Global Landfill Mining
Conference and Exhibition

Proceedings volume

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Edited by Dr Robert McCaffrey.

The editor would like to thank all contributors to this volume

Global Landfill Mining
Conference and Exhibition
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Conference Convenor	Robert McCaffrey
Commercial Director	Paul Brown
Conference organiser	Saija Nakari
Conference support	Lisa Morley

Contents

PROGRAMME.

08.15 Registration opens: Coffee and Neworking

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9.10 'Divert, dig up or distributed energy?.....Balancing the drivers of carbon and financial desires - a 5 Dimensional approach,' Peter Jones

9.40 'Landfill mining regulation: how do we start?' Jonathan Atkinson, technical specialist, Environment Agency

10.10 'Landfill Reclamation: Drivers and Requisites,' Edwin Falkman, EGF Associates

10.40 Meet the delegates session

11.00-11.30 Coffee and networking

11.30 'Regulatory requirements associated with landfill mining in the United States,' Robert Schreiber, Christa Russell, Doug Abeln; Schreiber Yonley and Associates

12.00 'System, technology and experience of 17Mt of landfill mining projects,' Reinhard Goeschl, Innovation und Technik AG, Emirates Environmental Technology Co. Llc. Sharjah / UAE

13.00-14.00 Lunch and networking

14.00 ' The cumulated energy demand (CED) for landfill mining and reclamation,' Ingo Hölzle, Technical University of Munich

14.30 'Possibilities for landfill mining in Turkey, Pakistan and worldwide, for the production of alternative fuels,' Dirk Lechtenberg, MVW Lechtenberg

15.00 ' Landfill mining is what we do,' Peter Crofts, RockTron Ltd

15.30-16.00 Coffee and networking

16.00 'In-situ waste aeration preliminary to landfill mining,' Roberto Raga, Raffaello Cossu; University of Padova, Italy: Andrea Dal Maso, Moreno Zanella; Spinoff s.r.l., Padova, Italy

16.30 'Factors influencing business models for landfill mining,' Amit Shankar Ranjit, Energy and Environmental Engineering, Linköping University

The programme is subject to change. The conference language is English. Dress code for the conference is smart casual or business suit.

Delegate information.

By delegate surname.

First	Family	Telephone	Country
		Lindner Recycling	Austria
Doug	Abeln	Schreiber Yonley and Associates	USA
Jonathan	Atkinson	The Environment Agency	UK
Florent	Bourgarel	Lafarge	France
Kate	Burt	Freelance Journalist	UK
John	Cole	SLR Consulting	UK
Raffaello	Cossu	University of Padova	Italy
Peter	Crofts	RockTron Ltd	UK
Andrea	Dal Maso	Spinoff s.r.l.	Italy
Thierry	Dalle	Umicore SA	Belgium
Edwin	Falkman	EGF Associates	UK
Michael	Flynn	FLI Environmental	Ireland
Reinhard	Goeschl	Emirates Environmental Technology Llc	UAE
Andrew	Goodwin	Mott MacDonald Ltd	UK
Ingo	Hölzle	Technical University of Munich	Germany
Peter	Jones	Peter Jones Associates	UK
Dr.Ulrich	Kohaupt	Steinert Elektromagnetbau GmbH	Germany
Dirk	Lechtenberg	MVW Lechtenberg & Partner	Germany
Hitomi	Lorentsson	Stena Metall AB	Sweden
Jordi	Marza Brillas	CESPA GR	Spain
Philip	Norville	Deme Environmental Contractors	UK
John	O'Donnell	Mott MacDonald Ltd	UK
Roberto	Raga	University of Padova	Italy
Neville	Roberts	CEMEX UK	UK
Norbert	Rousset	Lafarge	France
Christa	Russell	Schreiber Yonley and Associates	USA
Robert	Schreiber	Schreiber Yonley & Associates	USA
Amit	Shankar Ranjit	Linkoping University	Sweden
James	Short	Open University	UK
Luk	Umans	Ovam	Belgium
Moreno	Zanella	Spinoff s.r.l.	Italy

Delegate information.

By delegate company name.

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Norbert	Rousset	Lafarge	France
TBA		Lindner Recycling	Austria
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Andrew	Goodwin	Mott MacDonald Ltd	UK
John	O'Donnell	Mott MacDonald Ltd	UK
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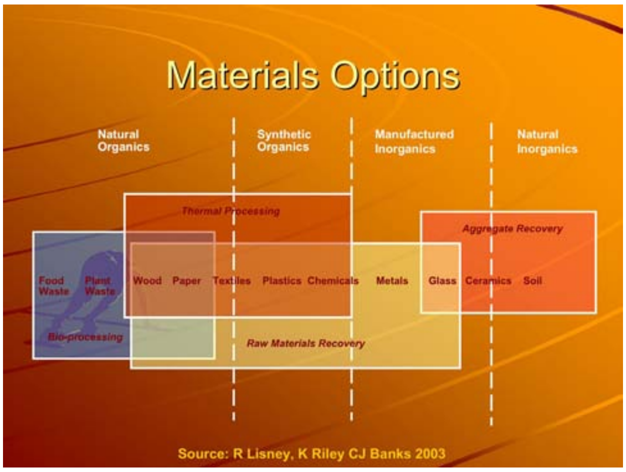
Christa	Russell	Schreiber Yonley and Associates	USA
Robert	Schreiber	Schreiber Yonley & Associates	USA

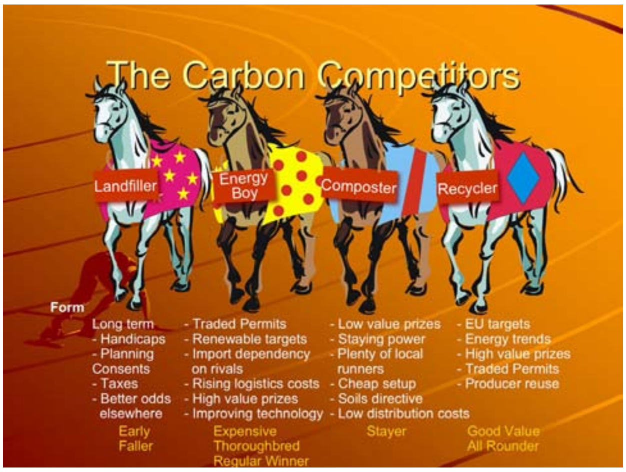
Paper 1

Divert, dig up or distributed energy?.....Balancing the drivers of carbon and financial desires - a 5 Dimensional approach

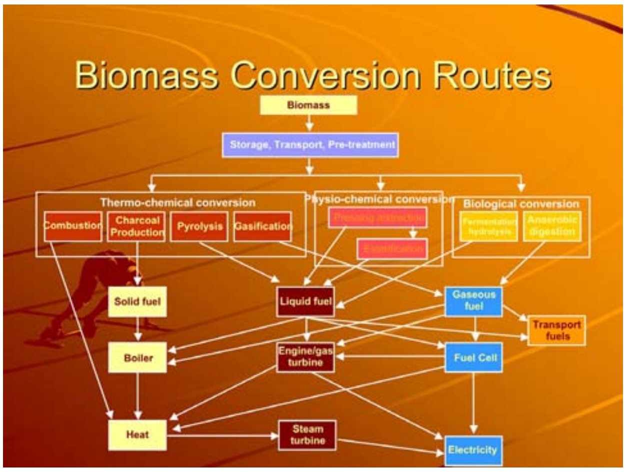
Peter Jones

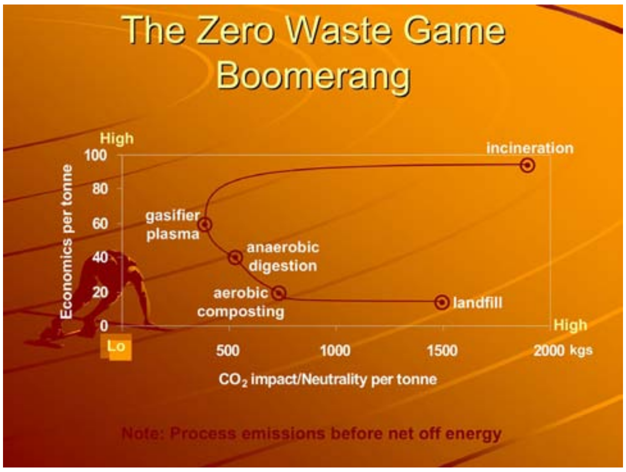
Landfill industry consultant



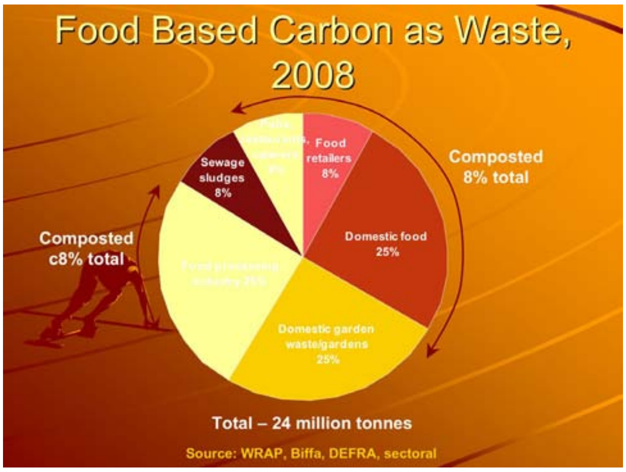

The Carbon Competitors
Landfiller
Energy Boy
Composter
Recycler
Form
Long term
- Handicaps
- Planning Consents
- Taxes
- Better odds elsewhere
- Traded Permits
- Renewable targets
- Import dependency on rivals
- Rising logistics costs
- High value prizes
- Improving technology
- Low value prizes
- Staying power
- Plenty of local runners
- Cheap setup
- Soils directive
- Low distribution costs
- EU targets
- Energy trends
- High value prizes
- Traded Permits
- Producer reuse
Early Faller
Expensive Thoroughbred Regular Winner
Stayer
Good Value All Rounder

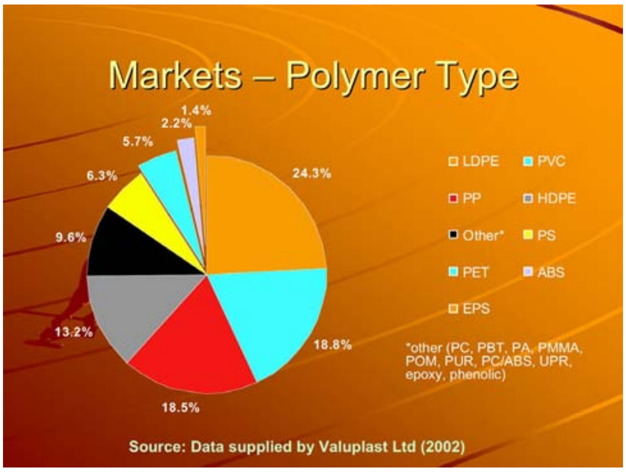

The Resources Hierarchy
Value by Financial and Fossil Carbon Tradeoffs
1 tonne bale of waste floc
Compost/fertiliser soil fuels
Recycling into new Materials
Pyrolysis to Carbon
Anaerobic Digestion
Gasification/steam turbine
Gasification/internal combustion
Gasification/hydrogen/fuel cells

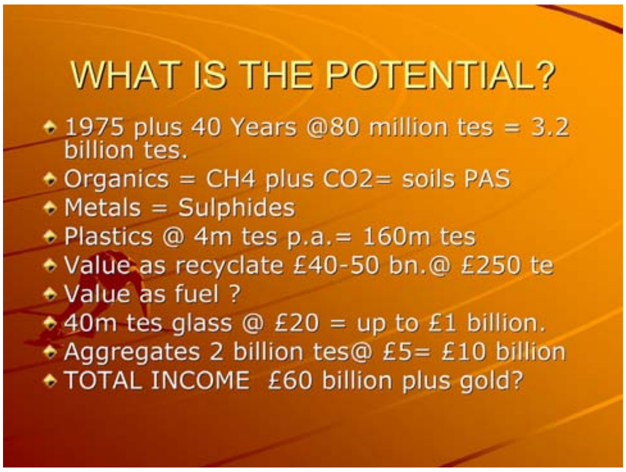

Biomass Conversion Routes
Biomass
Storage, Transport, Pre-treatment
Thermo-chemical conversion
Physio-chemical conversion
Biological conversion
Combustion
Charcoal Production
Pyrolysis
Gasification
Solid fuel
Liquid fuel
Gaseous fuel
Transport fuels
Boiler
Engine/gas turbine
Fuel Cell
Heat
Steam turbine
Electricity


The Zero Waste Game Boomerang
High
Economics per tonne
100
80
60
40
20
0
Lo
incineration
gasifier plasma
anaerobic digestion
aerobic composting
landfill
High
500
1000
1500
2000 kgs
CO2 impact/Neutrality per tonne
Note: Process emissions before net off energy


THE IMPACT OF MINING
Ch4 Releases
Asbestos et al
CO2 Balances
"Thought that was it" syndrome
Regulatory demands
Traffic Impacts
O2 Domes?
Robots?
Liability Insurance
Freehold or Royalty?


Food Based Carbon as Waste, 2008
Food retailers 8%
Sewage sludges 8%
Composted 8% total
Domestic food 25%
Composted c8% total
Food processing 25%
Domestic garden waste/gardens 25%
Total – 24 million tonnes
Source: WRAP, Biffa, DEFRA, sectoral


Markets – Polymer Type
1.4%
2.2%
5.7%
6.3%
9.6%
13.2%
18.5%
18.8%
24.3%
LDPE
PVC
PP
HDPE
Other*
PS
PET
ABS
EPS
*other (PC, PBT, PA, PMMA, POM, PUR, PC/ABS, UPR, epoxy, phenolic)
Source: Data supplied by Valuplast Ltd (2002)

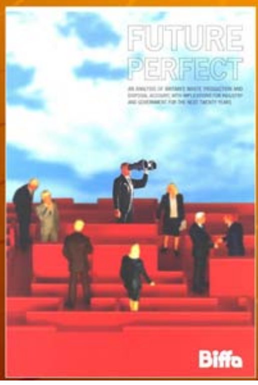

WHAT IS THE POTENTIAL?
1975 plus 40 Years @80 million tes = 3.2 billion tes.
Organics = CH4 plus CO2= soils PAS
Metals = Sulphides
Plastics @ 4m tes p.a.= 160m tes
Value as recyclate £40-50 bn.@ £250 te
Value as fuel ?
40m tes glass @ £20 = up to £1 billion.
Aggregates 2 billion tes@ £5= £10 billion
TOTAL INCOME £60 billion plus gold?

COSTS to ACCESS?

- £25 per tonne ??
- Inclusive of Washing/Drying?
- 4 million cube site = £100 million
- 2000 sites = £200 billion? (high)
- Or £100 billion (low)
- BUT……gold? Platinum?
- Rare Earths and Ph of 11 plus?
- Post Clean-up Site Values

Investment Profile in Waste Technology

System	Tonnes capacity annually	Capital £m	£ per process tonne
Windrow composting	40,000	1-2	c50-80
Mechanical separation	100,000	10	100
Anaerobic digestion	50,000	10	200
Small scale ADVANCED thermal	50-60,000	25	500
Large scale EfW	500,000	250	500
Medium scale EfW	120,000	60	450
Small scale gasifier/syn gas	60-80,000	40	280



FUTURE PERFECT

- 1200 to 1500 major sites
- Bio-treatment
- Thermo-chemical treatment
- Mechanical Treatment
- Material Recovery Operations
- Temperature Gradients 85 to 2600
- EXIT routes to gas,electricity,heat,road fuel,recyclate or fertiliser substitutes.

2012-2013 The Perfect Storm

- Landfill Diversion Targets on organics
- Carbon Reduction Commitment bites
- 120 fewer Landfills
- Ongoing coal and nuclear non replacement - Brownouts
- Evidential climate chaos
- EU Resource Efficiency and IPP Agenda
- Recession Ends

The Lights Go Out???

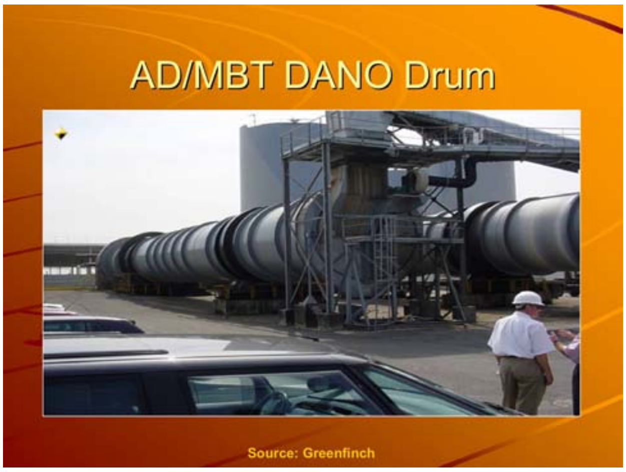
Source: DTI

The Regional Route Map

- **Define the energy sink**
- **That defines the energy need**
- **That defines the technology**
- **That defines the 'fuel' mix**
- **That defines the logistics**
- **That defines the collection discipline**

What are "Good" Fossil Substitution Sinks?

