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ADVANCED LANDFILL GAS ENERGY PROJECTS IN THE REGION OF SARAJEVO

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ABSTRACT
The first sanitary landfill has been established and built in the city of Sarajevo for the population of 400,000 inhabitants. Initially, capacity of the mentioned sanitary landfill, in the landfill gas generating, by year 2000, was 300 m_n^3/h and expectation is that, by 2030, it should be increased up to 1500 m_n^3/h. Methane concentration in the landfill gas is in average 57%. Currently the landfill gas has been used, since 2000, in power production using electrical power generator of 300 kWe. The excess of the landfill gas has been burned out (using open flame). This paper has the aim to propose advantages in the landfill gas application through tri-generation system for: electrical power production, as well as heating and cooling power production at the same time. Analyses of adjustment of needs for energy and potentials in their production, using combined dynamics concept of the energy production with static energy accumulation concept, have to give the answer for the optimal solution. This paper is going to present analyses of the two concepts: one for the heat accumulation and the other for the landfill gas accumulation.
Keywords: Landfill gas, renewable energy resources, tri-generation system, accumulation energy,

1. LANDFILL GAS – POTENTIALS IN BOSNIA AND HERZEGOVINA

Situation in Bosnia and Herzegovina regarding to solid waste is that the most of large towns are under the World Bank project that is made to organize existing and to establish new as real sanitary landfills. Following locations are included in the WB project: Sarajevo, B.Luka, Zenica, Tuzla, Mostar, Bijeljina, Bihać and Goražde.Some of them are in progress of establishing and some of them will be converted from wild waste areas into sanitary landfill. Sarajevo waste disposed area is still under construction but very close to be sanitary landfill with proper waste management and with system for gas extraction and its use in specially designed gas power electrical generator. Complete CHP system is not installed yet (only power production), but it is in progress. Extension of the system is on the level of feasibility study and should be in progress very soon. Current electrical power production of the unit is around 300 kW_e and landfill has potential in capacity to supply with fuel units with around 1.5 MW_e. So, interests and potentials, following all what is happening in B&H, show that the landfill gas use with high potential for power and further heat production is the most attractive.

To have proper gas production, solid waste has to be treated properly. That means, it is to be organized using "layer by layer" technology and to be compacted properly. Also, system for gas extraction must be done and developed together with growth of the landfill. Summary of all presented facts that make the landfill gas as one of the most attractive low energy fuel for use, are: Acceptable heat value; Potentially stabile and continuous production; Rather fast implementation of the possible projects; Following that several locations are under sanitary landfill project, all necessary preliminary works will be completed in very short period; Gas extraction must be done on sanitary landfill, because of the elimination of potential explosion and consequently impact on air pollution; Rather long period of location use as source of gas (minimum 10 years, but with proper management it could be from 15 – 20 years).

2. TECHNOLOGIES OF LANDFILL GASES USE

2.1 Landfill gas composition

The landfill gas is produced through the natural anaerobic decomposition of organic landfill wastes. As it naturally occurs, the landfill gas has a composition that is: 50 – 55 % of methane and 45 – 50% of carbine dioxide. Concentration of methane and carbine dioxide varies depending on the landfill management technique. Practically typical landfill gas composition is: 45 – 50 % methane, 35 – 45 % carbine dioxide, 0 – 2 % oxygen, 1 – 15% of nitrogen and other components in trace.

2.2 Landfill gas contaminants

Landfill gas (also some gases generated by biomass) contains very corrosive components and abrasive solid particles. That can cause serious damages on the machines for its use in e.g. power production. Monitoring and as much as possible reductions of them must be done. Corrosive component can be grouped into several categories: Sulfur components, halides, acids and solids.

2.3 Landfill gases process equipment

Following all mentioned about the compounds in the landfill gas, it has to have special treatment before use in any engine. Figure 1. presents typical system for gas processing. The typical components are: Gas compressor, Demister, Gas to air cooler, Gas to air cooler, Gas/gas Heat Exchanger, Dryer, Coalescing filter, Pressure control valve. Some of the landfills do not need all mentioned items of the system (depends on the landfill gas composition).

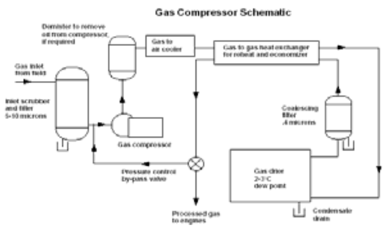

Figure 1. Typical system for gas processing

2.4 Power Production Section

In power production solutions with the landfill gas, there are two possibilities, which can realistically be applied in Bosnia and Herzegovina and which can be very quickly implemented. They are:

- Combined heat and power production with gas power generators and
- Combined heat and power production with gas turbines

In comparison to gas turbines use, combined heat and power plants, with gas engines indicate clearly: Higher electrical efficiency (efficiency for the heat section should be the same), Lower investment costs, Less complicated plant for operation, Lower costs for maintenance and service, Less trained operators (does not need specially trained and educated persons)

3. SARAJEVO SANITARY LANDFILL – CURRENT SITUATION

As mentioned above, Sarajevo has proper sanitary landfill that is currently in operation. It produces 1,250 m^3_n/h of the landfill gas (generated mainly from the residential type of the waste, including small percentage of industrial). Current situation and projections of the landfill gas production up to 2050. in Sarajevo, are shown in Figure 2.

