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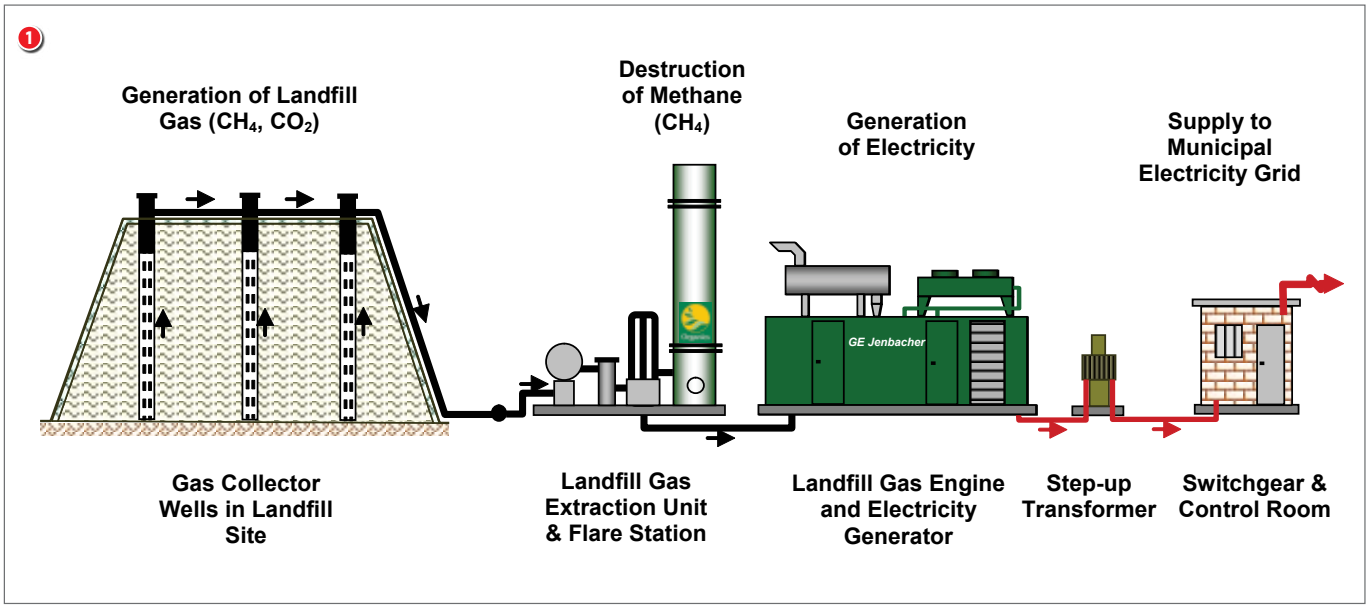
Landfill gas recovery, green energy, and the clean development mechanism

THE ENVIRONMENTAL advantages of the extraction, destruction and possible utilisation of landfill gas (LFG) have been well documented, and South Africa is in an advantageous position in terms of the Clean Development Mechanism (CDM) provisions of the Kyoto Protocol, an initiative of the United Nations Framework Convention on Climate Change (UNFCCC). In addition to the environmental benefits associated with a significant reduction of landfill emissions, the sale of such quantifiable units, called "Emissions Reductions" (ERs), can provide a sustainable source of funding that can be channelled back into waste management initiatives. The potential use of the gas as a renewable energy source for power generation, coupled with the revenue derived from the sale of the electricity is an added bonus. Specifically, the methane content of the landfill gas is the primary target, as it is 21 times more potent than carbon dioxide as a greenhouse gas. Landfill gas, with a typical methane content of 45 – 50%, has a thermal energy content of 5 kWh/Nm^3 and a lower calorific value (LCV) of some 16 – 18 MJ/Nm^3. This heat value is roughly half the heating value of natural gas. By comparison, the LCV of coal and fuel oils is 22 and 40-42 MJ/kg respectively.