- **Food –freezing,preparation+retail**
- **Diversified industrial estates**
- **Hospitals**
- **Prisons**
- **Bus and truck complexes**
- **Docks and Airports and Distribution**
- **Data centres**
- **Energy distribution pipes and wires**
- **Confectionery factories**
- **Sewage plants**
- **Road fuel distribution depots**
- **Industrial gases operations**


AD/MBT DANO Drum
Source: Greenfinch


Inside A MRF


Gasification Plant – Isle of Wight


Japanese Gasification Technologies
Kazusa, Japan, Nippon Steel, 2002, 60,000 tpa
Aomori, Japan, Ebara, 2001, 135,000 tpa (ASR)
Kawaguchi, Japan, Ebara TIFG, 2002, 125,000 tpa
Toyohashi, Japan, Mitsui R21, 2002, 120,000 tpa
Source: Juniper


Why is there an Investment Hiatus in Waste?
Innovation Risk comprises those on-
.........Feedstock supply
.........Site and Land
.........Technology
........Exit markets for output
........Funding
THERE IS NO PLc with a singular approach to these risks!


New Alliances in Carbon Efficiency
Energy Suppliers
Technology Skills
Grid Backup
Grid Inputs
Regulatory Risk
Infrastructure
Electrical & Heat Users
Contracts
Locations
Economic Role in Communities
Carbon CSR Agenda
Forward Price Uncertainty
Solutions & ESCOs
Technology Suppliers
Waste & Resource Logistics
Rising Gate Fees
Process Technology
Conditioning Technology
Supply Chain
Strong Balance Sheets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Paper 2

'Landfill mining regulation: how do we start?

Jonathan Atkinson

Environment Agency

'Landfill mining regulation: how do we start?'
Jonathan Atkinson, technical specialist, Environment Agency

Landfill mining is not new, other papers at this conference will explore some of the history, but is has been undertaken as far back as the 1950's in several countries around the world for a variety of reasons. In the UK to date, most landfill mining has in reality been excavation of landfilled materials to make way for new developments of one form or another. In my own experience this has included removal of the old dockyard tip on part of the old Chatham dockyard estate to make way for a new housing area, transfer of domestic landfilled materials from two old council tips to a new engineered modern landfill to make way for the CTRL and trial removal of old landfill wastes in a railway cutting to make way for extension to the recreational Bluebell railway in Sussex. These projects have all included excavation of tip materials and removal to disposal with little, if any, additional treatment other than perhaps quarantining obvious hazardous wastes like drums, gas canisters and other similar materials. The Environment Agency remediation statements make it clear that excavation of materials from a non-permitted site is not in itself a waste activity. It is the further storage, treatment and disposal or recovery that are waste activities that may fall under Environmental Permitting Regulations permitting. If however the site has an existing permit If carried out at currently permitted site, the permit will need varying,. Excavating a landfill to create a void, if the site is permiited, does not guarantee immediate surrender of the permit. There is still a requirement to show that any groundwater contamination has been cleaned up/has no effect as per permit surrender guidance

In the 21st century landfill mining or landfill reclamation has new potential to offer more than just moving the material or problem from one place to another. Recovery not disposal is the new order of the day. As Ed Falkman points out, mining has always had a negative impact associated with it, ripping open the land, spoil heaps, dust, dirt and heavy plant and structures. Rape and pillage of the land as Ed puts it. Waste disposal has also had similar negative connotations, so perhaps as we move to this new arena we should be discussing landfill reclamation. As anybody who is familiar with the old waste exemptions, reclamation in itself has a specific interpretation, but in the context of today's discussion we are talking about land reclamation by taking out landfill materials, treating or separating them into components in some way or other and recovering the separated materials for re-use or further treatment, i.e. as bio-waste fuel for some form of heat or energy recovery. The resultant void can be reclaimed for further development or additional valuable void space for future disposal purposes.

One can already see where this leads in terms of regulation, it is the follow on activities that will be covered by relevant waste regulatory permits up to the point of full recovery. So the sorting, screening, separation plant, the energy recovery facilities and the onward transfer of recovered materials like scrap metals would all readily fall under the existing permitting regime for waste management and duty of care, either as fixed facilities or under temporary mobile treatment permitting.

The overall project of landfill excavation and the new use of the created void or landform would be covered by planning permissions and any supplementary requirements like EIA. Unless, of course new use is as another landfill, then this also requires permit and LDF Directive applies.

The conceptual model of the activities and the risk management of potential emissions are the key regulatory frameworks to bear in mind. The exact permits or permissions for each site will be down to site specifics following on from the type of activity to be undertaken, and the generation of the risk assessment and risk management context.

So we have a clear starting point, but in a new context and application perhaps, modern regulation is about “yes if” and risk based approaches, worked up with the regulators from an early proposal point. This will allow us all to move forward in a positive framework rather than one with negative mining or disposal perceptions.

Recovery of valuable metals, the use of biodegradable waste fractions for controlled heat and power recovery, directly or indirectly, and the formation of potentially useful products like biochar as well as the segregation and recovery of soil fractions from the buried cover materials all offer added value to proposals to reclaim land for future use. The older landfills that were largely filled in an era prior to waste disposal controls still pose risks to adjacent land uses and the surrounding environment. Many still emit fugitive greenhouse gases that impact on local air quality and add to the global carbon emissions. Landfill reclamation can perhaps address these problems in an innovative way if properly project managed and regulated. In the right circumstances landfill reclamation seems to offer a win-win scenario, however these projects always need to be fully understood from a risk point of view to be cost-effective and beneficial.

EA Part A1 permits

- Waste Incinerator Directive (WID) may apply (schedule 1, chapter 5).
- Waste Incineration or co-incineration? Be clear
- >3MW and waste >50MW non waste
- Each proposed scenario should be discussed with EA to determine appropriate permit at this stage. Further guidance in future

Environment Agency

WID cont

Co-incineration of waste gases or recovered oils would potentially be covered by WID requirements Part A1 or A2, depending on size of installation.

- Excluded plant include experimental plants used for research, development and testing in order to improve the incineration process. This is because of the nature of the plant, not because of the waste it burns, only if less than 50 tonnes of waste per year are treated.

Environment Agency

Part A2/Part B

- <3MW to fall under Local Authority control, WID requirements apply unless exempt materials are feedstock
- Non-hazardous waste in an excluded plant with a capacity of one tonne or more per hour will be regulated under Part A
- Non-hazardous waste in an excluded plant with a capacity of 50 kg or more per hour but less than one tonne per hour, regulated under Part B

Environment Agency

cont

- The incineration of hazardous waste in an excluded plant, regardless of the quantities or capacities involved, is regulated under Part A

Environment Agency

Waste to Land

- Site Permit if not covered by an exemption
- Exemptions for listed wastes for certain scenarios only and now limited quantities
- Standard permits or bespoke recovery permits can be used for improvement of previous industrial land.
- Temporary treatment plant may be covered under Mobile treatment permits and deployments

Environment Agency

Other options

- Waste Trials panel –pyrolysis already trialled for organic wastes so may not apply but ask re any specific proposals that are innovative.
- Low Risk Panel option for trials of specific activities

Environment Agency

Other options cont/

- with respect to any proposals, there needs to a detailed assessment by technical experts as to the benefits and risks of site specific projects.

Environment Agency

Quality Projects are the key

- "Rubbish in rubbish out"
- Control of quality paramount
- Know your materials and contaminant problems
- Ensure technology development provides appropriate plant for specific uses
- Develop relevant permits/protocols/exemptions

Environment Agency

Way Forward

- All need to work together
- Business case - clear objectives
- Trials - good controls and evidence collection
- Formal proposals consult EA/LA
- Funding – EU?
- Industry, LA and EA working together to develop protocols, Codes of Practice and relevant SR permits or bespoke permits

Case Studies

- Marley Pit, Charing Kent – fully engineered site in old sandpit taking excavated waste form two old closed pre-1974 sites in way of CTRL route (2000)
- Bluebell Railway W Sussex– Infilled railway cutting requiring removal to allow extension of tourist railway (Current)
- Chatham Dockyard historic site, 3 trains a day for two years to remove materials to Bedford brickpits! (Late 1980'2)

Lessons learned

- Be prepared; Monitoring and Site Investigation
- Watch for hazardous wastes for segregation
- Old tips can hold anything but 50-60% often soil fraction from daily cover and capping
- Removal to disposal very expensive!!! St Marys Island claims against consultants
- Can be done, not as bad as some think – depends on site conditions; dry=good

Conclusions

- It can be done
- Know your site
- Know the business case
- Know the locality
- Talk to all regulators early
- Be clear about objectives
- Plan for a good track record if this is to go forward.

Paper 3

Landfill Reclamation: Drivers and Requisites

Edwin Falkman

EGF Associates

I am currently Chief Executive of BFL Management Ltd.("BFL") which is developing a 300 acre brownfield site in east Kent. I am also a principal in the company. The goal is to restore this brownfield site, which previously housed a 340 MW coal fired power plant operated by the Electricity Board as well as a 200,000 tonne per year domestic waste landfill over the 20 year period from 1976 to 1996 operated by Kent County Council, to a productive energy park. My 35 year experience in the environmental service sector, particularly as Chief Executive of Waste Management International PLC, which I built from a £100M turnover group to £1.5B turnover operating in 26 countries with over 20,000 employees, has given me experience in waste, water, renewable energy from waste and environmental management. Therefore, when I assessed the potential of the Richborough site, I was impressed with the development opportunities the site offered.

In the process of developing the Richborough Energy Park ("Richborough"), it has become apparent to myself, and to those involved in the project from the public sector, that Richborough is well suited for landfill reclamation ("LFR"). The landrise landfill currently constitutes 5.5M cu metres of airspace. Kent County Council face ongoing expenditure to environmentally manage the landfill and undertake costly remedial actions, such as leachate treatment and methane gas collection. Our plan to install a number of energy generation processes on the site are, coincidentally, also useful to processing a variety of material that may be reclaimed from the Richborough landfill. Accordingly, today we will discuss LFR in the context of the Richborough project. However, we will start with a brief outline of prior LFR projects around the world to assess some of the main drivers that contributed to their success.

Prior Global Landfill Reclamation

There is substantial literature documenting cases where LFR has been successfully executed. Indeed, the 1st Global Landfill Mining Conference included presentations covering several examples. Accordingly, to avoid repeating prior literature, below is simply a brief reference to cases where LFR has been undertaken in the past:

- Israel 1953
- Florida 1986 +
- Pennsylvania 1990-1996
- New York 1990
- Virginia 1972 + 2003
- New Jersey 1999
- Massachusetts 1993+
- Florida 2010
- Netherlands 2000+
- Germany 1990+
- Sweden 1994

- India 1989
- Korea
- Thailand

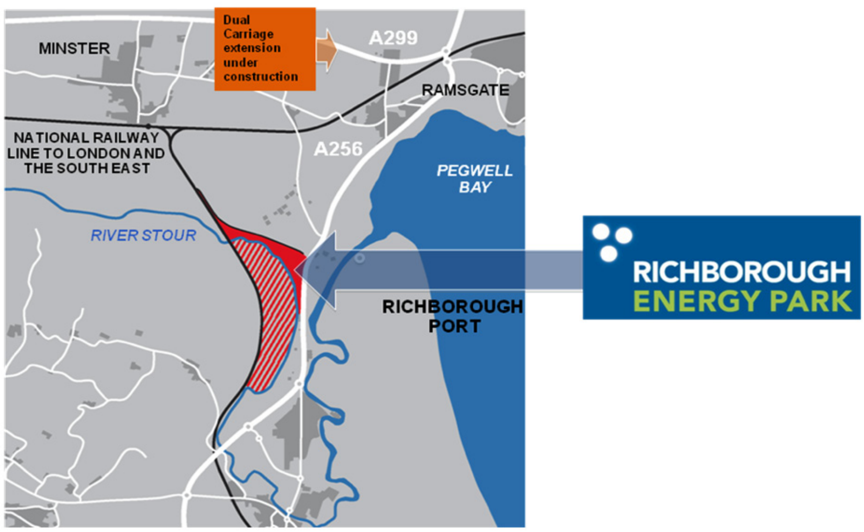
What we can glean from this list is that the time span and the varied geographic diversity indicate LFR has been successful under diverse market, environmental and planning conditions. What is interesting is that there are different main drivers for undertaking LFR, such as:
- Soil conditioner - Israel
- Soil cover for landfill operations - FLA
- Combustibles for EfW facility - FLA and Pennsylvania
- Avoid Cost of Long Term Care - FLA and NY
- Prevent Contamination - Netherlands
- Productive land use
* New Landfill Space - FLA and PA
* Recreational Use - VA
* Housing/Commercial Use - VA; Netherlands

It is important to note that retrieving metals and other recyclables was not a key initial driver in any of these cases. Rather, the metals and recyclables obtained were incidental to these various main drivers. Nevertheless, metals and recyclable revenues helped defray the cost of LFR.

While the actual results of materials recovered vary by each LFR, on average the results globally typically tracked the following breakdown:
- Soil - 40% to 62% - the soil added value either as soil for developing new landfill cells or for sale to 3rd parties.
- Combustibles - results varied; some achieved ~3,080 Btu per pound; to maximise value, the grit must be removed.
- Recyclables - OK for concrete, aggregates and scrap metal; glass, plastics and other metals require costly processing to produce marketable material
- Airspace - much uplift in value
- Long term care cost avoided

The Richborough Site in more detail
The Richborough site is located on the east coast of Kent directly on the A256 dual carriageway between Ramsgate and Sandwich. Current road construction upgrading the A256 and A299 by Marston airport will provide for dual carriageway connection from London.

The site includes the following elements:
- 300 acres in total
- Former Coal Fired Power Station later converted to Oil. Closed in 1996. The Richborough site has been cleared and cleaned except for 3 cooling towers and a chimney stack
- 400 MW Grid Connector in place

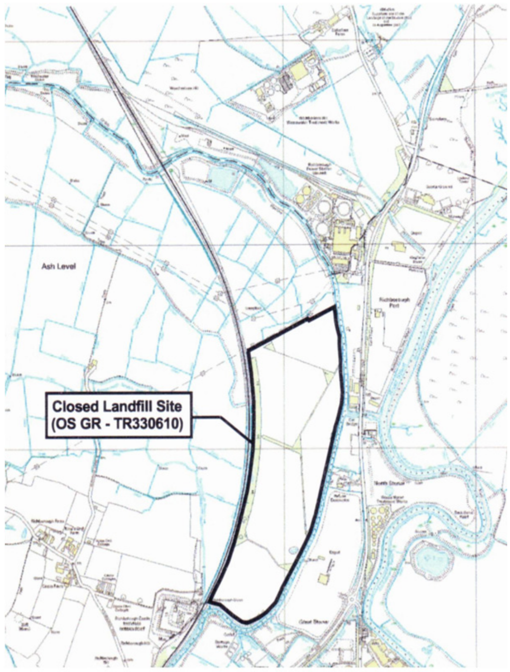


- 140 acres closed domestic waste landrise (5 million cu metres) leased and operated by KCC (1976-1996) who retain residual liability and manage environmental requirements.
- Waste Management License and Planning remain live. This is particularly attractive and useful as it greatly facilitates LFR and re-utilising the air-space as new landfill space for inert material, which will be in critical demand in Kent over the next 20 years.

The site has exceptional logistics which assist in the distribution of materials related to LFR output as well as input into the restored landfill:

- Road: A256 four lane dual carriageway to site entrance via roundabout
- Rail: spur available into the site
- Water: Barge access (1000T) along 560 meter quay at Richborough Port directly across from site, and barge access inside the site from the River Stour (100T); at Ramsgate Port there is access for 4000T ships.

Some of the existing processes on the site support LFR, in addition processes that are being planned for the site will strengthen the suitability of Richborough for LFR.



Of the ten processes BFL plan to introduce to the Richborough site, five coincidently support LFR by providing onsite processing capability of the output from the Richborough landfill. The supporting processes are indicated below in italics:
- Advanced Thermal Treatment 8 MW: Fuel from LFR Organics
- Wind 21 MW
- Peaking 25-50 MW
- Anaerobic Digestion 1 MW: Fuel from LFR Organics
- Tire shredding and combustion - 20 MW
- Landfill Gas Capture 1-2 MW - manages the gas from the landfill
- Bio Char
- Contaminated Soil Hospital - available to treat any contaminated soil in the landfill
- MRF pre-treatment facility - available to treat the recyclables
- National Grid 1000MW interconnector

Almost 50% of the site (140 of 300 acres) consists of the closed Richborough landfill:

Activities Encompassed by LFR and how they relate to Richborough

LFR includes a multitude of activities and disciplines. Usually, initially, one must identify a landfill site. In the case of Richborough, the landfill came with the 300 acre site. The next step is detailed assessment of the landfill. For Richborough, substantial environmental management surveys are available for the landfill that captures what is going on inside and around the landfill. In addition there are verbal and written records of the material disposed at the landfill as well as plans which set out the various cells built within the landfill and when they were filled. These records will prove useful when excavating the site, which will be the next step following assessment. The cost and the feasibility of obtaining these detailed assessments need to be taken into account when considering LFR.

Once excavated, the materials recovered must be segregated and, to the extent required, processed in order to be marketable or useable on site. In the case of Richborough, soil that is contaminated will be cleaned at the planned contaminated soil hospital and then stored for use in rebuilding the landfill. The recyclables will be processed by the onsite MRF to recapture metal and glass and would then be marketed. The plastics and organics will be utilized by the planned energy recovery facility (advanced thermal treatment). Any seriously hazardous materials would be sent to appropriate 3rd parties for processing.

The remaining clean area recovered from the landfill will be utilized to rebuild, on a cell by cell basis, a new inert landfill, compliant with current standards. It will then be open to receive a variety of inert materials over the next 20 years, such as bottom ash from other energy recovery facilities and various construction/demolition residues. In cases other than Richborough, the cleaned area might be considered for residential or commercial development. In the case of Richborough, which does not lend itself to residential or commercial/office development, the space is more appropriately used for new landfill, particularly as it will fill a critical future strategic need for Kent.

