Techno-economic evaluation for energy production from the landfill in Heraklion, Greece

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Introduction

Landfill Gas (LFG) is considered as a valuable renewable energy resource. LFG quality and production rate are demined factors for the selection of the optimal technology for electric energy production. In addition, environmental legislation, flue gas emissions, carbon footprint and maturity of technology should also be considered. The most common process for electric energy production from LFG is the use of internal combustion engines (ICE), which can operate if the methane (CH_4) concentration is above 40%. On the other hand, a novel process, gradual oxidation (GO) (www.ener-core, 2016), can operate at CH_4 concentration as low as 1.5%. The present study examines the techno-economical applicability of the above technologies for electric energy production from LFG at the landfill of Heraklion, Crete, Greece, in Fodele (at the site of Pera Galinoi). The study has taken into account not only the CH_4 production rate, but also the long term CH_4 concentration in LFG.

The landfill of Heraklion, Crete, Greece is located near Fodele village. It receives Municipal Solid Waste (MSW) from greater Heraklion, serving a population of about 238,000 inhabitants. The landfill comprises of four distinct parts: two older dump places (dump “A” and “B”) and two new landfill cells (cell “A” and “B”). Dump place “A” was in use between 1992 to 1997 and covers an area of about $50·10^3 m^2$, it has a volume of about 530 $10^3 m^3$ .and contains about $352·10^3$ tn MSW. Dump place “B” was in use between 1998 to 2008 and covers area of about $35·10^3 m^2$, it has a volume of about 1 $·10^6 m^3$ and contains about $719·10^3$ tn of MSW. Cell “A” was in use between 2009 to 2012 and covers an area of about $50·10^3·m^2$, it has a volume of about 720 10^3 m^3 and contains about $480·10^3$ tn of MSW. Finally, cell “B” was in use between 2012 to 2015 and covers an area of about $28·10^3$ m^2, it has a volume of about 662 $10^3·m^3$ and contains about $441·10^3$ tn of MSW. A new cell has been constructed to receive the MSW from 2016. The MSW in Cells “A” and “B” typically comprises approximately of food residues (39%), paper (20 %), plastics (17.5%), leather-wood-fabric-tires (4.7%), glass (4.25%), metals (6%), inert materials (3%) and non-classified wastes (5.55%). LFG is currently collected only from dump places “A” and “B” and cell “A”, and conveyed to a central collector via three individual pipes. Then, LFG is flared out in a flare tower.

Modeling

A number of models have been used for the prediction of CH_4 production in landfills. Landgem (EPA) is one of the most widely used model (Aydi et al, 2015). One of the Landgems’s basic assumption is that LFG comprises only by CH_4 and CO_2 at 1:1 ratio. However, this may approximately apply for about 15-20 years, after the closure of the landfill, as after this period the concentration of CH_4 and CO_2 is usually reduced, mainly due to the intrusion of air inside the landfill body (Pawlowska, 2014; Bozkurt *et al.*, 1999). The reduction of CH_4 concentration in LFG is often the main reason for the cease of LFG exploitation for electric energy production (as ICEs do not operate at CH_4 bellow 40%). As the landfill site in Fodele consists of various cells, which have closed during different times, both the quantity and quality of LFG should be taken into account for determining the best technology for electric energy production. In our study, we have modified Landgem model to take into account CH_4 reduction, with time. Fig. 1a shows the projected annual methane production from each of the three sites in Fodele landfill; while Fig. 1b shows the expected CH_4 concentration (%) in the produced LFG.

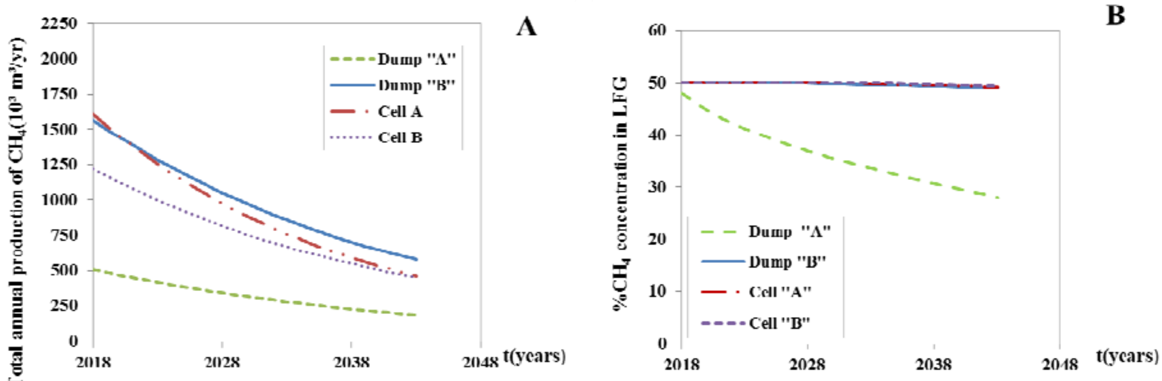

Figure 1. (A) Total annual production of CH_4 from dump sites “A” and “B” and from cells “A” and “B”, and (B) the expected CH_4 concentration in the produced LFG (there is no significant difference between dump “B” and cells “A” and “B”. The results are based on the modified Landgem model.