Increasing of the landfill gas production is caused by re-establishing existing waste area into sanitary landfill, through some phases. Completion of the whole area should be in around 2020. Presented peak is because of the consolidation of the existing re-done area and new one. Current situation with utilization of the generated landfill gas is: as mentioned above capacity of the existing gas engine is 300 kWe and until now it has completed 16,000 h of operation. Following up the gas engine and its operation since March, 2001, some problems has been pointed out (it is: 37,5% of the total possible time of usage). The main problem is: Fluctuation of the landfill gas flow rate from 0 to 120% (even more). During low flow rate (up to 30%) and over flow rate (above 100%), landfill gas has been burned out as an open flame, so its utilization is very low. Following that, the most important is to provide optimal operational condition for the existing gas engine before any extension of the plant (adding new engines). Second part of the problem solution is to provide utilization of the thermal energy finding out place and way to use it. Figure 3. presents current situation with the mentioned power plant, additional reconstructions that have to be provided as well as the extension for the future period, using development plans and capacity in the landfill gas production. Segment “B” is present power plant (300 kWe), for electrical power production only.

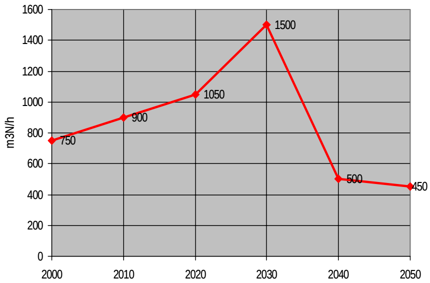

Figure 2. Predications of the landfill gas production in Sarajevo

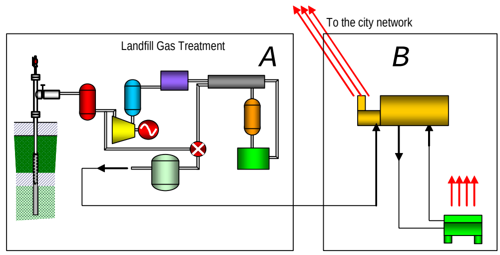

Figure 3. Current situation of power production

4. CONCEPT OF ADVANCED SYSTEMS FOR SANITARY LANDFILL GAS APPLICATION

4.1 Layout of advanced system

This part of the article should give full analyses for the advantages produced by the extension and re-construction of the existing power plant. Concept of advanced system for sanitary landfill applications has intention to use thermal energy for business building, small district heating and winter garden. New concept of advanced system is illustrated in Figure 4. Components, which should be added to the current power plant, are: New gas power generator with the same capacity (E), Landfill gas storage (C) with compressor and reduction station or heat storage (F), Peak load boiler (H), Absorbing cooling system (G), Heating of the office space and sanitary water preparation for the same space (D1), Heating of the winter garden for flowers planting (D2), Heating of the residential areas, small district heating (D3).

Segment “C” will provide stabile landfill gas supply (to increase number of operating hours under full load), which means maximal efficiency. In fact, during some period through a year, landfill has reduced gas production and machine has very unstable operation. Capacity of the gas storage is around 200 m^3 and pressure of 50 bar. Such characteristics should provide that one machine could operate, under the maximal load, at least 10 hour. Segment “D” should help to have maximal utilization of the thermal energy use, which will increase and make stable overall efficiency of the CHP Plant. Segment “E”, new power generator (machine) of the same or similar capacity, should be the future step in the plant development, following that the landfill gas production is much higher than the existing generator capacity. So, as the conclusion: one power generator more with electrical capacity of 300 kW_e and 480 kW_t of heat capacity. Segment “F” is required to provide balance in electrical energy and heat production. Segment “G” , absorption chiller (NH_3-H_2O), is designed for further improvement of all system and give the charactheristic of trigeneration to it. The capacity is 30 kW of chilled water. The heat consumption at maximum load on the absorption chiller is approx. 50 $kW_{t.}$

Segment “H” is Peak load boiler for covering peak load in very cold period of the year and as substitution during service period of the plant. Its capacity should be determined from difference in Demand Side and Supply Side. Because of the very often and intensive fluctuations of the landfill gas production, gas storage is essential segment, which will provide high availability of the plant. At the same time peak load boiler is essential too, because of the peak load and to provide uninterrupted heat supply. If the two mentioned segments would be incorporated into the plant, segment of heat storage is not necessary. Following that, the whole investment will be reduced.