LFR Drivers

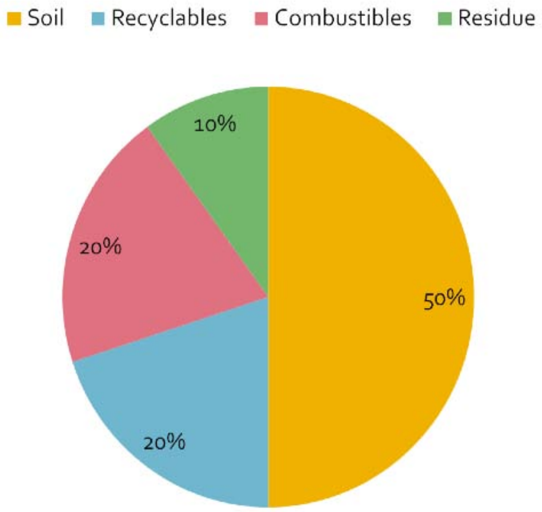
The drivers for BFL to consider LFR for Richborough are similar, of course, to other LFR projects. They include:

- Recovering precious metals and other recyclables to the extent possible.
- Recovering organic non carbon sourced fuel that support ROC tarrifs in the advanced thermal energy recovery facility.
- Recovering valuable new inert landfill space that supports the strategic needs of Kent in the future.
- Resolves ongoing leachate and methane gas issues that will present the Kent County Council (“KCC”) with ongoing costs in the future.
- Removes a 60 year cloud to KCC’s balance sheet.

Estimated Outputs

The estimated percentage outputs of material to be excavated from the Richborough landfill, based on assessment of LFR projects around the world, are as follows:

In Richborough, we estimate that this will translate into:



- Soil: 2.75 Million cu meters
- Recyclables: 1.1 Million cu meters
- Combustibles: 1.1 Million cu meters
- Residue: 0.55 Million cu meters

At these rates the annual LFR output over a 20 year period of excavation are as follows:

- Soil - 137,500 cu meters
- Recyclables - 55,000 cu meters

- Combustibles - 55,000 cu meters
- Residue - 27,500 cu meters

In addition, the LFR process means that Kent will have at their disposal a valuable and vital volume of ‘new’ inert landfill capacity:

- New Annual Landfill Capacity - 275,000 cu meters

The turnover generated from the creation of new landfill airspace alone is estimated to achieve £165 million over a 20 year period (@ 30/cu meter of fill) and £ 8.25 million annually.

Main Issues for LFR

Planning

Planning can be a long term, costly and involved process, especially in the case of England. For Richborough, the planning/permitting process is greatly facilitated by the planning and waste management license for the site remaining live. Accordingly, our planning activities will focus on our basic development goals of introducing a number of energy generating processes on the Richborough site. However, typically, the planning issues would encompass a multitude of factors such as:

- Hierarchy framework of the planning authority. It might be necessary to demonstrate that LFR is the best practicable environmental option for the site in question.
- Resource recovery. LFR should meet any resource requirements established by the planning authority.
- Location guidance. The regulatory authority may mandate certain recovery of materials in order to justify disturbing a quiet countryside community.
- Amenity. LFR could be restricted by various health and safety requirements for workers where the excavation activity could be considered particularly risky.
- Traffic. Obviously issues involving the local highway network and potential neiboroughing traffic disturbances must be addressed.

Operational Challenges

The practical operational challenges involved in excavating a landfill and processing the variety of materials extracted are formidable but feasible. Among the challenges to be dealt with are the following:

- Potential for causing damage to groundwater and incurring liabilities
- Leachate and gas management
- Health and safety issues from a methane gas work environment
- Odour
- Underground Fire - Spontaneous Combustion following the introduction of oxygen into the landfill
- Rainwater management to avoid leachate from escaping the site perimeter
- Buried hazardous materials and properly treating them
- Avoid undermining the integrity of individual landfill cells which could potentially collapse or sink
- Sorting messy and nasty material;
- Removing high particulate content which is very abrasive to all processing equipment
- Achieving minimum recovery efficiencies
- Providing onsite processing of most matter recovered

Requirements for financial success

The cost of extracting, sorting and processing the materials in a closed landfill are extensive. Even in the case of Richborough, where the treatment processes will be in place for other purposes, the cost of extraction is over and above the processing cost involved in normal waste reception and processing, where the customers typically bring the waste material to the gate and pay a fee for the processing. In the case of LFR there is no customer gate fee and over and above this there are extraction costs.

Accordingly, in order for the LFR to be financially successful, the benefits of the LFR must be more than the revenue from the sale of precious metals and other materials. The financial benefit must also come from the uplift in the land value, which in the case of Richborough would be the new landfill capacity generating future disposal fees, but in other cases might be land re-development. Also, in the case of Richborough, LFR provides an additional quantity of non carbon fuel that could qualify for ROC tariffs in an advanced thermal treatment unit.

Richborough Site Fits Selection Criteria

- Presence of key drivers - new landfill space and provision of non carbon fuel
- Planning/Waste Management License - already exists so not an issue
- Minimal operational issues - excavation issues no more difficult than normal landfill operation

- Depth of old landfill - because Richborough is a landrise, excavation can be processed in stages.
- Geology - not an issue as a landrise
- Groundwater proximity - not an issue from the environmental monitoring reports
- Stability of surrounding area (foundation) - not an issue from the environmental monitoring reports
- Environmental assessment (borehole testing) - not an issue from the prior borehole tests
- No Housing proximity - the site is not located near any residential communities
- Access logistics - outstanding
- Treatment processes will exist on site which will minimise processing costs

Conclusion

LFR is worth serious consideration for a limited number of sites. However, as noted by the various factors discussed, LFR should be undertaken only after studying how it fits under the selection criteria above. Over time, the drivers for LFR should grow in value which will make more sites feasible for LFR. At the same time, processing systems are becoming more efficient which could reduce the costs of processing the output from LFR.

In short, for the right site, there is much to be gained. However, one should not underestimate the challenges involved. Careful consideration should be given to each of the diverse points discussed, as the fiscal balance of LFR relies on a matrix of interlinked aspects that need to be examined in totality to ensure success.

Paper 4

Regulatory requirements associated with landfill mining in the United States

Robert Schreiber, Christa Russell, Doug Abeln

Schreiber Yonley and Associates

There are many operational hurdles and regulatory requirements associated with the mining of waste materials from existing landfills and their use by cement plants in the United States. The two most significant regulatory requirements are those under the Resource Conservation and Recovery Act (RCRA) and those under the Clean Air Act (CAA). An overview of landfill mining processes, project considerations, potential regulatory requirements, and how a cement plant would navigate through this regulatory "mine" field are discussed.

First, a description of landfill mining is in order. Landfill mining is simply removing materials already in place in the landfill and using them for beneficial purposes; i.e., recycling. The term at first seems counter intuitive since landfills are where discarded materials are placed for decomposition, not a source of new materials. In reality, however, discarded municipal solid waste (MSW) contains materials that can hold significant heat value for use as an alternative or non-conventional fuel. According to the US Environmental Protection Agency (EPA)[1], approximately 30% of materials by weight in MSW landfills are paper and wood products and 17% are plastics. These materials present a great opportunity for heat recovery as the heat content of wood, paper and plastic are approximately 5,200, 6,000-7,500 and 18,000-20,000 Btu/lb, respectively[2]. Recovering energy from MSW landfills would reduce demand for traditional fuels. In some cases, metals and soil used for landfill cover also could be extracted for use as alternate raw materials in cement kilns. Removing materials from MSW landfills would open space within the existing landfill. The difficulty lies in retrieving, sorting and preparing the materials for use in a cement kiln in an acceptable form and finally, transporting and handling the material prior to combustion of the material in the kiln. These processes can be labor intensive, require significant up front planning and capital investment in equipment, and necessitate expenditures to obtain various permits to comply with federal, state and local regulatory requirements.

Landfill mining requires the excavation, sizing and separation of MSW materials. Excavation of the landfill involves the physical removal of bulky materials using large mobile equipment. Some states may require a mining permit for these excavation activities. A series of trammels, or vibrating screens, are then used to sort the materials by size. Finally, the sized materials are sorted according to material type or heat content. It is at this point that metals are separated. Materials not to be used in the kiln or otherwise recycled would be returned to the MSW landfill either as waste or for use as daily cover, as appropriate. The sizing and separating operations may take place at the MSW landfill or at a different location, such as at a solid waste processing facility or at the cement manufacturing facility. Both the design and operation requirements of the MSW landfill and the landfill mining activities are regulated by RCRA in addition to various state and local regulations. Since some processing activities may take place at locations separate from the MSW landfill, separate air and solid waste construction and operating permits would be required for each location. Examples of required permits associated with MSW landfill mining activities include MSW processing permits, air construction and operating permits, and storm and process water discharge permits. These permits will undoubtedly contain monitoring, testing, recordkeeping and reporting requirements, in addition to the necessary financial assurance mechanisms.

Development of operational plans may also be required by the conditions of one or more permits. The landfill site will need to develop gas management, leachate management and groundwater monitoring plans. In addition, both the landfill and the processing facility will need dust control, odor control and

1 USEPA, "Municipal Solid Waste in the United States 2008 Facts and Figures"
2 USEPA AP-42 Appendix A and "Heating Value of Common Fuels" by John W. Bartok, Jr. of the University of Connecticut.

facility closure plans. Even if a landfill is permitted as an MSW landfill, there is always the possibility that prohibited materials have made their way into the landfill. Detailed plans will have to be implemented to address unexpected exposures to materials such as asbestos, methane, hazardous waste and unknown/unidentified materials. Before the mining and use of MSW fuels can begin, it is critical for the materials in the MSW landfill to be thoroughly characterized. While this may be a tedious process, the goal is to avoid "surprises" that can affect the applicable regulatory requirements and the types of permits needed for subsequent operations.

Once the operational considerations are understood, the regulatory hurdles must be addressed. For the landfill, the RCRA and state regulations set specific design, operation and closure requirements. During the active life of a landfill there are specific daily, interim and final cover requirements. The mining of landfills, either before or after closure, was not contemplated by these regulations. Therefore, no clear path is available that delineates the necessary requirements for such mining. In addition, the permitting and operational requirements for MSW landfills are different from those for industrial waste landfills.

There are also various critical and complicated federal requirements under the CAA as well as additional corollary state requirements. Cement kilns are regulated under various aspects of the CAA, which protects human health and the environment through permitting requirements and the establishment of emissions standards for regulated pollutants. Permitting requirements under the CAA are divided into two realms -- those for construction and modification of a source are under New Source Review (NSR) and those for operations are under the Title V Operating Permit program. The NSR permitting program was established under the CAA to ensure that air quality is not significantly degraded from new or modified sources. To accomplish this, NSR requires the installation of modern air pollution control devices when an air emissions source is constructed or modified. Under the NSR program is the Prevention of Significant Deterioration (PSD) permitting program that is to be used when the source is located within geographical areas of the US that have attained compliance with the established National Ambient Air Quality Standards (NAAQS). Areas which do not meet the NAAQS for criteria pollutants (i.e., ozone, particulate matter, CO, SO2, NOx, lead, etc.) are covered under the non-attainment NSR permitting program.

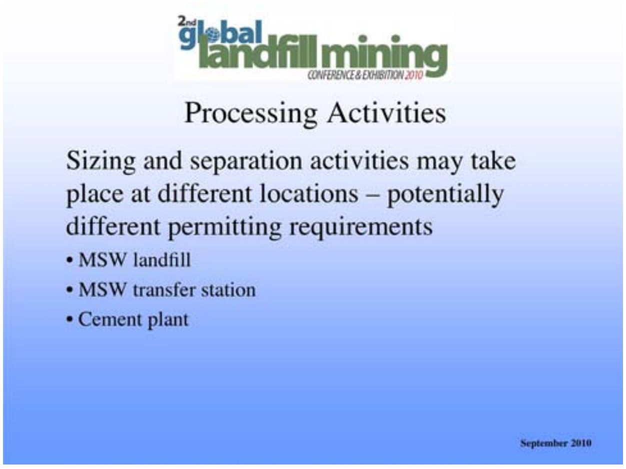
In addition to the permitting hurdles, the CAA requires the USEPA to establish National Emission Standards for Hazardous Air Pollutants (NESHAP). NESHAPs are established based on what is the Maximum Achievable Control Technology (MACT) for individual industry groups. The NESHAP regulations are commonly referred to as MACT rules. NESHAPs pertinent to the operation of cement kilns are the Portland Cement MACT rules (PC MACT) and the Hazardous Waste Combustor MACT rules (if the cement kiln burns hazardous waste). Regulations were also recently proposed for Commercial and Industrial Solid Waste Incineration Units, commonly referred to as the CISWI rules. There are also separate regulations for Municipal Waste Combustors (MWCs). Both the CISWI and MWC rules fall under the incineration section of the CAA, Section 129.

There are potentially three different major CAA regulations that may be applicable to the cement industry. The first is the PC MACT, which contains specific and stringent emissions limitations, compliance demonstration methods and operational requirements. The PC MACT rule also contains specific requirements for additional compliance testing when process or fuels changes are made. This rule has been in place since 1999, but a new rule was just finalized that substantially lowered the emission standards. The second is the potential to also be regulated under the proposed CISWI rule. The third is to be regulated under the HWC MACT rule, which applies in lieu of the PC MACT and CISWI rules if the kiln beneficially uses hazardous waste fuel. Each of these regulations has different emission limitations for pollutants. To add complexity, the list of pollutants regulated under each MACT is slightly different. All three of these rules set limits for particulate matter, dioxin/furans and mercury emissions; however, some also regulate other metals, while the CISWI rule proposes to also set emission limits for NOx and SO2. In addition to these three CAA regulations, a facility undergoing modification may trigger the portland cement NSPS and have to meet even more stringent particulate matter, NOx and SO2 emission limits. With respect to MSW, cement kilns are specifically excluded from the definition of MWCs, even if the kiln beneficially uses MSW. Therefore, if a cement kiln uses MSW, it is specifically exempt from regulation under the MWC rule and is subject to the PC MACT rule.

The additions to and changes in equipment and/or operations associated with utilizing the mined wastes as either fuel or raw materials would trigger evaluation under the NSR permitting requirements. EPA considers changing fuels a modification to operations under the NSR program. A PSD or non-attainment NSR permit would therefore be required if the net increase in emissions from the use of MSW-derived fuels is more than the "trigger level" for certain pollutants. One of the first things that needs to be determined for permitting the use of MSW, or for any new fuel in a cement kiln, is the expected net change in emissions from switching to MSW-derived fuel. In some cases, a state air permit can be obtained that contains emissions limitations restricting the emissions increases to below the PSD significance levels. For non-attainment NSR, if there are any potential increases in non-attainment pollutants above the threshold levels, there will be a requirement to offset the potential increase. The offset credits are usually generated through reductions in emissions from existing sources or the shutdown of existing sources. The required offset ratio is greater than 1:1.

The regulation to which a cement kiln is subject depends on the fuel or alternative raw material it uses. Before using any waste-derived or alternative fuels, a cement kiln operator must determine which air regulations will apply. Some rules allow less stringent (or at least different) emission limits, but can restrict the types of fuels allowed for use and can limit operational flexibility. For a simple example, if a cement plant uses only MSW-derived fuel, PC MACT could apply. But if that same kiln would want to use both MSW and industrial/commercial waste, compliance with CISWI would be required (as currently proposed).

Although the advantages of mining MSW landfills are obvious -- beneficial reuse of discarded materials, energy recovery, reduced demand on virgin fuels and materials, opening up space and extending the life of existing MSW landfills -- many regulatory challenges exist. There can be significant benefits of mining MSW landfills and returning the former waste to a useable format as fuel and raw materials in the cement manufacturing process. As can be seen, the regulatory requirements are quite complicated. This type of activity was not originally considered in the regulations. Also, the applicability and details of certain CAA regulations are continuing to transition over time. Identifying all of the options and developing a path forward that considers the complexities of waste processing, permitting, compliance strategies and cement processing limitations will help plan for and resolve issues associated with pursuing a landfill mining and/or alternate fuels and raw material project.



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Excavation

Removal of bulky material

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Sizing

Trommels, Vibrating screens

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Material Separation

Electromagnets, air classifiers, manual processing

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Landfill May Be Active or Closed

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Landfill Mining Challenges

Getting it permitted!

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Applicable Regulations

- MSW landfills, processing activities regulated by Resource Conservation and Recovery Act (RCRA)
  - Subtitle D – Non-hazardous solid wastes such as:
    - Garbage
    - Non-recycled household appliances
    - Metal scrap
    - Industrial and municipal waste water treatment plant sludge
    - Exempted hazardous waste (from households or exempt small generators)
- Various state and local regulations also apply

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Associated Permits & Plans

- May require mining permit
- May require land reclamation plan
- Will require financial assurance

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Associated Permits

Landfill Site	Processing Site
• MSW disposal	•MSW processing
• MSW processing	• Storm water
• Storm water	• Discharge
• Discharge	• Air
• Air	

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Landfill Site Permits

- Site-specific
- Driven by state, county or city regulations
- Dependent on current state of MSW landfill
  - Active operating permit
  - Post-closure permit
  - Un-permitted

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Associated Plans

Landfill Site

- Gas management
- Leachate management
- Groundwater monitoring
- Post closure
- Closure
- Operations
- Dust control
- Odor control

Processing Site

- Closure
- Operations
- Dust control
- Odor control

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Associated Plans – Landfill Site

Detailed plans to address unexpected exposures

- Asbestos
- Methane
- Hazardous waste
- Lechate
- Unknown materials

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Use of Materials in Cement Kilns

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Kilns Require a Lot of BTUs and Raw Materials!