LFG to Energy Technologies

A number of technologies have been used for the production of electricity from LFG, such as ICEs, turbines, microturbines, fuel cells and GOs (Manasaki and Gikas, 2013). The use of ICE is the most common process for electric energy production. It can achieve electric energy yield of 40%, and has operational availability of about 85%, but requires minimum CH_4 concentration in the LFG of 40%. On the other hand, Gradual Oxidizers (GOs), can operate at CH_4 concentrations as low as 1.5%, have operational availability 95% and electric energy yield of 29% (www.ener-core, 2016). Obviously, GOs appear the sole realistic solution in poor LFGs, however, the minimum available market size is of GOs is 250kW, thus it should be investigated if the employment of such system can be justified.

Techno-Economic Evaluation

Installation and operational and maintenance (O&M) costs, electric energy production yields and operational availabilities, and sale price of electric energy have been assessed to estimate the technology with the maximum net present value (NPV), for Fodele Landfill. ICE have capital cost of about 2,400€/kW, while the installation cost of a typical 250 kW GO is about 4,150€/kW. Annual O&M cost of an ICE is approximately 220€/kW (for engine capacities below 800 kW), while an additional cost of 250,000€ occurs, for replacement of engine parts for every 7 years of operation. In case of the GO, the annual O&M cost is 74€/kW, while the cost for replacement of engine parts is about 400,000€ for every 9 years of operation (Ener-Core Power, Inc., USA). In our calculations we have assumed 5% interest rate, and a time period of techno-economic analysis of 25 years, from 2018 to 2043.

Six different scenarios for electric energy production from dump sites “A” and “B” and from cells “A” and “B” have been examined, as shown in Table 1. In all scenarios 250kW GOs or ICEs, or combinations of the above have been considered. The main constrain for GOs is that there are few types of commercially available GO engines, with the smaller one 250kW. Thus, in the financial analysis, GO with capacity 250kW have been considered. To treat the technologies in equal basis, ICE engines of the same capacity have also been considered. It is worth noting that due to the different yield, one GO engine consumes more LFG, compared with in equal capacity ICE engine. From Table 1, it is obvious that the scenario which involves two ICE engines yield the highest NPV (scenario 3), followed by the one with two GO engines (scenario 4). It seems that the use of an extra engine is not justifiable, as the installation and maintenance cost of such engine exceeds the expected profits (scenarios 2, 5 and 6), while the use of a GO exclusively for dump site “A” (which will be depleted first) is not justified, as the available size of GO is by far larger than the potential for methane production from this site. However, for an integral analysis the expected LFG production from the new cell (which has just started to fill up) should also be considered.

Table 1. NPV of the various examined techno-economic scenarios

Scenario	**LFG to Electricity options**	**NPV (M €)**
1	One 250kW GO engine for dump site “A” and two 250kW (each) ICE engines for dump site “B” and cells “A” and “B”	0.8
2	Three 250kW (each) ICE engines for dump sites “A” and “B” and cells “A” and “B”	1.6
3	Two 250kW (each) ICE engines for dump sites “A” and “B” and cells “A” and “B”	2.2
4	Two 250kW (each) GO engines for dump sites “A” and “B” and cells “A” and “B”	1.8
5	Three 250kW (each) GO engines for dump sites “A” and “B” and cells “A” and “B”	0.5
6	One 250kW GO engine for dump sites “A” and “B” and two 250kW (each) ICE engines for cells “A” and “B”	1.1

Conclusions

The LFG production from the landfill of Heraklion, Greece, in Fodele, has been estimated based on modified Landgem model, which takes into account the reduction of CH_4 concentration, with time, in LFG. Then, the potential for electric energy production from the above landfill has been estimated and the relative NPV profits have been calculated, by the use of combinations of ICE and/or GO engines, for the period 2018-2043. Modeling, indicated that the use of two ICE engines, with capacity 250kW each, yields the highest NPV (2.2M€), followed by the use of two GO engines with capacity 250kW each (1.8 M€). The main reason for the low NPV yield of GO engines (even when they are used exclusively for the exploitation of dump site “A”, which will shortly yield LFG with CH_4 concentration below 40%) is the absence of commercially available engines with capacities below 250kW. For better evaluation of the model outputs, experimental verification of LFG flows and qualities should take place, and the expected LFG production of the new cell should also be taken into account.

References

Aydi, A., Abichou, T., Zairi, M., & Sdiri, A. (2015). Assessment of electrical generation potential and viability of gas collection from fugitive emissions in a Tunisian landfill. Energy Strategy Reviews, **8**, 8-14.

Bozkurt, S., Moreno, L., & Neretnieks, I. (1999). Long-term fate of organics in waste deposits and its effect on metal release. Science of the Total Environment, **228**(2), 135-152.

Manasaki, V. & Gikas, P. (2014). Landfill gas to electric energy: Pros and Cons of available technologies, International Solid Waste Association (ISWA) World Congress, 8-11 September, Sao Paulo, Brazil.

Pawlowska, M. (2014). Mitigation of Landfill Gas Emissions, CRC Press CRC Press/Balkema, London, UK

www.ener-core/technology (accessed February 3, 2016).