Landfill Mining

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1. Introduction

As available land and resources become increasingly scarce, options to harness these from alternative sources become more sought after. One of the options available is Landfill Mining (LFM). This paper has been prepared to highlight the key social, environmental and economic factors that need to be considered before undertaking an LFM project. LFM is commonly understood to be the extraction of waste from a landfill site after that site has closed and is no longer accepting waste.

The concept of LFM is not new: There have been examples cited since the later 1940s and it is likely that earlier, unrecorded activities took place. It is not a practice unique to one country, region or has any specific strategy that determines whether LFM should take place or not. The reasons for LFM are often unique to the site itself and there are specific factors that may lead to an LFM operation. Whilst there are a number of reasons for LFM, explained further in this paper, there are also disadvantages that preclude it from being a commonly practiced activity.

With a significant proportion of the world's waste still being disposed of in landfill, there is the potential for significant resources to be recovered post-disposal. In the future old landfills are likely to be considered as exploitable material stocks.

2. Reasons for considering Landfill Mining

It appears that there are three main strategic reasons for LFM operations: Extraction recycling potential; extraction for energy recovery; and the reclamation of land. Whilst the first two are clear economic arguments about the potential income from the deposited wastes, the third has greater potential for considering environmental and wider sustainability drivers. These reasons may be independent drivers for LFM but may also be combined to deliver wider benefits and maximise the LFM opportunity.

The extraction of wastes for their recycling potential is highly likely to be driven by the material values in the market place for specific recyclates. Metals and plastics are those materials which have the highest values and the lowest level of degradation within a landfill site. These are, therefore, often cited as targets for LFM. However, there may be others that have a specific local value. The benefits to resource security need to be considered.

Recovery of material for conversion to energy seeks to extract the value of the un-degraded portion of the biomass that has been disposed of. Whilst it could not be considered a 'renewable' source of energy in the purest sense, with dwindling fossil fuels and the need for more sustainable use of natural resources, waste landfilled may provide a short- to medium-term resolution to energy demand. Waste in landfill sites may also satisfy future demand for waste supplies in mass burn incineration facilities in locations where waste minimisation is expected to impact on future trends.

The reasons covered by the broad term 'land reclamation' may include one or a combination of the following:

- Landfill sites may be in locations that are, was it not for the landfill operations, ideal for traditional development purposes;

- The landfill site may form a physical barrier to a development that is planned, such as the Channel Tunnel Rail Link in the United Kingdom;
- It may be contaminating the groundwater or surrounding area and the source requires removal; or,
- There may be a need to reuse the available landfill space at that site for different kinds of wastes more suitable to long-term disposal, such as non-reactive hazardous wastes (e.g. asbestos).

Materials and energy recovery are likely to be primarily dependent on economic factors, land reclamation may be driven by environmental reasoning. When the widest range of benefits is considered, the greatest benefits can be driven from an LFM operation that can have significant costs and other impacts.

3. Reasons for avoiding Landfill Mining

LFM has the potential to have significant economic and environmental impacts. Historic landfill sites have many unquantifiable variables and estimates must be made of the wastes within them and the subsequent impacts that those wastes may have. It is only in recent years that accurate knowledge, and then only in broad terms, is available to assess what wastes a landfill site may contain. This lack of knowledge merely increases the risks that would otherwise be present during LFM operations.

The risks of excavation of a landfill site include:

- Nuisance caused during the LFM operation
- Potential for presence of hazardous materials
- Escape of leachate or landfill gas during LFM operations

Many of these risks are similar to traditional mining operations but are enhanced by the heterogeneous nature of the wastes in a landfill. They are also similar to the risks posed by landfilling operations but in reverse. If LFM were not to take place, the waste would remain contained and have limited opportunity to realise the hazards caused.

The uncertainty of what LFM will produce is a clear factor for investors and business cases to address. Whilst the extremes are the hazardous risks mentioned above, whether the materials excavated will be marketable or not is a clear factor to be determined. Ensuring that they meet the requirements of end-users and reprocessors will ensure that the LFM operation is successful.

If material recovery is not the aim, and land remediation or re-development is, a clear factor is to ensure that there is any residual contamination of the land or groundwater is removed as part of the excavation. LFM should be avoided in situations where a properly engineered landfill is unavailable to receive the remnants of the excavated material that cannot be recovered or treated by other means.