4.2 Demand of heat load

Produced heat would be used for: heating (110 kW), cooling (50 kW) and sanitary water (10 kW) for the office space, heating of the winter garden (160 kW) and small district heating (960 kW). Total heat load is 1290 kW. Figure 5 presents diagram for the described heat demands with average heat demand levels and their duration through number of operating hours.

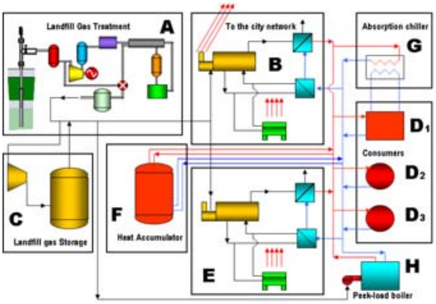

Figure 4. Concept of advanced system for sanitary landfill gas applications

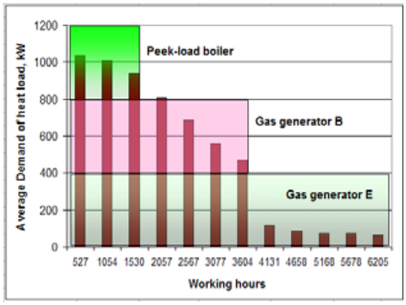

Figure 5. Average heat demand as function of working hours

4.3 Supply of heat load

Sources of the heat are: existing and new gas power generator. It is necessary to determine capacity of the peak load boiler: B-gas generation, 300 kW_e-480kW_t, E-gas generation, 300 kW_e-480kW_t. Total of CHP is 600 kW_e-960kW_t, but demand of heat is 1290 kW_t. So, capacity of peek-load boiler is 330 kW_t.

5. ECONOMIC CALCULATIONS OF ADVANCED SYSTEMS

Determination of the economical effects of the mentioned system has been done using static method estimation of the return of investment. The result of the payback period calculation is that payback period for the analyzed plant is less than four years, what is the main point for such plant to be acceptable for building. Benefits in CO_2, NO_x and CO reductions have not been analyzed. Estimation is that mentioned reductions should be used to make such constructed plant more acceptable from the eco-trading side.

6. SUMMARY AND CONCLUSIONS

Tri-generation systems on the basis of landfill gas are very profitable investments for the sanitary landfill owners. A new advanced system for sanitary landfill gas applications might pay for itself in as little as four years, depending on local electric rates, heat rates (or other fuel) costs, and the load profile of the consumers. The on site tri-generation system can be economically attractive for the other mentioned locations. The main goal of the research of landfill gas application is to acquire the knowledge and experience for the development of the technology of projects on sanitary landfill gas application, in the function of the increase of energy efficiency and decrease of the emission of CO_2, NO_x and CO. The following significant advantages of advanced system for sanitary landfill gas applications are: increased power reliability, reduced energy consumption, reduced power requirements on the electric grid, improved environmental quality, reduced dependence on imported natural gas. Advanced system for sanitary landfill gas applications helps not only the power plant owners, but also benefit society in many ways. Because of these advantages, the system is very applicable for central heating and cooling systems of residential buildings, heating of domestic hot water, heating of winter garden, etc. The Kyoto Protocol is moving ahead with ratification throughout the world. Countries throughout much of Europe and Asia view cogeneration and tri-generation as the single best energy technology to meet the stringent emissions requirements of the Kyoto Protocol. Because of that, benefits in CO_2, NO_x and CO reductions have not been analyzed. Estimation is that mentioned reductions should be used to make such constructed plant more acceptable from the eco-trading side.

7. REFERENCES

[1] Overview of cogeneration, Phare Multi-country Energy program, WS ATKINS, May 1999.
[2] Delalic, N.: Small-Scale CHP systems and barriers in their implementation, Phare Multi-country Energy program, Workshop, Sarajevo, 1999.
[3] Delalic, N. Sadovic, T., Gafic, A.: Promotion of Small Scale Co-Generation Solutions In CEECs – Stady of Cogeneration in Bosnia And Herzegovina, Phare Multi-country Energy program, Workshop, London, 1999.
[4] Delalic, N. Sadovic, T., Gafic, A.: Possibilities of using CHP Systems in B&H, International Workshop and Round Table Discussion "Energy Future of Bosnia and Herzegovina", (15 - 16 june 2000.) Sarajevo.
[5] Sadović, T., Delalić, N.: Possibilities of reducing energy cost by using CHP systems in urban area of Sarajevo Region, New and Renewable Technologies for Sustainable development, Madeira Island, Portugal, June 2000.