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MSW Content

Paper – 20.7%	Plastic – 16.8%
Glass – 5.6%	Rubber / Leather – 3.8%
Ferrous Metals – 6.2%	Textiles – 6.3%
Aluminium – 1.3%	Wood – 8.9%
Other Metals – 0.3%	Other – 2.0%

Source: 2008 Data from Franklin Associates, a Division of ERG

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Air Permitting for MSW-derived Fuel Use in Industrial Process

- USEPA: fuel change is *modification* under PSD
- Must determine applicability to PSD
- Also address state permitting provisions

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Air Permitting – PSD Applicability

- Determine net emissions increase
  - Determine baseline for existing operations
  - Determine future emissions
  - NEI = FE - B

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Air Permitting – PSD Applicability

- If NEI < significance level
  - PSD permit not required
  - State permit required
- If NEI > significance level
  - PSD permit required; OR
  - State permit limiting emissions (PSD avoidance)

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PSD Significance Levels

PM: 25 tons/yr
NOx: 40 tons/yr
SOx: 40 tons/yr
VOC: 40 tons/yr
GHG*: 100 tons/yr

CO: 100 tons/yr
Lead: 0.6 tons/yr
MWC metals: 15 tons/yr
MWC organics (D/F): 3.5E-06 tons/yr
MWC acid gases: 40 tons/yr

*New tailoring rule includes details of phase in for CO_2 and other GHGs

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PSD Avoidance

- Choose your own control strategy
- May require public participation
- Also address state requirements

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Clean Air Act – What regulations apply?

- Which regulations apply to cement kilns?
  - Depends on the fuel or alternate raw material
- Section 129
  - NSPS
  - CISWI unit emissions guidelines [40 CFR 60 Subpart CCCC]
  - Separate regulations for MWC

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Clean Air Act – What regulations apply?

- Section 112 – addresses HAPs
  - PC MACT [Citation: 40 CFR 63 Subpart LLL]
    - Recently republished with significantly lower emission limits
  - HWC MACT [Citation: 40 CFR 63 Subpart EEE]

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Municipal Waste Combustor

- Cement kilns specifically excluded from definition of MWC
- MSW definition: household, commercial/ retail, and/or institutional waste (discarded materials). Does not include used oil, sewage sludge, wood pallets, construction waste, medical waste, vehicles, clean wood, or industrial process or manufacturing waste.

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Why does it matter which regulation?

- More fuel and/or operational flexibility
- Emission limitations vary
  - Not easy to compare – UNITS ARE DIFFERENT!

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Cement Kilns Utilizing Municipal Solid Waste Subject to:

New PC MACT Subpart LLL Emission Limits

- PM: 0.04 lb/ton clinker (PM CEMs with 30 day averaging)
- D/F: 0.2 ng/dscm (or 0.4 if T < 400°F)
- THC: 24 ppm (THC CEMs with 30 day averaging)
- Hg: 55 lb/MM ton clinker (Hg CEMs with 30 day averaging)
- HCl: 3 ppmvd (HCl CEMs with 30 day averaging)

Note: Rule finalized in 2010 to lower PC MACT emission limits as noted

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Cement Kilns Utilizing Hazardous Waste Subject to:

HWC MACT Subpart EEE Emission Limits

- PM: 0.028 grains/dscf
- Opacity: 20%
- D/F: 0.2 ng/dscm (or 0.4 if T < 400F)
- CO / THC: 100 ppm / 20 ppm hourly
- Hg: 3 ppm in waste stream and 120 µg/dscm
- Cd, Pb: 7.6E-4 lb/MMBtu from haz waste and 330 µg/dscm
- As, Be, Cr: 2.1E-5 lb/MMBtu from haz waste and 56 µ g/dscm
- HCl / Cl_2: 120 ppm

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Cement Kilns Utilizing Hazardous Waste Subject to:

HWC MACT Subpart EEE Emission Limits

- PM: 0.028 grains/dscf
- Opacity: 20%
- D/F: 0.2 ng/dscm (or 0.4 if T < 400F)
- CO / THC: 100 ppm / 20 ppm hourly
- Hg: 3 ppm in waste stream and 120 µg/dscm
- Cd, Pb: 7.6E-4 lb/MMBtu from haz waste and 330 µg/dscm
- As, Be, Cr: 2.1E-5 lb/MMBtu from haz waste and 56 µ g/dscm
- HCl / Cl_2: 120 ppm

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Air Regulation Comparison

- Kilns using MSW
  - Exempt from MWC rules
  - Subject to PC MACT
- PC MACT generally less stringent than CISWI
- Can burn ONLY MSW and traditional fuels

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Air Regulation Comparison

- Kiln uses commercial, industrial waste
  - Subject to proposed CISWI
  - No longer subject to PC MACT
- Generally more stringent limits
- Can burn BOTH MSW and CISWI
  - More operational flexibility

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General Steps to Implement Process

- Identify waste source, existing characteristics
- Identify desired energy, environmental and handling characteristics
- Identify range of potential environmental contaminants

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General Steps to Implement Process

- Design flexible process for changing waste characteristics
- Design effective mitigation program

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General Steps to Implement Process

- Ensure emissions meet regulatory standards
- Ensure process is protective of human health and the environment
- Acquire required permits

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Paper 5

System, technology and experience of 17Mt of landfill mining projects

Reinhard Goeschl

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Introduction

Landfill mining technology is in fact nothing new. The first project of this kind took place in Israel in 19531 when a landfill owner tried to get organic fertilizer for farmers out of an old landfill. The first project in Europe was a landfill relocation (1 million m3) in Wolfsburg, Germany in 1985/86. Also in 1985, a 5 million m3 landfill was relocated in London. Other projects in Germany (Landfill Fitten, Landfill Aach and Landfill Düsseldorf-Hubbelrath) were based on a similar concept. Most of these landfills had been old dumps filled mostly with construction and demolition waste or waste from households and were already in the oxidation phase. The first landfill relocation with odour stabilization was carried out in Austria (Vienna Donaupark) involving the transfer of about 600,000 m3 in 1990/91.

The first landfill mining project with full treatment of the excavated waste was started in Collier County Florida in 1986[2]. This project was documented very well by the EPA report3 in September 1993. A second landfill mining project in Lancaster County, Pennsylvania was launched in 1991 and continued until 1993 to process fuel material for an incineration plant. Because of the high fine ash content the concept had to be changed in 1993 to avoid excessive wear of the grate of the incineration plant.

The first project of the author of this paper was a pilot project at the Perry Sound landfill in Ontario, Canada in 1989. A milestone in the development of landfill mining technology was the Demonstration Project in Burghof / Ludwigsburg, Germany from 1993 to 1996. Since then, many projects have been completed world-wide. The author of this paper was personally involved in projects in Austria, Germany, Italy, the Netherlands, the Czech Republic, Canada, Japan, Korea, UAE, etc. Some of these were well documented and published while others were documented only by the author. In total, approximately 17 million m3 of landfill volume have been processed under the author's direction since 1989!

The idea to use aerobisation technology to reduce odour emissions during excavation work and transport first arose under a feasibility study done for the landfill relocation project in Vienna (landfill Donaupark)[4]. Dipl. Ing. Dietrich Ranner from Salzburg pursued this idea further and developed the "Biopuster" technology for the Vienna project. Biopuster has since been used in many projects for landfill aeration.

The IuTGroup was commissioned in 1991 by the authorities of Ludwigsburg with the development of a demonstration project showing the feasibility of landfill mining at a MSW landfill. The Burghof project in Ludwigsburg was put into operation in spring 1993 and was fully monitored from the beginning by Prof. Gerhard Rettenberger (University Trier and Stuttgart), who also published the results of these projects many times. Prof. Gerhard Rettenberger also published the results of this demonstration project in a book[5] in 1998. Many components of the technology were developed during this Demonstration Project: aerobisation with the Smell Well system, treatment technology, long-term stabilization of treated material, worker protection, permitting procedure (in Germany), emission reduction and control, etc. The project is still getting positive coverage in current papers and discussions in Germany[6].

Picture 1 Burghof 1994

Picture 2 Burghof 1993

Definitions with Examples

The first projects were mostly relocation projects where a landfill was excavated and the material redeposited on a new site. The question is if these projects may even be called “landfill mining” projects according to our definition? Basically they are landfill mining projects because they provided lasting solutions to former landfill sites and prevented negative impacts on the neighbourhood and the environment. But they led to the establishment of new landfills!

Therefore we should use the following definition:
A landfill mining project should create a lasting solution including treatment of the material excavated, reduction of new landfill volume, and minimisation of emissions from the new landfill!

In practice, there are three major reasons for undertaking a landfill mining project:
1. The Environmental Reason - Lasting remediation of a landfill
The landfill contaminates the environment (air, water, soil, and neighborhood) and needs a clean-up. This is the most popular reason in rich regions like Europe.
2. The Commercial Reason - Creating space for infrastructure
The site of the landfill becomes valuable as it becomes part of the urban area or is needed for roads, railroads etc.
3. The New Volume Reason - Creating new Volume at an existing landfill site,
Sometimes it is essential to solve waste management problems within a short time.

The IuTGroup carried out projects for each of these reasons during the last 17 years:
Projects for environmental reasons were done in Germany, Italy, Austria, Czech Republic and the Netherlands;
Projects for creating infrastructure were done in Austria, UAE, Korea, Japan and just recently in Belgrade, Serbia;
The IuT Group has completed projects for the creation of new landfill volume within existing landfill sites in Austria. A project in Canada (Depot Rive North near Montreal) is currently in progress.

System and Technology

Based on the Ludwigsburg project it was possible to develop a system and technology for landfill mining. The landfill mining project in Sharjah, UAE of a magnitude of 7,506,551 m3 was made possible only by the experiences gained from Ludwigsburg and other projects and was the logical next step!

1st Step: Exploration

Remediation of an old landfill requires the availability of certain information about the landfill before the process of mining starts. Most important is the composition of its contents and knowledge about the gas and dust emissions[7] to be expected. This information is important in selecting the proper method of treatment and any action necessary before starting the work. Special conditions in the landfill, if any, such as water in the landfill or the presence of asbestos in the waste, should be known. To obtain complete information, a number of steps have to be taken. They include:
* Examination of the history of the landfill, including lifetime.
* Eyewitness reports
* Surface examination of the site, including where possible the collection of data on the composition of waste dumped.
* Test excavations and/or test drilling.

Independent consultants or universities[8] are often good sources for the history of old landfills and general information on them. Consultations and interviews of people involved, checks of old weigh bridge and landfill site reports etc. are most important to get an overview of the possible contamination of the landfill. The next step is the surface investigation including measurement of surface gas composition to locate bio-activity hot spots.

Careful investigation work includes the excavation of trial pits. Depending on the result of the surface examination and the quantity of data available, these trial pits should be 50x50 to 100x100 metres in size and go down as far as possible to the landfill bottom. The gas emissions released during excavation should be measured, the dumped material classified, and its composition (by volume) assessed.

Picture 3 - Trial pits

This step already requires the installation of a chemical laboratory on the site (or collaboration with a lab nearby) to make the necessary analyses of soil and water samples.

The exploration results in an assessment of the composition of the waste volume. This assessment should include estimates about the composition as well as the chemical contamination of the waste and should provide information about the presence of common types of hazardous waste, sludge's etc.

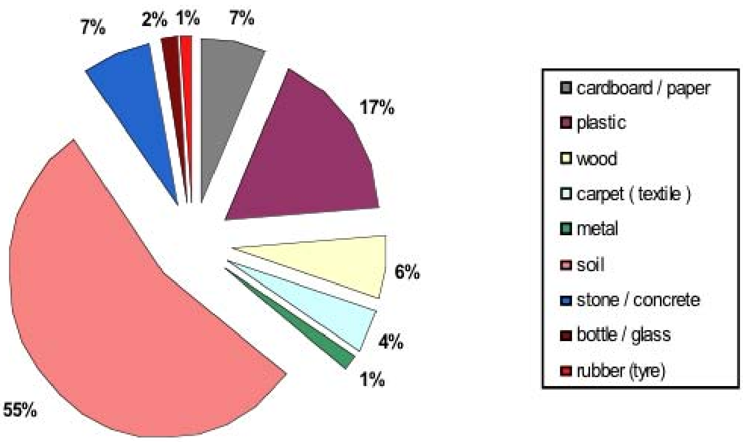


Table 1 Composition of the dumped waste

What is important is the average chemical composition and the estimated contamination of the landfill volume. Table 2 shows the results of the chemical analysis done for the Sharjah landfill mining project, published in 20059

Average of Contamination inside the landfill

Contamination	Units	Average	Threshold Values
MS	%	17,1	no
DSS	%	82,6	no
LbC	%	1,9	10,0
Lead: Pb	mg/kg	4,8	50,0
Cadmium: Cd	mg/kg	3,3	10,0
Mercury: Hg	mg/kg	1,0	3,0
TPH	mg/kg	542,1	1.000,0
ER	mg/l	1.300,2	2.500,0
pH-Value	-	8,2	6,0-13.0
Conductivity	mS/m	124,2	300,0
TPH	mg/l	1,0	0,5
Nitrite:No_2^-	mg/l	2,0	10,0
Nitrate:NO_3^-	mg/l	17,0	500,0
Ammonia:NH4+	mg/l	5,1	40,0
Chloride: Cl^-	mg/l	68,4	5.000,0
Sulphate:$SO4^{2-}$	mg/l	356,1	5.000,0

MC- Moisture Content; DSS - Dry Solid Substance; LbC - Loss by Combustion;

Conduc.-Conductivity; TPH-total Petroleum Hydrocarbon; ER Evaporation Residue

Table 2
All results are averages and variance could be very high. Because of the large sample quantities extracted from a 50x50 m grid, for example, the results are close to those obtained after completion of landfill mining.

The first step also includes preparation of the infrastructure for the mining work, i.e. mostly the construction of roads, water retention cells, and the removal of cover material.

2nd Step Aeration of the Landfill
There are basically two systems for landfill aerobisation available: The BIOPUSTER and the SMELL WELL SYSTEM. Many new developments of similar aeration systems have been registered during recent years. Most of them are copies or /and variations of these two original systems.
The basic requirement is to expose anaerobic bacteria to oxygen as fast as possible, which will kill them, and start an aerobic biodegrading process inside the landfill.
There are some basic differences between the two systems:

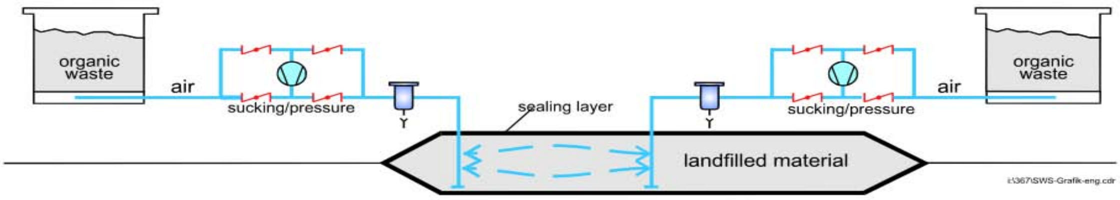
Basic Difference	BioPuster	SWS
Operation Method	Air Push	Air continuously, change direction
Excavation height	up to 9 m	3 m levels
Aeration Medium	Oxygen	Air
Aeration time	2-3 weeks	4-6 days
Set lances	drilling	push with Excavator
Change Lances	2-3 weeks	daily

Picture 4 SWS in Japan

Both systems have their advantages and disadvantages. In the end, the final choice of a system is a matter of availability and, most importantly, cost.

The IuTGroup is patent holder of the Smell Well system.

Principle of the Smell-Well System:
The Smell-Well System is used to transform the biological climate inside the landfill from anaerobic to aerobic conditions.



The activity of anaerobic bacteria, which are responsible for offensive smells, is stopped by blowing air into the landfill. At the same time, the foul-smelling mixture of gas and air is drawn off the landfill and cleaned in a biofilter. Supply air is passed through a biofilter before it is blown into the landfill. In the biofilter, it is heated and enriched with aerobic bacteria, which - when blown into the landfill - encourage the creation of an aerobic atmosphere and at the same time stop the regeneration of anaerobic conditions.
Figure 1 - Principle of the Smell-Well System.

One of the problems in odour stabilisation is the need to keep water content constant. If the landfill has no leakage drain, it is very wet inside. While the gas/air mixture is being drawn off, water is drawn off as well and condenses in the piping system. Problems are sure to arise as the water blocks the pipes. To solve this problem, the direction of the airflow is reversed every hour. This is done by means of butterfly flaps, so that those lances that before blew air into the landfill, then draw it off.

To supply the landfill material with enough air, lances of a length of 3.5 m (standard lance) are forced into the landfill in a grid-like array, at intervals of 5 to 6 meters. The hourly reversal of the air flow prevents canalisation inside the buried material and facilitates a continuous aeration of the excavation area.

Picture 5 - Smell Well Plant

After the installation of all lances and pipes, the aeration process is started. On the 1st day, high peaks of methane are measured by the control instruments. On the 2nd day, the change from an anaerobic to an aerobic atmosphere inside the landfill is completed and the levels of methane in the waste air decrease to a normal rate. All in all, the excavation area is aerated for 5 to 7 days so that easily degradable organic pollutants can be reduced and the water content of the dumped material lowered further, which facilitates subsequent treatment. Besides, the aerated excavation field thus remains in an aerobic condition for a longer period of time (approx. 6 weeks).

The change from anaerobic to aerobic condition insides the landfill proceeds very fast and is completed within just 200 minutes. The lances must be left in place for the remaining time to be sure that all parts of the aerated area are reached by oxygen. One can clearly see that aerobic degradation starts already after approx. 400 minutes. The oxygen content drops again a little and the carbon dioxide content increases. The excavated material stays aerobic for about 6 weeks after treatment with the Smell Well system.