4. Regulations, laws and standards

Because of the emerging nature of LFM operations, there are few regulatory controls in place. Where they do exist, they are set at a local level and the perspective they take varies.

For example, in the United States, there have been State-specific regulations for LFM operations that take into account the LFM operation itself, the waste processing of the excavated material and the associated environmental impacts. These are comprehensive and built on research studies of LFM.

However, by contrast, in the United Kingdom, regulatory controls do not specifically focus on LFM but merely the processing of the recovered materials and rely on existing environmental pollution and nuisance legislation to minimise the risk of pollution of the surrounding area. The Environment Agency have issued guidance that the excavation of the material itself is not a regulated activity where the landfill site no longer has an active permit.

The most significant set of regulatory controls are likely to be local health and safety laws. LFM could be considered as falling in either (or possibly both) landfill and mining regulatory controls and standards due to the unique nature of the activity. This will impose a variety of regulations that may be unusual to the operator, depending on their background.

5. Technical Requirements and Considerations

LFM is a combination of processes. These can be broken down into:

1. Preliminary works
2. Extraction of waste
3. Processing of waste
4. End-markets
5. Remediation of land
6. Subsequent development

Following the preliminary works of site preparation, surveys, investigations and programming resources, the physical operation of LFM is a relatively simple one for an experienced landfill or mining operator. However, there are specific risks that need to be considered. The discovery and handling of hazardous materials within the landfill has the potential to hold up, and increase the costs of, LFM operations.

Once the waste is extracted, it needs to be processed according to the objectives of the scheme. This may be for recyclables recovery, where there will be specific standards depending upon material and the end-markets will have their own requirements. These will vary from place to place and may have specific regulatory controls.

Any form of energy recovery is likely to require pre-treatment shredding, trommel screens and metal extraction. It may also require drying to reduce moisture content. There will be significant variability in the composition and consistency of the waste through the different stages of the excavation and the pre-treatment systems need to be able to provide a homogenous output for a waste-to-energy plant to deal with. This may need to be completed on site prior to transportation so that only a stabilised product is being moved and the associated haulage costs and risks reduced.

Once the site has been completely excavated, there will be a requirement to remediate the land to remove any residual pollution if the intention is to develop the site for an alternative purpose or to remove the future burden. This will be a specific operation that will require intensive ground investigations and analysis of the groundwater and soils in the area. By removing the source, this part of the process becomes one of containment and decontamination. It is likely that this would be possible using traditional land remediation techniques.

The subsequent development of a landfill may be specified as part of the objectives of the scheme. Depending on the extent of the remediation, it is likely that a specialist operator would not be required at this stage and a construction contractor experienced in brownfield development may be sufficient.

6. Environmental impacts and potential mitigation

Whilst the recovery of waste from historic deposits is beneficial to reduce long-term detrimental effects on the environment, it should not be considered as a means of avoiding an appropriate pro-active waste management strategy using the traditional waste hierarchy. It would appear to be a false economy to allow waste to be landfilled and then seek to recover residual value at a later date.

Where wastes have already been landfilled, LFM may be used to reduce the future negative impacts on the environment. Although LFM is likely to be beneficial in the long-term, it is necessary to mitigate the short-term impacts as these are one of the concerns that surround LFM.

The standard controls for landfilling waste (daily cover, odour and dust management plans) will be necessary to minimise short-term nuisance and impact on the local environment. Additional controls to manage the escape of LFG may also be required during the excavations. This might take the form of smaller digging faces than the usual tipping face or in extremes, enclosed environments with specially designed machinery for working in explosive atmospheres with air conditioning for operators. Before LFM begins, it may also be worthwhile to used forced aeration of the landfill to maximise LFG recovery prior to excavation and minimise odour and methane production during that phase.

Processing the waste for recycling or energy recovery will also impact on the environment and these need to be controlled in a similar manner to regular waste operations but with extra attention due to the volatility and heterogeneous nature of the excavated waste.

7. Financial considerations / costs compared with potential income streams

A proactive strategy for LFM will be required to recover income, or reduce expenditure, to enable it to break-even or, preferably, generate a profit.

The expenditure for an LFM project will be significant, with long-term investment potentially required as it is unlikely to have a short payback period. The costs of excavation, environmental controls, transport, processing and remediation of the land are all likely to be high-value elements of the project.

