,650,000 Nm^3 of upgraded landfill gas was sold in 2018. The upgraded landfill gas is used as vehicle fuel. The new technology for monitoring involves drones (see Figure 6). The drones are able to provide images of the landfill for spatial characterisation, thermal mapping, mapping of vegetation cover and methane concentration. All these measurements help to understand the processes inside the landfill and detect leakages.

Figure 6. Drone equipped with a laser methane sensor mapping the methane concentration at the Álfsnes landfill outside Reykjavik, Iceland[31].

7. Conclusions

All three countries are working actively to fulfil the EU landfill directive in regards to operating permitted landfills and minimising emissions from closed landfills. In all three countries landfill gas is extracted and the energy is recovered through different technologies, e.g. gas engines, micro gas turbines, Stirling engines and thermal oxidisers. By ex-changing best practice and lessons learned related to landfill gas extraction and utilisation climate-resilient and resource efficient solutions are promoted.

Poland has the highest power production, as expected due to the large population. More unexpected is that Lithuania has a higher landfill gas-based power production than Sweden but it's a consequence of the difference in electricity price and the structure of the power sector in the two countries. In Lithuania the tariff for electricity produced from landfill gas is 8.6-11.1 euro cent/kWh depending on installed power production capacity but in Sweden the producer might get less than 5 euro cent/kWh including electricity certificate. The Swedish power sector is more or less decarbonised and there is currently no strong incentive to produce electricity from landfill gas. However, this might change when the Swedish nuclear power stations will be phased out.

Since less and less organic material is landfilled and hence the gas production decays by time the interest to invest in energy recovery systems and optimisation seems rather low. Especially in Sweden where a ban to landfill organic material was introduced 1 January 2005. The interest seems more related to taking care of the methane emissions which have to be done in order to fulfil the EU landfill directive.

This might also be the explanation why there is no upgrading of landfill gas to natural gas quality in Lithuania, Poland and Sweden. Upgrading of landfill gas to natural gas quality is done in several countries, e.g. Iceland, France, the Netherlands and USA.

By taking advantage of the experiences and development in the BSR and operate the landfill in a more optimal way it's likely that the extraction of landfill gas for energy purposes can be extended in time and more energy can be recovered and aggressive greenhouse gas emissions from landfills reduced. By deploying the best available technologies and lessons learned related to extraction and utilisation of landfill gas accelerates the transition to a low carbon circular economy.

The LFG Baltic Seminar was successfully arranged in collaboration with 6th International Conference on Renewable Energy Gas Technology. Researchers and experts from the Baltic countries and EU's Eastern partnership presented advances in landfill gas technology at the seminar together with invited international experts. In total 185 delegates from 26 countries participated in the combined seminar/conference.

8. Outlook

There is a strong trend to reduce the amount of organic matter going to landfills. This implies that the amount of landfill gas and the methane content will decrease by time. Technologies that are able to utilise landfill gas with low methane content are therefore of great interest. Another option is to improve the heating value of the landfill gas by upgrading, e.g. removing carbon dioxide and impurities, and take advantage of conventional conversion technology, e.g. gas engines.

It would be of great interest to compare these two different approaches to use landfill gas with a low methane content (<40%) in terms of technology, economy and environmental footprint. Is it more beneficial to upgrade the landfill gas and extend the use of conventional technology or to opt for a change in technology?

The decreasing landfill gas production, as a consequence of the ban to landfill organic material, seems to decrease the interest to optimise the production or make any investments. However, by taking advantage of international technology development and experiences, especially related to low calorific landfill gas with methane content below 40%, there is probably a good opportunity to both extend and increase landfill gas utilisation and reduce the need for flaring. One of the aims with this report was to show examples of related technology development and contribute to cross border transfer of knowledge, experiences and results.

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ISSN 2001-6255

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