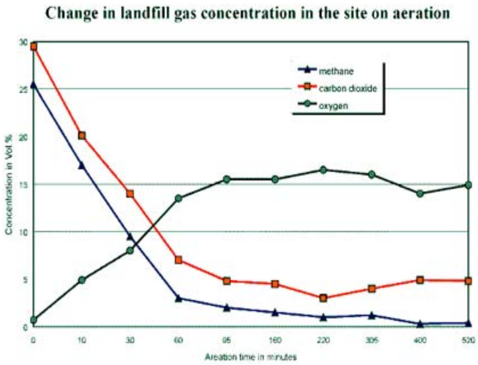
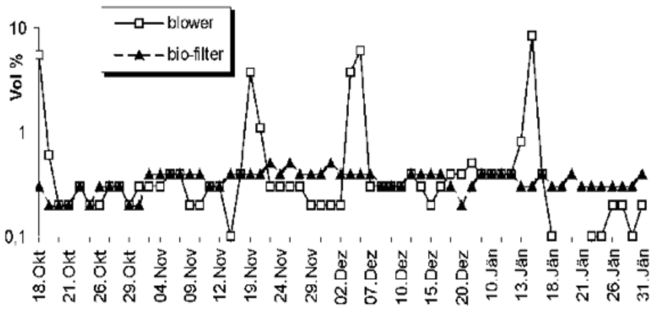


Diagram 1 - Change of the gas concentration

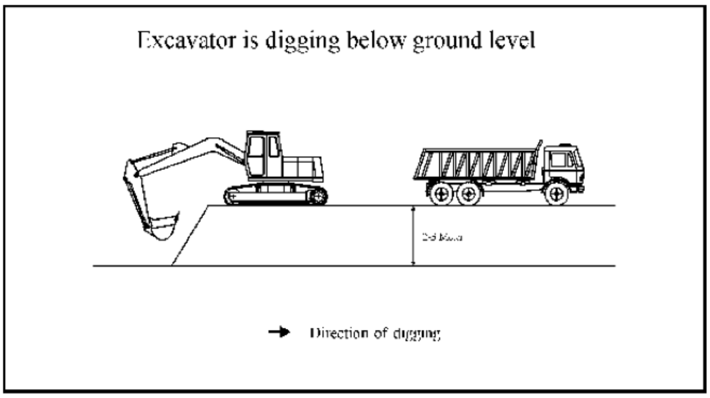


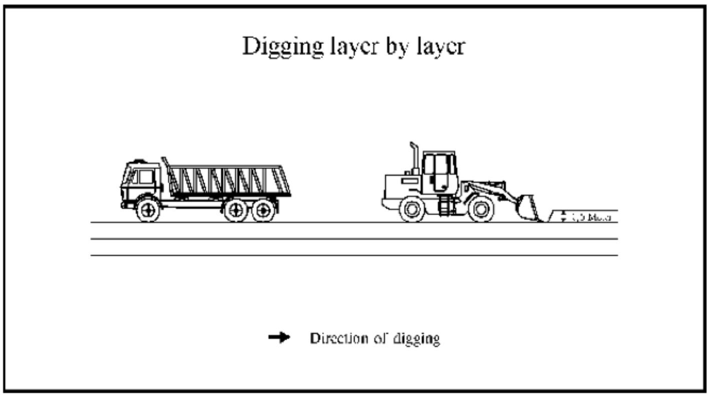
The Biofilter is activated every hour by fresh air and moisture, i.e. normally by the air-and-gas mixture coming out of the landfill which is saturated with water. The Biofilter actively reduces methane to carbon dioxide and water and also buffers peaks very well.

Diagram 2 - Emissions from Biofilter

Even high concentrations from the aerated area such as arise after instalment of a fresh field of lances are buffered by the Biofilter and emissions from the Biofilter do not change significantly.

3rd Step Excavation of the Landfill





There are basically two options for excavation of a landfill:
- From the top with an excavator in 3 m levels
- From the bottom with a front loader removing thinner lifts

The most effective and most economical method of excavation is by excavator, using the front loader only for cleaning the bottom level (natural ground) or in special cases.
If ground water interferes with the excavation procedure, the ground water level has to be lowered by pumping to allow dry excavation.
The lances of the Smell Well System have an effective aeration length of 3.5m, which allows aerobisation down to another 0.5m below the area excavated. This layer operates like a Biofilter and prevents odour emissions from being released to the open, newly excavated space.

The volume excavated per day depends on aeration capacity and the throughput of the treatment plant
Example Sharjah:

Daily excavation rate	8.500 m3/day
Excavators	7
Landfill trucks	28
Treatment plants	2

As excavation work approaches the natural ground special care has to be exercised and closer monitoring by the chemical lab is required. The top strata of the natural ground are often contaminated by leachate from the landfill and have to be excavated along with the waste material. Good experience has been gained with biological de-contamination of material taken from the top of the natural ground. Additional makeup with sewage sludge accelerates the biological process and reduces the time needed for it.

The largest source of emissions from a landfill mining project is on-site transport. The excavated waste should be moved to the stock piles at the treatment plants fast and efficiently. The temporary roads there are often only lightly paved and dust emissions are normal. They can be controlled only by daily watering of the roads.

4th Step Treatment
The treatment of the excavated material depends mostly on the targets to be achieved. Different treatment steps will result in different volume reductions. The most popular option is simple screen-

Picture 6 Excavation

Picture 7 Cleaning

ing, which may achieve reductions of up to 15% by volume. Combined with air separation, the quality of the fine material can be improved and a significantly higher reduction (approx. 50%) achieved. Recycling ferrous and non-ferrous metals and wood may reduce volume by another 5%. The largest reduction can be obtained by the production and usage of RDF.

The treatment plant itself is a combination of different mechanical processes such as screening, separation, sorting, shredding, baling etc. The machinery has to be designed with due regard to the expected composition of the landfill and the targets to achieve. The technology itself is very well known and has not changed dramatically since 1993. Just size and throughput increased with each project. Throughput of 120 m3/h per line is now the common standard. The plant itself has to be maintained very well as, because of the type of materials processed, it is subject to much wear and tear. For every two shifts worked per day another shift is needed for cleaning, maintenance and repair.

Results from the Sharjah project:

Picture 10 natural Ground

Picture 11 Biodegradation

Of the material excavated (100%):
1.2 Vol% recycling material, mostly ferrous metals and wood
53.2 Vol% refilling material, which is the fine and inert fraction used for backfilling at the landfill site
45.6 Vol% plastic residue (RDF), which was compacted with a baler to approx. 15 vol% of the original landfill material and taken to a new landfill.

This residue has a high heat value (approx. 18,000 kJ/kg) and can be used as RDF in differ-

Table 3 - Quality of Refilling Fraction from MSW

Contamination	Units	Average	Threshold Values
MC	%	11,5	no
DSS	%	88,5	no
LbC	%	8,6	10,0
Lead: Pb	mg/kg	2,8	50,0
Cadmium: Cd	mg/kg	0,7	10,0
Mercury: Hg	mg/kg	2,1	3,0
TPH	mg/kg	697,8	1.000,0
ER	mg/1	1.127,7	2.500,0
pH-Value	-	7,7	6,0-13,0
Cunduc.	mS/m	148,0	300,0
TPH	mg/1	0,4	0,5
Nitrite: No_2^-	mg/1	2,0	10,0
Nitrate: NO_3^-	mg/1	14,9	500,0
Ammonia:NH4+	mg/1	5,4	40,0
Chloride: Cl^-	mg/1	103,0	5.000,0
Sulphate: $SO4^{2-}$	mg/1	584,2	5.000,0

Picture 12 Refilling Material

Picture 13 Refilling Material

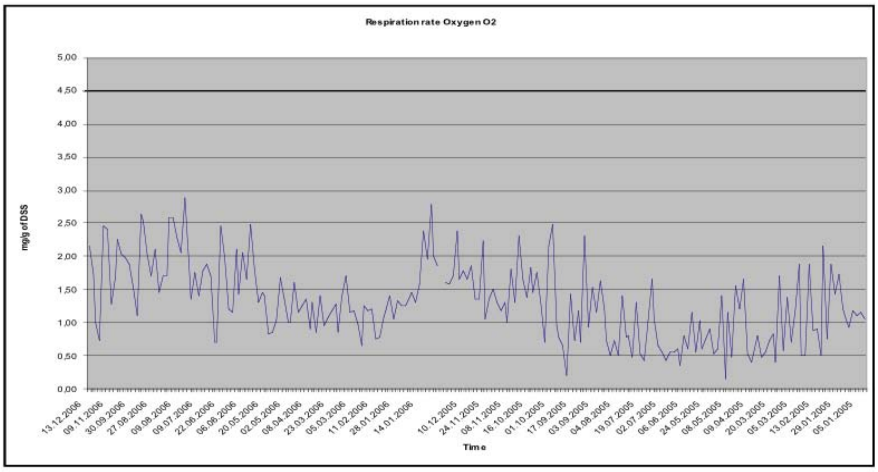
Picture 14 Stones for refilling

Picture 15 Stones for external usage

ent types of incineration plants. If no incineration plant is available (like in Sharjah) it makes sense to compact the material and store it in bales again. The demonstration project of Ludwigsburg also showed the possibility of recycling most of this plastic fraction to LDPE granulates again. But this is a very costly procedure because of heavy contamination and not economical.

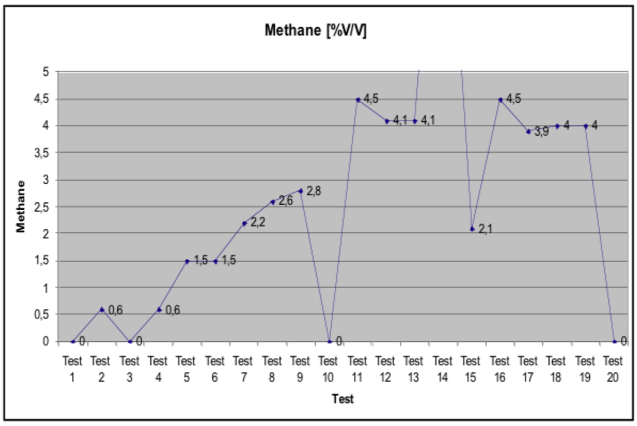
Of high importance is the quality of the refilling material to be used as backfilling soil at the former landfill site. The reduction of organic matter contained in the refilling fraction is achieved by a combination of different steps during the mining procedure: the aeration system at the beginning, then aeration during treatment, and finally biodegradation of the fine material during storage. In nearly 99% of all excavated landfill material this combination is enough to reduce the carbon content (specified by the LbC Loss of Combustion) to below 10%. The remaining carbon is present in small particles of plastics and wood. The native organic matter in food waste and similar fractions is reduced inside the landfill and during the different treatment steps. We can prove this from our experience with waste that was dumped a minimum of 2 years before the mining procedure started. In “younger” landfills it is possible to find LbC levels of up to 20%, which is why it is necessary to add a biodegradation process before refilling.

Excavated material from the bottom layer (last layer of waste and top layer of original ground) is more highly contaminated and often requires special treatment by a biodegradation process.



All numbers in this table are from the Sharjah project and represent an average of app 2,3 Mill m3 refilling material produced from MSW with a sample rate of 2.500 m3 (practically the average of app. 920 samples). It is surprising that a project like Sharjah old landfill where beside MSW and CDW a big amount of hazardous waste (mostly oil sludge) have been dumped has no higher chemical contamination. But we found this effect in many other old landfills.

Diagram 4 Methane concentration at a hot spot



The activity of the refilling material is also influenced substantially by the respiration rate (AT4), which is a good indicator for the presence of native organic matter.

Diagram 3 Change of the respiration rate

The refilling itself takes place in layers depending on compaction requirements. After refilling, monitoring wells must be provided to measure the gas production. The government normally specifies the minimum distance between such gas wells (in Sharjah it was every 10,000 m3). It may happen that a “hot spot” is detected as was the case with one gas well in Sharjah after completion of mining. This was attributable to the inflow of contaminated ground water into the refilled area. In such a case it is the best to measure the development of the gas concentration during the following weeks. Normally the gas concentration decreases very fast.

Costs

The cost structure of a landfill mining project depends very much on local circumstances and any numbers can only be rough estimates. Influencing factors are:

* Infrastructure at the site
* Accessibility of the site
* Relation of depth of the landfill to the covered area
* Type of dumped waste
* Knowledge of the landfill history and information available on the dumped waste
* Local costs of staff, machinery, administration
* Possibility of on-site refilling
* Treatment of the residue
* Distances to treatment plants for residue

Approximate cost structure (without costs for residue treatment):

Type	% of Costs
Exploration	7
Aerobisation	15
Excavation, int. Transport	32
Treatment	34
Refilling / Compaction	7
Monitoring/chem. Lab	5

The costs of residue treatment may amount to 100% of the mining costs in case of long distances and high tipping fees. In some projects (e.g. Omuta, Japan) it was cheaper to construct a small sanitary landfill beside the former dump site to store the residue in a controlled way there.
The costs of the mining procedure itself without costs of

- Treatment or land filling of the light fraction
- All transports outside the landfill

are approx. per m3 of landfill volume:
Small landfills (up to 500,000 m3) 18 - 25 EUR
Large landfills (more than 1 million m3) 10 - 14 EUR

Conclusions

Based on approx. 17 million m3 of landfill mining volume handled under different projects all over the world we have arrived at the following conclusions:

* It is state of the art to remediate a landfill with mining technology.
* There are several reasons to start a landfill mining project.
* Landfill mining is a lasting solution for a landfill.
* Infrastructure projects can pay for a landfill mining procedure with the value of the land.
* Landfill mining technology allows cleaning up sites without negative impact on the environment.
* A big portion of the landfill volume can be backfilled for landscaping or construction purposes.

Paper 6

The cumulated energy demand (CED) for landfill mining and reclamation

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Introduction

The Technical Guidelines for the Disposal of Municipal Solid Waste (TASi) of Germany banned with June 1, 2005 the dumping of waste that has not been pre-processed [1]. With the price developments for oil and metals between 2003 and mid 2008 the objective for landfill mining shifted from acquiring landfill volume to recover recyclables materials, in particular RDF and metals. After two decades of intensive landfill mining pilot studies the gained knowledge will be used in this research to calculate and assess the energetic potential of landfills for an entire region, here the German Federal Land of Bavaria. By means of the energy efficiency the energy balance of demand and production as well as savings are considered and set against the costs. First the average composition of excavated materials is calculated, then the energy demands for excavation, sorting, transport etc. and finally the energy generation and costs of thermal recycling as well as energy savings from metal recovery. This study considers only energetic aspects and not any other environmental impacts like Global Warming Potential, Acidification Potential etc.

Keywords: Landfill mining and reclamation (LFMR), cumulated energy demand (CED), energy efficiency, life cycle inventory (LCI), waste-to-energy (WtE)

Recovered Materials

The comparison of international case studies [4,6,7,9,10,14,15,16,17] showed a general high amount of soil and minerals, a modest part of a lightweight fraction, consisting predominantly of plastics, and at least a small part of metals (Figure 1). In some cases wood formed part of the recovered materials up to 9%. Normally manual sorting in pilot studies led to more fractions and purity respectively amounts than automated processing at excavated landfills.

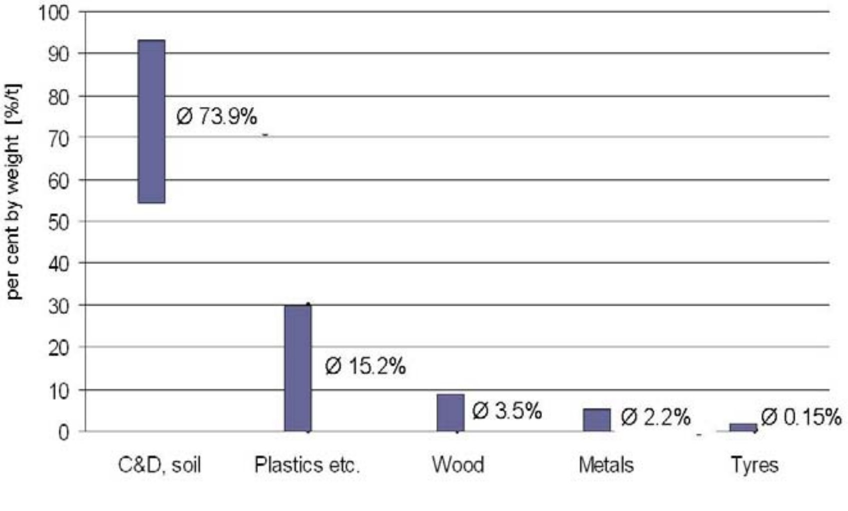


Fig. 1: Composition of recovered materials from landfills of international case studies

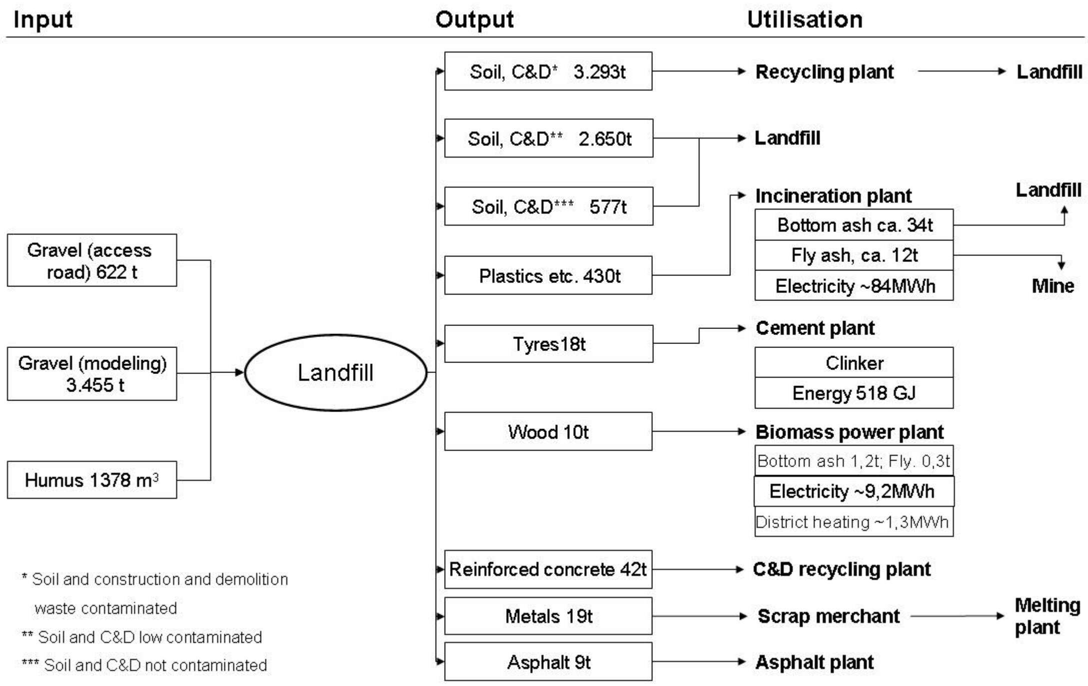
Generally the composition depends on the dumped material and grade of decomposition. The former is influenced, by regional factors, e.g. urban or rural, pre-treatment, economical and social factors. The latter varies due to climatic and hydrological conditions.