A landfill gas extraction and flaring or utilisation system typically comprises a number of vertical and horizontal

1 Schematic layout of landfill gas to electricity installation



2 Landfill gas recovery – power generation units, Bisasar Road, Durban

gas wells, connected to a gas collection pipe network, leading to a Gas Delivery Unit (GDU) or "fuel skid" equipped with a variable speed blower and high-temperature flare. The fuel skids normally include various gas filters, a condensate knock-out chamber and shut-off valves. Vertical gas wells are normally constructed using an auger drilling technique, followed by the insertion of perforated HDPE recovery pipes, surrounded by a stone packing. The gas wells are completed with the installation of prefabricated HDPE well-heads which allow for the regulation of gas flow from any particular gas well, since conditions may vary considerably from one gas well to the next, and a hydrated bentonite seal to prevent the ingress of air under continuous extraction conditions of negative pressure. Each wellhead is connected to the HDPE gas collection pipework, laid to falls to enable the efficient drainage of condensate forming in the pipes. At low points in the collection pipework, condensate drainage or "knock-out" systems are installed, facilitating the delivery of relatively dry LFG to the fuel skid. Following delivery of the gas to the fuel skid, it can either be flared or used, typically as fuel for reciprocating gas engines and generation modules.

Landfill gas to electricity CDM projects can potentially take years to develop. Although these projects may appear to be lucrative at the outset, the requirements of the rigid CDM process should not be underestimated. The complex financial, administrative, socio-economic, legal and environmental issues are normally the main focus areas for a project developer, and there is a risk of overlooking the critical engineering factors involved. It has been said that a CDM project will not transform a poor landfill operation into a good one. The mere facts that a landfill exists and that well established technologies are available, are not the ingredients for instant success. The detailed engineering aspects, including landfill design and site operations, pose the greatest number of variables, directly impacting on the long-term revenue potential of the project.

THE CDM PROJECT CYCLE

All CDM projects must adhere to the project cycle as defined by the Clean Development Mechanism of the United Nations Framework Convention on Climate Change (UNFCCC). This is an extensively documented process, with over one thousand CDM projects having been registered with the Executive Board worldwide to date. The project owner is mainly responsible for three aspects, i.e. the Project Design Document (PDD), Financing and Implementation, and Monitoring. This is where the engineering aspect of the project is paramount. The PDD includes a baseline estimate of the net carbon emissions reductions, and is reliant on detailed information regarding the physical characteristics of the landfill and sound engineering judgement. The

implementation phase includes the design of the gas extraction and flaring system, which should be able to deliver the emissions reductions as provided in the PDD. The monitoring phase simply necessitates having a settled structure in place for the continuous monitoring of project performance and the recording of key CDM data.

PROJECT DESIGN

A detailed desk study is required, where all the physical attributes of the landfill must be considered. Various software packages such as GasSim are used for the development of a theoretical model which predicts the sustainable gas generation by the landfill over a period of time into the future. Where accurate data does not exist, such as historical waste composition, careful judgement has to be exercised.

The next step in the process should be the implementation of a "pumping trial" to confirm the theoretical findings. A pumping trial is critical in determining the sustainable gas recovery rate from the landfill. A few gas wells are constructed in strategic locations and landfill gas is extracted from these wells over a period of months with a small blower and flare. Over this time, gas quality and flow rates are monitored. Besides proving the sustainable gas yield for a typical gas well, a pumping trial also provides physical confirmation of other factors, such as the composition of the waste body, and whether or not leachate is present in significant quantities.

Based on the findings of the gas modelling and pumping trial, the full gas extraction system can be designed. The industry rule of thumb allows for a nominal gas well spacing of 50 m c/c, but experience has shown that this is not a good enough assumption when one considers the cost of gas well installation (at least R100 000 per vertical gas well, depending on the depth). Site specific conditions will dictate the gas transmissivity of the waste, and accordingly, the extraction "sphere of influence" of each particular gas well. The information obtained during the pumping trial should be used to more accurately estimate the correct gas well spacing. Influencing factors also include the landfill lining system, leachate drainage, the type and quantity of daily cover material used, the degree of waste compaction, and the nature of the surface or cover of the landfill, including surface drainage design.

The future design, construction and operation of the landfill itself must also take cognisance of typical gas extraction requirements. This includes the size and three-dimensional shape of landfill cells to provide a sufficiently large area and volume for an effective sphere of influence of the gas wells, the use of a proper lining system incorporating leachate drainage, and the proper selection and application of daily cover material. In addition, the landfill capping design needs to be carefully considered, allowing for a surface of relatively low permeability.

It may be decided to put the gas to productive use immediately, following construction of the extraction system. However, only after the gas extraction system has been in operation for some months, and the wellfield has been properly balanced, will a project owner have the hard facts and figures on which decisions can be based. Considering the significant cost of a power generation system compared to a relatively simple and cost-effective flaring unit, a period of flaring only is often recommended. This period would allow for sampling and detailed analysis of the gas. Landfill gas is known to contain many contaminants which can cause a wide range of engine maintenance problems. Gas testing and analysis would provide information for the planning and design of gas treatment systems, and budgeting for preventative maintenance.