Income from LFM will be dependent upon the content of the site and the potential after-use. The composition of the waste, as already highlighted, is uncertain in most cases and high-risk. Even where content of the site is known, there may be varied rates of decomposition that result in poor-quality material being available. This is also the case for energy recovery, where the biomass content of the waste will vary. Future income from land redevelopment may also be a driver.

It is also necessary to consider the cost-avoidance of future aftercare burden but also the reduced income from any LFG-based electricity generation. The financial considerations are summarised in Table 1.

Table 1 - Financial considerations

<u>**Negative values**</u>	<u>**Positive values**</u>
Expenditure	**Income**
• Site investigation preliminaries • Excavation • Environmental controls • Waste preparation/pre-treatment • Haulage	• Recyclate sales • Waste fuel sales • Land redevelopment
Income loss	**Cost-avoidance**
• LFG electricity generation schemes • Planned after-use income (e.g. agricultural rents)	• Future aftercare costs • Unknown legislative change • Unknown financial penalties

8. Implications regarding landfill tax, subsidies, legislation, aftercare

As LFM is not specifically regulated at this time, there is little indication as to whether it will be affected by future legislative change. There are opportunities to argue that specific allowance for LFM operations should be made to incentivise the reclamation of land and the beneficial use of resources.

One of these arguments is the role of Landfill Tax (LFT): This is a tax, which is paid on waste disposed of to landfill. If that was is subsequently recovered from landfill, should this tax be reclaimed or refunded? This would be an additional income stream to help offset the costs of LFM. However, LFT was implemented primarily to encourage waste producers to divert waste from landfill in the first place and it is a permanent tax. With landfills than span changes in rates and the introduction of taxes in the first place, it would be difficult to prove whether tax had been paid on the waste excavated and will be subject to local interpretation of LFT legislation.

Subsidies have been available for the remediation of land and these may be appropriate where it can be shown that the land is being remediated for a beneficial purpose. Tax relief on expenditure made for land remediation may also be available depending on the country and objectives of the LFM project.

One of the benefits of LFM is to remove the risk of future legislative change placing additional burden on landfill operators and owners. Avoidance of future pollution risk will avoid the risk of future sanctions.

There will also be a reduction in the burden of aftercare. In most countries, there is no defined period for aftercare liability. Whilst operators are *advised* to make provision for sixty years after the closure of a site, this is not an absolute and, if there is still an environmental risk posed, the aftercare period will continue indefinitely. A successful LFM project will remediate the land so that a site can be surrendered with no further aftercare requirement.

9. Life Cycle Assessment and Cost-Benefit-Analysis

To determine the overall benefit of an LFM operation, it is important to calculate the environmental and cost benefit. It is likely that these will be necessary to secure investment for LFM projects and an initial life-cycle-assessment (LCA) and cost-benefit-analysis (CBA) would be completed as part of the preliminary study for a site (or group of sites).

Environmental assessment through LCA will consider all parameters of the landfill and the benefit of LFM can be defined as the **difference** between leaving the landfill to naturally degrade over an unknown period against the impact of the LFM project. This may expand to take into account the beneficial use of materials recovered compared against raw extraction or production of those materials and the comparison of using traditional fossil fuels against the use of waste-derived biomass extracted from landfill. However, it is important to calculate the impact of the LFM operation, including any emissions caused by the excavation and the premature release of contaminants.

Whilst a business case may have been predicated on the financial considerations shown in Table 1, a CBA may expand on this and take into account social costs and carbon costs to determine the overall value of an LFM project. Using values such as the 'shadow cost of carbon' and the disamenity values of property near landfill, it is possible to provide a monetary comparison of the site before and after LFM operations.

10. Conclusions

LFM operations are likely to be complex and needs to consider a long-term view of the economic and environmental considerations surrounding the project. There are a range of factors to take into account and all landfills will not result in a positive return. Any organisation considering undertaking LFM needs to fully evaluate the proposed sites and conduct highly detailed site investigations to determine the likely return and the controls that will be required during the excavation. There need to be clear aims and objectives to enable the project to take the right approach to investment and appropriately quantify expenditure and income.

Whilst the LFM excavation itself is relatively simple, a holistic approach to wastes management and mining is required to fully understand the implications.