Material flows

In German case studies the recovered materials were recycled, incinerated or dumped again in other landfills. The material flows

are shown for a Bavarian case study (Fig. 2) and didn't vary so much to other European case studies. Significant difference may caused by dumping of non recyclables materials like mineral at the excavated site instead of transporting to and dumping on other landfills. In this case study most of the power and recycling plants as well as dump sites were in the region, with the exception of some melting plants. The mineral fractions were dumped after mechanical treatment at landfills which fulfilled the current technical standard.
The plastics were incinerated at a waste incineration plant for municipal solid waste and wood at a biomass power plant. In Bavaria are located 17 waste incineration plants but only one power plant for RDF. Thus recovered RDF from landfills was mostly treated in waste incineration plants. The poor quality and contamination of the wood induced the classification to A IV, the lowest category of the German Regulation for Waste Wood (AltholzV) [2]. Therefore only special biomass power plants are allowed to accept it. Corrosive reactions in the boiler require lower temperatures and induce consequently less efficiency.
The tyres were burned in the furnace of a cement plant. The steel carcass made part of the produced clinker. The metals were transported to closed steelworks and melting plants. Small loads of reinforced concrete and asphalt were processed in closed building companies for further use in road construction. Beside excavated materials a notable amount of gravel for the access road, gravel and humus for reclamation were transported to the landfill.

Fig. 2: Material flows of an excavated landfill in Germany

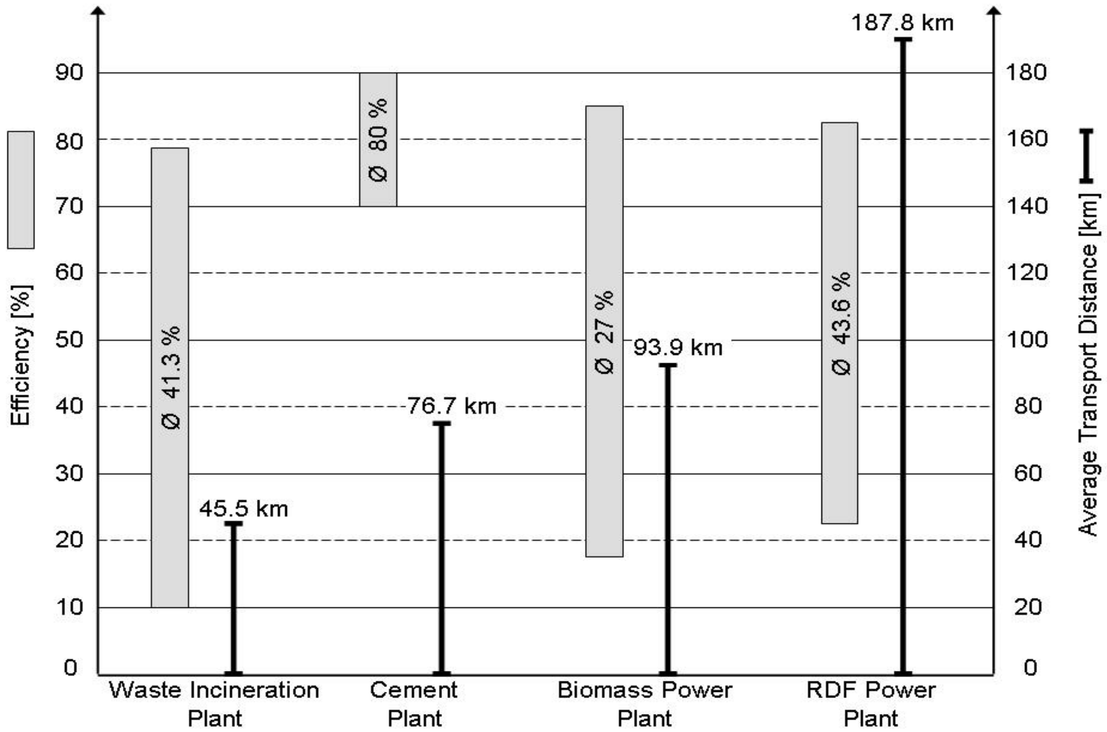


Energy balance

By means of an energy balance the generated energy of thermal recycling and energy savings of recovered metals are set against the energy demands for excavation, processing and transport as well as losses due to conversion into electricity.
In a detailed own investigation the major energy consumption was caused by the excavator. The consumption for processing amounted nearly as much as the consumption for transport, although this case study recorded transportation about 40,000 km one-way of loaded lorries. The excavated landfill was refilled with primary gravel from a closed quarry and humus. Refilling and modelling with gravel from primary production took 19 % of the total energy consumption, though the gravel pit was closed to the landfill. The calculations included primary-energy consumptions for all operations on the landfill site, separation processing, transport and if possible as well for further operations like final disposal. Significant for the energy generation is the lower heating value of the recovered materials and the efficiency of the power plants. The efficiency ranges from 10 to over 80 %, but the average of waste incineration plant, biomass power plant and RDF power plant are quite similar (Fig. 3).The efficiency of simply conversion into electricity is compared to combined heat and power or process steam very low. The thermal treatment in cement plants has efficiency up to 90% due to direct use of the heat.

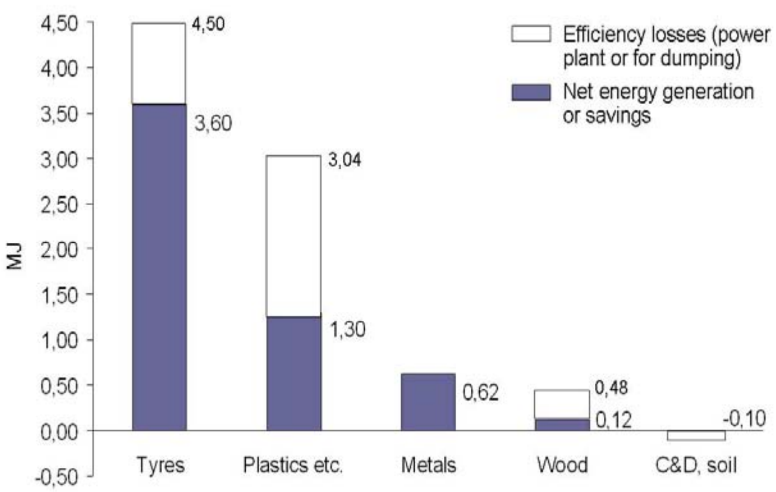
But cement plants require high caloric materials, thus not all materials are usable. Almost all power plants in Bavaria have a combined heat and power.
The network of waste incineration plants is very dense, inducing an average transport distance of 45.5 km (Fig. 3). The average efficiency of waste incineration plants in Bavaria has a notable value of 41.3 % [13]. Whereas only one power plant for RDF induces an average transport distance of 187.8 km.

Fig. 3: Efficiency of plants and average transport distances (Bavaria)



The lower heating value of tyres is well known and about 28 MJ/kg, but more difficult is to estimate the lower heating value of RDF derived from landfills or wood. Rettenberger [15] assumed a lower heating value of 18-22 MJ/kg for the light weight fraction from landfills. In international case studies the lower heating value ranges from 7 to 14.4 MJ/kg [7,8,12,15]. In this study a lower heating value of 20 MJ/kg for the light weight fraction and 13.8 MJ/kg for wood are assumed. The energy saving values due to metal recovery are based on Ecoinvent data from Switzerland [5] and the ratio of iron to non ferric metals is assumed to be 9.25 to 1 [16].
One kilogram of excavated material has an average energetic potential of 8.0 MJ, but will be reduced to 4.8 MJ due to losses of energy conversion (Fig. 4). Another 0.1 MJ are subtracted for the disposal of mineral but 0.62 MJ credited for energy saving due to metal recovery.

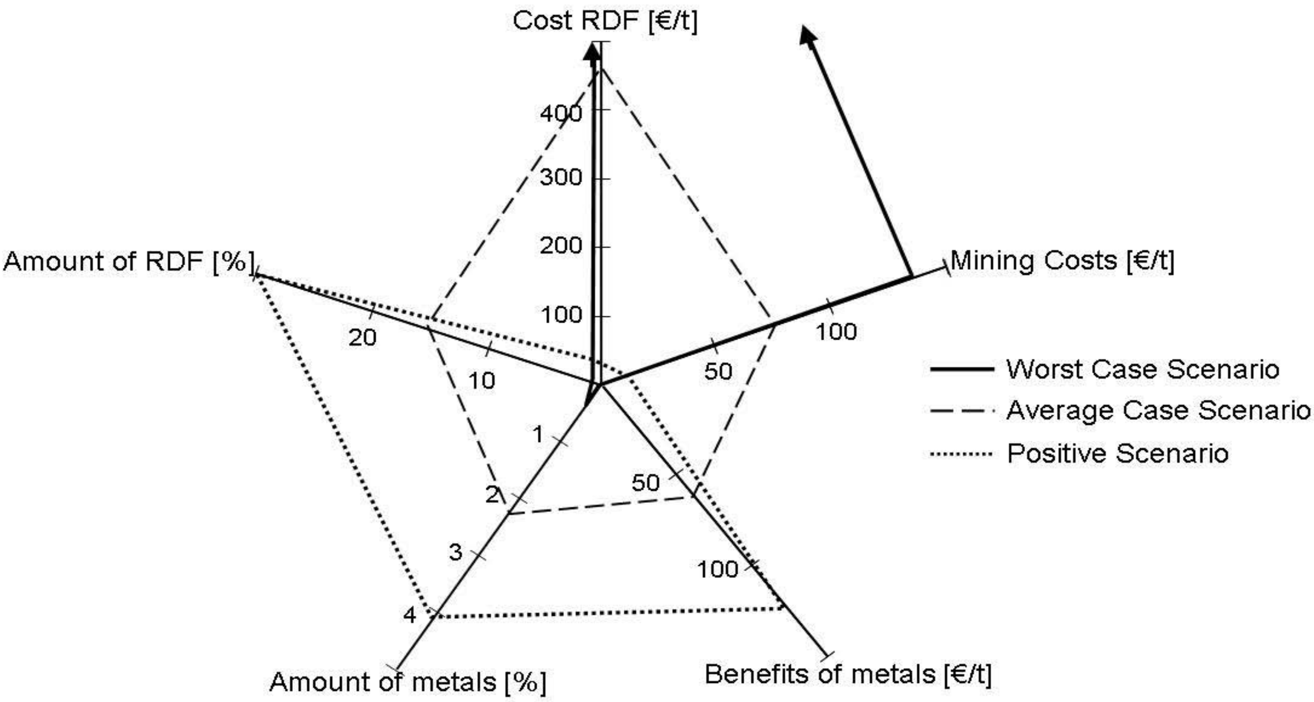
Fig. 4: Energy generation, savings and demands for one kg of excavated material



The losses of energy conversion into electricity exceed significantly the energy demand for excavation, processing and transport which are for this reason not shown in figure 4.

Energy efficieny

The energy efficiency expresses the ratio of economic creation to net energy generation. In this study the costs for landfill mining are set against the data of the energy balance.
Revenues of scrap vary a lot, Wiemer [16] mentions a range from 0 to 125 Euro/t. Additional payments of RDF are between 50 and 100 Euro/t [3]. Although the energy demand for transport is negligible, the costs have a major impact as well as dumping of non recyclable materials. The costs for landfill mining ranged in recent times between 8.28 and 138.89 Euro/t. This imposes costs of 10.4 to 196,000 Euro per ton RDF in the worst case (Fig. 5). The worst case scenario is based on small old landfills with small amounts of metals and plastic.
Fig. 5: Positive, average and worst case scenario



To assess the results of landfill mining the energy efficiency of other resources are considered and compared. The positive case scenario of RDF is set against energy efficiency of lignite, coal, natural gas and woodchip (Fig. 6). RDF derived from landfills has a slight negative energy efficiency compared to all other considered resources. Reasons might be on the one hand the higher energy demand compared to woodchip and on the other hand the relatively high costs compared to lignite and coal. A price increase of 400% for coal or 30 % for natural gas or significant exploration difficulties would equate them to RDF.

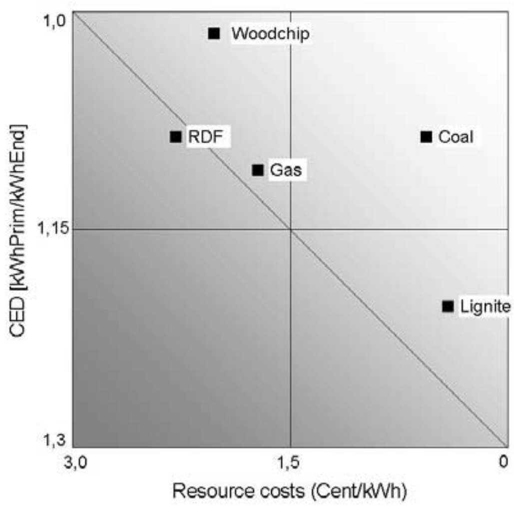


Fig. 6: Comparison of the energy efficiency of different resources

Conclusion

The main factors for efficient landfill mining are the size of the landfill, the composition of materials, the world market prices and the efficiency of power plants. Although the energy efficiency of RDF derived from landfills is moderate, RDF may constitute a reliable and independent energy source without requiring a lot of infrastructure. This might be interesting in developing countries especially for the cement industry as well as for industrialised countries to increase energy production of waste incineration plants. Especially anchor countries like Brazil, China, Egypt and India with high demand on energy, relatively cheap labour and different environmental regulations may provide better conditions for landfill mining.

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Paper 7

Possibilities for landfill mining in Turkey, Pakistan and worldwide, for the production of alternative fuels

Dirk Lechtenberg

MVW Lechtenberg (Germany)

Content:

- About MVW Lechtenberg & Partner
- Landfill mining as Source for Alternative Fuel`s
- Practical Experience in Landfill Mining Projects in Lebanon, Pakistan, India and Turkey
- Economical Key Figures
- Outlook

What do we do?

- Project development for municipalities in production of Alternative Fuels; reports and studies
- Project development for cement industry (worldwide) in using AF - independently
- Secondary fuel production , quality control & supply to act. 9 Cement Plants
- Technical support in AF Implementation (Engineering) as well as "Turn Key" Implementation

Some References:

Why Landfill mining?

- Landfill`s as an economical source for: Alternative Fuels / Calorific Value Recyclables?
- Landfill`s causing environmental Pollution: Leachate polluting Groundwater
- Landfill`s causing Greenhouse Gas emissions Methane Gas avoidance

- Landfill`s as an Fuel Resource: Alternative Fuels for the Cement Industry:

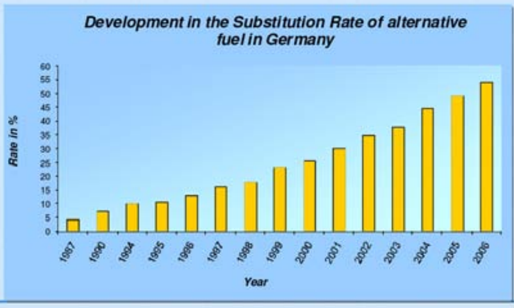
One common characteristic of all cement kiln systems is the long retention time in the high temperature zone of gas (2000°C) and material (approximately 1450°C). These temperatures are much higher than in waste incinerators (850 – 1100°C). The valorisation of waste in cement kilns maximises the recovery of energy from waste. All the energy is used directly in the kiln for clinker production. The valorisation of waste also maximises the recovery of the non-combustible part of the waste and eliminates the need for disposal of slag or ash, as the inorganic part substitutes raw material in the cement. The cement industry consequently offers a unique opportunity to handle a large variety of problematic industrial waste

Calorific value of fossil fuels:

FOSSIL FUELS	Kcal/kg
Coal	4000-7000
Coke	6500
Charcoal	7000
Carbon	8000
Fuel oil	9800
Kerosene and diesel	10000
Petrol	10800
Paraffin	10500
Natural gas	8600
Coal gas	4000
Electrical (Kcal/KW)	860

Calorific value of Alternative fuels:

Fuel	Approx. heating value Kcal/Kg	
	Natural State	Dry state
Wood	1500	3500
Cattle dung	1000	3700
Bagasse	2200	4400
Wheat and rice straw	2400	2500
Cane trash, rice husk, leaves and vegetable wastes	3000	3000
Coconut husks, dry grass and crop residues	3500	3500
Groundnut shells	4000	4000
Coffee and oil palm husks	4200	4200
Cotton husks	4400	4400
RDF from Municipal Solid Waste	**3500**	**4500**



The basic principles for the use of Alternative Fuels are as following:

- The chemical quality of the fuel must meet regulatory standards, assuring environmental protection.
- The calorific value of the fuel must be stable enough to allow control of the supply of energy to the kiln, as the achievement of homogeneous clinker requires a well controlled combustion process.
- The physical form of the fuel must allow easy handling of the material for transportation and a controlled flow into the kiln.
- The fuels must not introduce the chemical species into the clinker production process that might be deleterious to the stability of the process or the performance of the product.