IMPLEMENTATION

It is important for the project team, including the project owner, consultants and contractors, to work towards the common goal of producing and extracting as much good quality gas as possible, and the design and budget should be flexible enough to implement the necessary measures to achieve this objective.

Seasonal climatic variations have a significant effect on landfill gas generation and recovery. In the winter season, drier and cooler conditions result in a decreasing rate of gas recovery from the landfill, as wells have to be turned down to prevent the ingress of air. In summer, warm and wet conditions are conducive to the generation of landfill gas, and in addition, high levels of moisture in the capping and upper levels of the waste body provide a sealing effect, preventing the ingress of air.

Envitech Solutions' experience in the operation and maintenance of gas extraction and flaring systems at both coastal and inland sites has confirmed various technical issues that should be taken into account during project development, including the following:

- All gas wells will not provide the same quality and quantity of gas. A landfill site is non-homogeneous, and some areas will produce more gas than others. The variations can be significant.

3 The 3 000 Nm³/h flare at Rooikraal landfill, Ekurhuleni Metro

- Older gas wells and landfill cells should be treated with caution, and they will not produce the same quantity and quality of gas as new wells in relatively new waste.
- Planning a gas extraction system for a valley site can be more complex, and effective results hinge significantly on the shape of the cells.
- Access to landfill gas should be encouraged as soon as possible after waste placement and landfilling (within a few months), as the quality and volumes of gas produced from an early stage can be significant. This could be achieved through the construction of horizontal gas wells in operational cells. It must be understood that once landfill gas is generated within a landfill, it will soon be lost to the atmosphere. A landfill is not a "reservoir" for landfill gas.
- The volume of leachate in a site combined with the quantity and type of soil cover material used has a significant influence on the gas well sphere of influence, and the drainage properties and transmissivity of the waste body.
- The drainage properties of the compacted waste body also have a significant influence on the performance of a gas extraction system. Leachate extraction pumps are more than capable of pumping large volumes of leachate, but the rate of leachate ingress to the wells is the governing factor. For the leachate to be effectively

removed, it first has to drain into the gas wells, which can take a very long period of time. As the hydrostatic curve is drawn down in the vicinity of the gas wells, the leachate can take even longer to reach the gas wells, a situation which would be exacerbated by the non-homogeneous nature of the landfilled waste and the tendency for perched leachate layers to form at different levels in the waste body.

MONITORING AND CDM VERIFICATION

Accurate monitoring and record keeping is integral to a successful CDM project. The plant operator needs to keep a watchful eye on the proper functioning of the instrumentation and the automated data-logging systems. Of critical importance is the filtering and processing of the raw data, including the elimination of non-sensical data, the timeous identification of faulty instrumentation, and the presentation of the processed data in a format appropriate for CDM verification. Transparency of any data processing, conservatism with respect to assumptions made, and adherence to CDM Executive Board approved project manuals will ultimately assist in the auditing (verification) process.

Of critical importance is the fact that the CDM aspect of the project only really kicks off with the commissioning of the gas extraction (and potential power generation) systems. Project revenues are directly related to the quality of the information recorded on a continuous basis. Meeting all the requirements of the PDD and CDM Management Manuals for the project, including all environmental ROD and legal requirements, as well as implementing a fully functional QA/QC routine, is critical. The verification process is stringent, and the project team needs to be thoroughly prepared. Envitech Solutions' experience has been that the focus is not only on the data collection and processing, but on the overall quality of the entire project, from design through to implementation and monitoring, providing somewhat of a "balanced scorecard" approach.

POWER GENERATION

Typically, most landfill gas extraction and utilisation projects developed thus far in South Africa have been developed as CDM projects including power generation. There is significant potential in this sector, but unfortunately this potential remains largely untapped, with only a handful of projects having reached an advanced stage of development to date. The city of Durban (eThekwini) is the most notable at this stage, and is currently generating a total of 8,5 MW at their Mariannhill and Springfield (Bisasar Road) landfills. This is enough power to supply approximately 5 000 homes.

This scenario is expected to change in the near future, as strategies at various levels of government and the private sector begin focusing on renewable energy initiatives. A specific factor that could also have a catalytic effect is the rapidly rising cost of power, in addition to its increasing scarcity, rendering financial returns on the investment required much more attractive. □

Source:
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