Alternative Fuels from Landfill mining:
Normandy Landfill, Beirut, Lebanon 2006/7

Normandy Landfill Project: Some Figures:

-60 ha of land rehabilitation in the port of Beirut
-Mixed waste was dumped into the sea during civil war
-App. 350.000m³ of plastic waste processed
-App. 7 Mio tons of sand and soil processing

Normandy Landfill Project:

-High contamination with Na Cl and Ammonia from weapons!
-Beirut City District Development Company "SOLIDERE" was contract partner

Normandy Landfill Project:

-Manual sorting of "fuel parts"
-Screening, screening, screening!
-Fuels and Tyres used
-Project stopped due to political situation
-Waste relocated and land filled

Alternative Fuels from Landfill mining:
Ajmer Project, Rajasthan, India

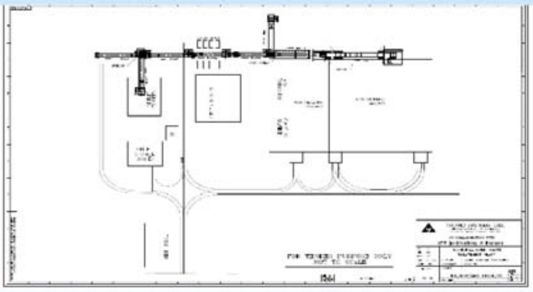
- With Tecpro Systems, India
- Old Landfill with 250 tons/ Day fresh waste
- 2007 Project start

Ajmer Project, Rajasthan, India

Waste composition, Ajmer

Organic	55%
Sand / inert	15%
Plastic	17%
Textile	5%
Metals	1%
Glass	0.5%
Other	6.5%
Total	100 %

Ajmer Project / Rajastahn



Ajmer Project / Rajastahn

- Low Content of „fuel components"
- No recyclables

Landfill mining: Europe

- Vassiliko Cement, Cyprus
- Old Landfill in quarry
- Since 2007, ongoing

Landfill mining: sorting analyses

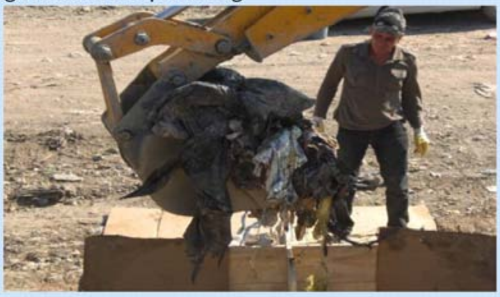
Alternative Fuels from Landfill mining: Tokat Project / ADO CIM / Titan

- Sampling guidelines
- Ongoing

Sampling Procedures: quartering

Lechtenberg & Partner

Sampling Procedures: quartering



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Sampling Procedures:

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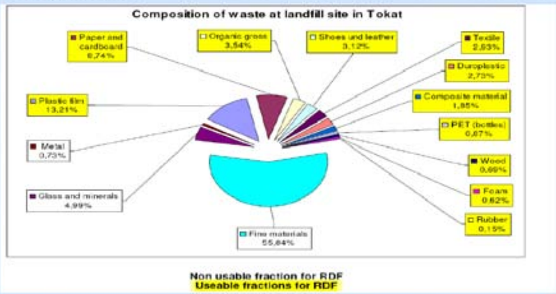
Waste Qualities:



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Waste Qualities:

	sample I	sample II	sample III	sample IV	sample V	average	average
Physical Composition Waste	weight in kg					in kg	% wt
Plastic film	4,5	8	8,5	4,75	6	31,75	13,21%
Paper & cardboard	9,75	5,75	0	4,75	0,75	21	8,74%
Organic gross	3,75	2.5	0	0	2,25	8,5	3,54%
Shoes und leather	1	0	6,25	0,25	0	7,5	3,12%
Textile	4,75	0.5	0	0,3	1,5	7,05	2,93%
Duroplastic	1,5	1	1	2,25	0,8	6,55	2,73%
Composite material	0,1	1,75	0,5	0,1	2	4,45	1,85%
PET (bottles)	0,1	0.5	0,75	0,75	0	2,1	0,87%
Wood	1	0	0,15	0	0,5	1,65	0,69%
Foam	0,2	0,75	0,25	0,1	0,2	1,5	0,62%
Rubber	0,1	0	0	0	0,25	0,35	0,15%
Metal	0,75	0,25	0,5	0	0,25	1,75	0,73%
Fine materials < 20 mm (inorg. + org.)	8,5	45.2	15	6,5	59	134,2	55,84%
Glass and minerals	1,5	5,25	2,5	0,75	2	12	4,99%
Total	37,5	71,45	35,4	20,5	75,5	240,35	100,00%
Useable fractions for RDF	*71,3%*	*29,0%*	*49,2%*	*64,6%*	*21,5%*	*39,3%*	*39,3%*

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Rivers as landfill: Turkey

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Rivers as Landfill: Pakistan

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Land filling in Pakistan: Fauji Cement project
-Started 2007
-In operation since 08/ 2008
-500 tons old MSW/day
-120 tons production of RDF

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Pakistan:
- MVW Lechtenberg is advising 9 Cement Plants for the Implementation of RDF from Landfills
-Peshawar, Nowshera, Lahore, Faisalabad, Rawalpindi, Islamabad, Karachi and many others

Fauji Cement: processing building

Fauji Cement: processing building

Fauji Cement: processing plant

Fauji Cement: pre-screening

Fauji Cement: separation of inert / sand

Fauji Cement: oversized consisting of plastics

Fauji Cement: manual separated big items/ stones

Fauji Cement: sand and organics

Fauji Cement: transport to Cement Plant

Fauji Cement: Rainy Season!!: high moisture

Fauji Cement: First RDF!

Landfill mining: Methane Gas avoidance

Project emissions		
Kiln Operation	Kiln operated with RDF	
NCV RDF	TJ/t	0,0147
CO2 emission factor RDF	t CO2/TJ	27,3
Incinerated RDF amount	t	52.560
Total energy	TJ	772,632
CO2 emissions	t CO2/yr	21.093
Emissions reductions	t CO2/yr	92.174

Landfill mining: Hazardous Wastes
Project in Australia

Landfill mining: spent cell linings from Aluminium Production

Landfill mining:

Processing of stored anodes / Refractory's from Aluminium Production

Landfill mining: Conclusions

-in developing countries no recyclables
-in developed countries high content of hazardous wastes!
-material sticks together
- high moisture, contaminated leachate
-drying to expensive
-"fuel" content only consisting of plastics
-complicated technologies too expensive
-Increasing fuel prices will boost Landfill mining!

Alternative Fuels, such as Biomass or refuse derived fuels (RDF) are used in European cement plants since decades. RDF is mainly containing high calorific valuable fractions from Municipal or Industrial wastes such as non recyclable plastics, paper, cardboard, textiles and wood.

Land filled waste contains a certain amount of plastics and other high calorific valuable wastes, which can be used as raw material for the production of refuse derived fuels. Increasing fossil fuel prices followed higher prices for commodities and higher environmental requirements such as CO2 reduction are forcing Landfill mining projects.

Landfills containing all types of unknown wastes and mixtures of wastes, collected in decades. Especially in industrialized areas, any kind of even hazardous wastes can be a part of the Landfill. Mixtures of unknown wastes may produce new unknown, dangerous chemical compounds.

Even in rural areas, residues from pesticides, batteries and other chemicals can be found on landfill sites- but only in smaller volumes. Normally they are no unknown postindustrial wastes stored on landfill sites in rural, agricultural areas.

During the extraction or "landfill mining" – even in rural areas- special attention and security measures have to be implemented:

- Health and safety issues
- Gas monitoring
- Continuous analyses of extracted wastes (dioxins, furans, radioactive substances, bio- hazardous analyses)

Separated, "mined" fractions have to be controlled before further processing or use. A detailed analyze of all chemical compounds or bio hazardous compounds have to be done- as it is not known, what type of contamination can be found.

E.g. also in rural areas- with a high content of organic wastes- the organic fractions are may contaminated with mercury or other heavy metals from accumulators, light bulbs or destroyed old thermometers. So- in any cases- the Health and safety as well as environmental pollution control has to be very intensive and continuously monitored.

Therefore this presentation concentrates on landfill mining projects in rural areas of developing countries.

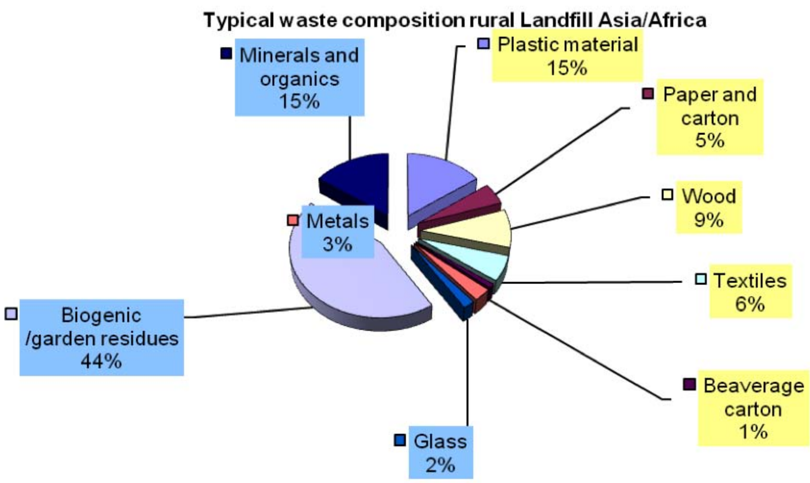
Assuming a typical landfill in a rural area of a developing country such as Turkey or a country in North Africa, the land filled waste will contain a high percentage of organic wastes, such as food waste, vegetables or others. Typically, more than 60% of the wastes in such countries are organic wastes.

Such a typical waste composition is shown in table 1:

The yellow marked fraction can be used as Alternative Fuel raw material. Blue fractions can be recycled or further processed into other products.

Due to the anaerobic situation in old landfills, we have discovered that even newspapers are rarely completely destroyed even after many years.

This paper describes experiences in ongoing Landfill mining projects – with the focus on alternative Fuel production.



Paper 8

Landfill mining is what we do

Peter Crofts

RockTron Ltd

My subject matter for this presentation concerns fly ash, a large volume by-product that is produced by coal fired power stations in the process of generating electricity. Fly ash is certainly a global problem with current estimates of 600 million tonnes of fresh ash being produced each year from the burning of over 4 billion tonnes of hard coal.

The focus of this presentation is on what can be done with the billions of tonnes of fly ash stored in lagoons and landfill deposits across the world. How much fly ash is there in long term storage around power stations? A difficult question to answer precisely but RockTron estimates that there are several billion tonnes in long term landfill with more added daily.

Why, you may ask, is so much fly ash landfilled and not recycled? The answer, in part, relates to its origin as a by-product of electricity generation; such waste streams have not historically been the focus of attention for many generators and finding beneficial uses for fly ash is only recently becoming a higher priority. The answer in part also relates to the quality and usability of resulting fly ashes particularly in the construction industries – the traditional home for fly ash products either in concrete or various ground works. The quality of fly ash waste streams often fails to meet the industry standards required for reuse in many forms of concrete and so the fly ash goes to long term storage in either lagoons or landfill stockpiles.

Reducing the production of fly ash at power stations is unlikely to be a solution as increasing legislation on emissions controls preclude high temperatures being used in the furnace. Fly ash is here to stay and we need to deal with it. Utilisation levels are increasing in certain countries, again driven the by environmental considerations, but levels are no more than 50% at best in the west and effective use is driven by the quality of the fresh ash material. Recycling landfilled fly ash has not been an economic proposition until now and the advent of RockTron.

The RockTron Beneficiation Process represents the first commercial solution to recycling fly ash stored in lagoons and landfill stockpiles worldwide. Why? Because it uses a wet mineral processing technology called froth flotation that is specifically designed to handle very fine particle sizes. Raw fly ash particles range in size from nano to 300 micron with the mass of the particles below 100 micron and the processing of such fine particles using a wet process helps minimise dust and enables better liberation of the carbon from within the raw fly ash. Wet processing technology enables RockTron to offer power stations the facility to process fresh fly ash and equally importantly lagoon and stockpiled fly ash.

Lagoon stored deposits of fly ash in the UK for example can be sizeable. Our first commercial plant at Fiddler's Ferry power station near Warrington, Cheshire, has 16 million tonnes of fly ash stored in well managed lagoons. RockTron has developed a typical alluvial mining plan in conjunction with external consultants that enables the lagoons to be mined in a structured way over the next 25 years until all the fly ash has been recovered, reprocessed and beneficiated using the proprietary RockTron Process. For the power station the RockTron Process and technology enables full recovery and recycling of a long term waste and as each lagoon is emptied the site can undergo further remediation and the land returned to alternative use. As responsible utility businesses the potential for improved site remediation is made easier for all power stations by the effective reuse of the minerals contained within the waste deposits of fly ash on site.

For RockTron as a mineral processing business, having access to 16 million tonnes of stockpiled fly ash provides 25+ years supply of raw materials to process and offer to industry as a range of recycled eco-minerals. One of the unique benefits of the RockTron process is it does not require a working power station to operate - a plant can be built on legacy ash deposits if they contain sufficient fly ash.

Now I would like to turn to the mineral processing part of the RockTron Beneficiation technology:

Stockpiled or fresh raw fly ash is pumped into the plant, where it undergoes several different processes that clean, separate and liberate the constituent minerals contained within the fly ash.

1 .A cleaning process removes the surface salts from the raw fly ash.

2.The first mineral that is recovered are the cenospheres – lightweight hollow glass spheres.

3. Next the carbon is liberated from the raw fly ash using froth flotation and our aim is to remove over

95% of the carbon.
4. Then the iron spheres within the raw fly ash are removed using magnetic separators.
5. The remaining alumino-silicate solid glass spheres represent approximately 85% of the initial feed material which is then classified using hydro-cyclones that are designed to work with very fine particles.

Further processing of these materials occurs including dewatering, drying and packaging.

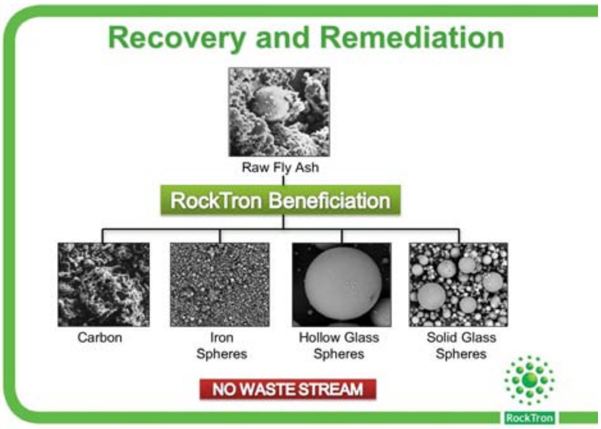
What happens to these beneficiated products?
1. The carbon can be sold back to the power station as coke to use as fuel. If the carbon grade is sufficiently high then it has applications as a reductant in chemical and metallurgical industries and in its activated form it can be used in gas and water phase filtration applications.
2. The cenospheres can be used in drilling muds and as lightweight fillers in certain plastics and composites.
3. The solid glass alumina-silicate spheres are in fact man made pozzolans and are used as class leading substitutes for CEM1 in blended cements, ready mixed concretes and precast concrete structures.
4. Following further processing, the finer particle alumina-silicate spheres can be used as technical fillers in a wide variety of polymers, elastomers and coatings.
5. The iron spheres offer industry a high density mineral filler for use in applications ranging from coal washing to specialist low level waste concretes and sound dampening and shielding applications in transportation and the built environment.

Helping to green the supply chain
1. The RockTron Process itself does not create a solid waste stream through processing the raw fly ash. 100% of what goes into the plant as feed is transformed into saleable products.
2. The RockTron plant uses energy but it also recovers energy in the form of the carbon recovered from the raw fly ash. Depending on the level of carbon recovered from the raw feed RockTron may be 'energy neutral' by returning as much energy in the form of reburnt carbon as it consumes.
3. All our eco-mineral products are recovered from a waste resource which carries an effective 'negative value' without further processing by RockTron.
4. Carbon footprinting work is currently underway to establish our individual product footprints and initial work indicates that significant CO2 savings can be made by substituting our 100% recycled eco-minerals for current mineral choices across some of the biggest carbon intensive industries including construction, cement, automotive and tyre industries.

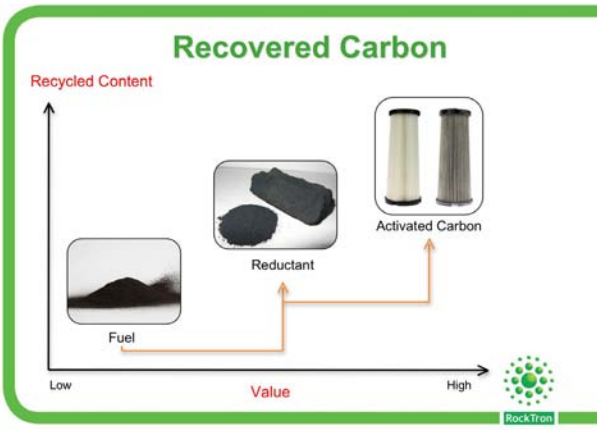
I hope you can agree with us that what is good for business can also be good for the environment.

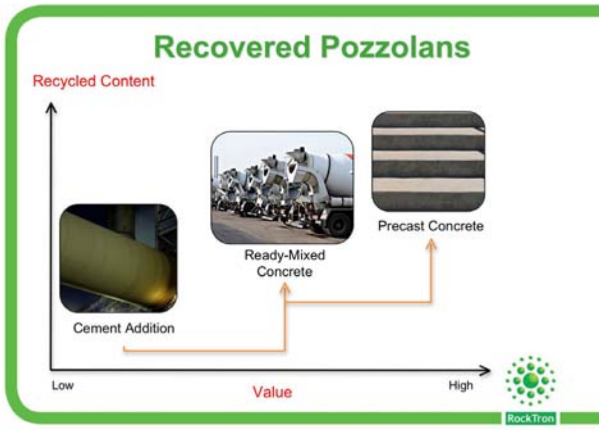

Ash Lagoon Operations
TVA Kingston Fossil Plant Coal Fly Ash Spill 2008.
Fly Ash Lagoon.
RockTron

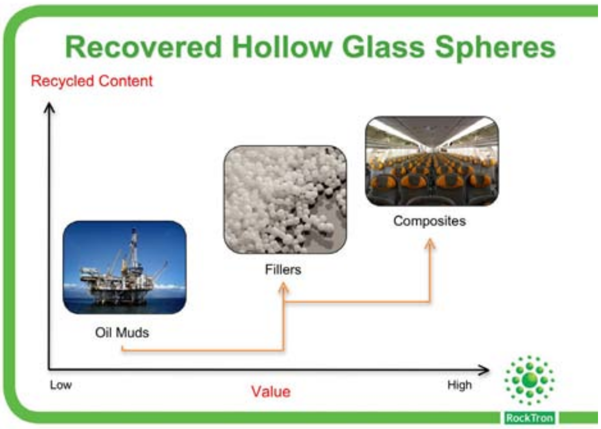

Mining Operations
RockTron

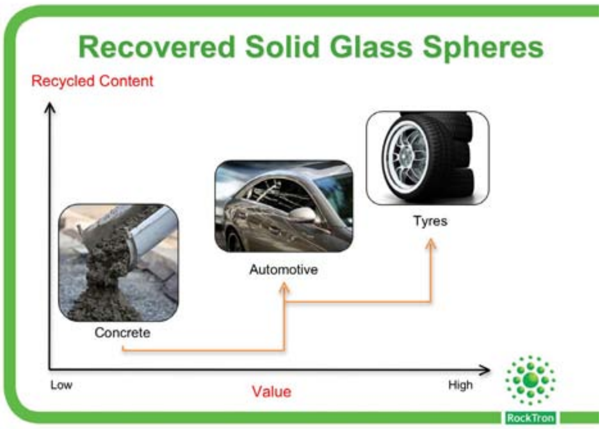

Recovery and Remediation
Raw Fly Ash
RockTron Beneficiation
Carbon
Iron Spheres
Hollow Glass Spheres
Solid Glass Spheres
NO WASTE STREAM
RockTron


Fly Ash Waste Site Remediation
Fly Ash Lagoon
RockTron Process
Remediated Site
NO WASTE STREAM
RockTron

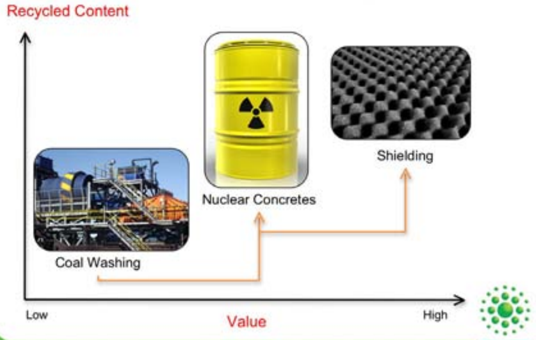

Recovered Carbon
Recycled Content
Activated Carbon
Reductant
Fuel
Low
Value
High
RockTron


Recovered Pozzolans
Recycled Content
Precast Concrete
Ready-Mixed Concrete
Cement Addition
Low
Value
High
RockTron


Recovered Hollow Glass Spheres
Recycled Content
Composites
Fillers
Oil Muds
Low
Value
High
RockTron

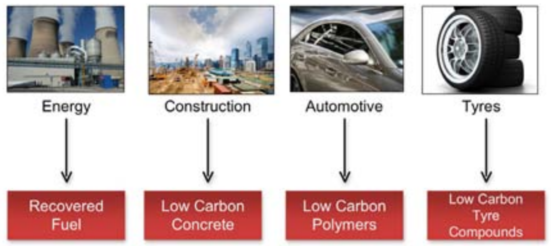

Recovered Solid Glass Spheres
Recycled Content
Tyres
Automotive
Concrete
Low
Value
High
RockTron

Recovered Iron Spheres



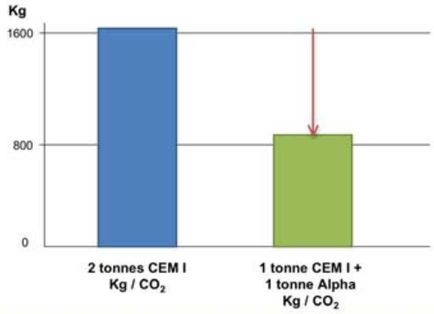
Coal washing image supplied by Parnaby Cyclones International Ltd

Major CO_2 Reductions



BENEFICIATION OF FLY ASH

Major CO_2 Reductions



Greening The Supply Chain

Construction Industry	Energy Industry
Automotive Industry	Tyre Industry

RockTron

Greening The Supply Chain

Greening The Supply Chain

'What is good for business can also be good for the environment.'

RockTron

POWERFULLY GOOD ECO-MINERALS

Thank You!

RockTron Limited

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Paper 9

In-situ waste aeration preliminary to landfill mining

Roberto Raga, Raffaello Cossu; University of Padova, Italy:

Andrea Dal Maso, Moreno Zanella; Spinoff s.r.l., Padova, Italy

SUMMARY: In situ aeration of landfills enables the aerobic degradation process to develop in the landfill with the subsequent reduction of the emission potential in a much shorter time than under anaerobic conditions. Moreover, in situ aeration is particularly recommended as landfill pre-treatment before landfill mining activities. Preliminary investigations are required, to be carried out on the landfill by means of a pilot scale plant, in order to acquire the relevant information for the design of a full scale in situ aeration plant. Some results are presented below, obtained during preliminary investigations carried out on a municipal solid waste landfill in a mountain area in northern Italy, aimed at the application of in situ aeration in view of landfill mining.

1. INTRODUCTION

It is very well known that long term emissions from landfills can cause harmful effects in the surrounding area for centuries (Belevi and Baccini, 1997, Kruempelbeck and Ehrig, 1999).
By means of in situ aeration, the conditions in the landfill can be converted from anaerobic into aerobic with the subsequent acceleration of stabilization processes of the biodegradable fraction, with the aim of a faster reduction of the residual potential emissions and of the related environmental impact (Cossu et al., 2007, Ritzkowski et al., 2006). Leachate extraction carried out from the aeration wells enable faster biological stabilization of waste due to the enhancement of air diffusion in the landfill body and provides enhanced mechanical properties of the landfill at the same time. For these reasons, in situ aeration can also be considered the best option for landfill pre-treatment before landfill mining activities, in order to establish proper conditions (minimization of the emissions of methane and other trace compounds, mechanical stability of the landfill) for the excavation works.

In the year 2002 the first full scale in situ aeration of a landfill was implemented in Italy in the landfill of Modena, as the preliminary step of a landfill mining project aimed at the excavation of a trench in the landfill (removal of 200.000 m3 of waste) for the construction of the high velocity railway line from Milan to Bologna (Cossu et al., 2003). In order to facilitate excavation and further disposal of the extracted waste, suitable measures were defined. Among others, the aerobic in situ stabilisation of the area coupled with leachate extraction took place before the start of the excavation. A specific technology was implemented and then patented by Spinoff as Airflow(r), that foresees the low pressure air injection and process gas extraction from the landfill by means of purpose made wells.

An Airflow(r) plant comprises blowers for air injection and gas extraction, aeration and monitoring wells, monitoring and control devices (flow meters and automatic valves for flow adjustment; facilities for gas and leachate sampling and analysis as well as temperature monitoring), an automatic control unit equipped with gas analyzer and a PC-PLC system, an exhaust air treatment system. The air extracted is conveyed to a biofiltration system before release into the atmosphere. Every aeration well is equipped with a pneumatic pump for leachate extraction in order to keep the leachate table low inside the landfill and thus increasing the volume of waste available for air diffusion.

The management phase of the plant foresees the implementation of a monitoring plan for analyses on waste, leachate and gas; monitoring of temperature and pressure and leachate table in the landfill body. The technology has been implemented in order to operate under adequate safety conditions: a patented safety system guarantees that no potentially explosive mixtures of methane and air are extracted form the landfill.

The full scale in-situ aeration plant in Modena landfill comprised 12 air injection wells, 16 gas extractions wells and 13 monitoring wells as shown in Figure 1, as well as two biofilters for biogas treatment and a leachate extraction system. The installation comprised two independent units (Unit 1 and 2 in Figure 1) in order to enable continuous operation of the plant during the excavation of the trench for the railway line between the two units (Figure 2): a low depression was maintained in the area beside the trench with atmospheric air flowing from the excavation area through the trench slopes into the waste, thus limiting biogas emissions from the rest of the landfill into the working area. The transversal section of the area during the preliminary in situ aeration (a) and the excavation works (b) is shown in Figure 3, where the additional leachate extraction wells used in order to enhance leachate removal during the excavation are visible.

The measures taken ensured an increased biological stabilisation of deposited waste thus safer conditions during excavation due to the reduced biogas production potential of the waste. Moreover, the increased biological stability of the waste provided better conditions for handling and treatment after the excavation.

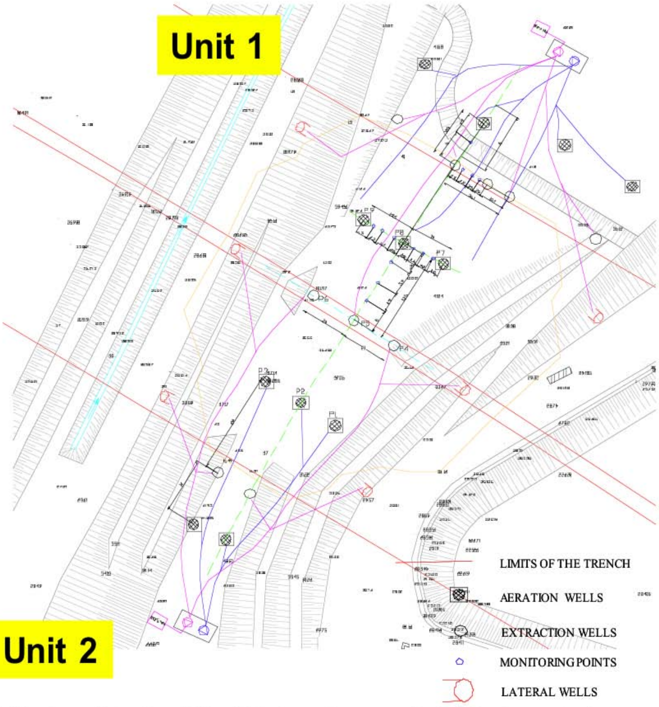

Figure 1. Aerobic stabilization of the Landfill of Modena. Lay-out of air injection and biogas extraction wells. Unit 1 and unit 2 are independent in order to enable continuous operation of the plant during the excavation of the trench between the two units.

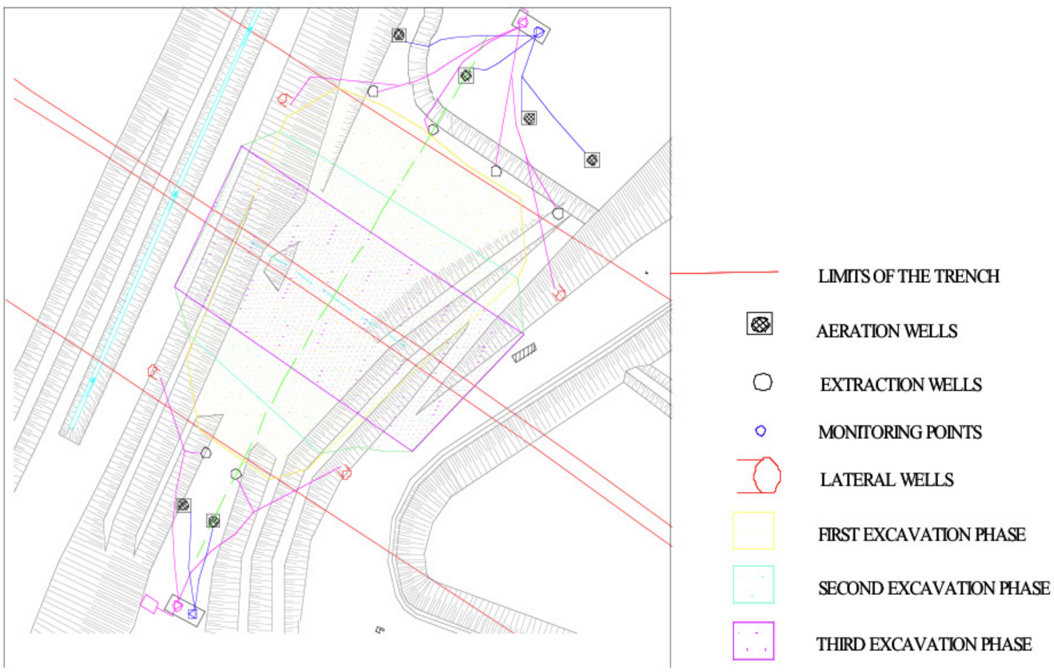

Figure 2. Lay-out of the in situ aeration plant during the excavation of the trench

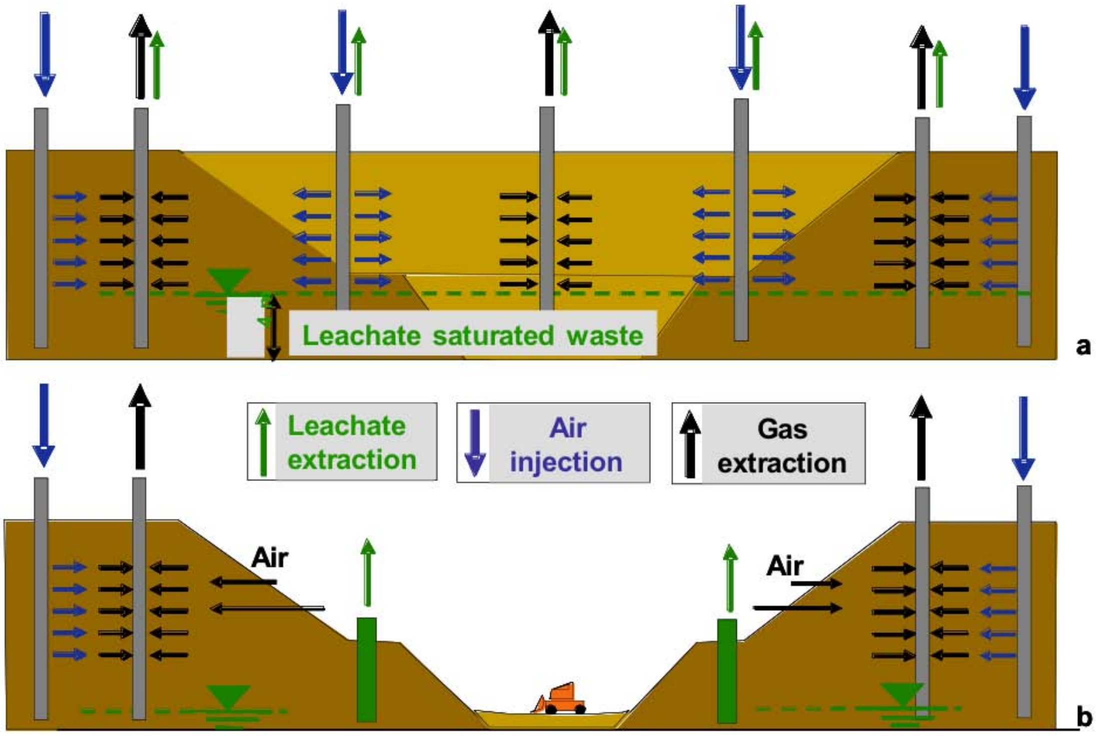

Figure 3. Transversal section of the area during the in situ aeration (a) and during the excavation works (b).

Proper investigations and preliminary tests are necessary to obtain all the necessary information to carry out the design of an in situ aeration plant and an effective monitoring of the stabilization process during the operation. Among others, the radius of influence of air injection and gas extraction wells and the pressure field in the landfill body during the aeration process have to be evaluated by means of pilot scale tests. Other preliminary investigations are related to waste characterization (i.e. biological stabilization) and the evaluation of mass balance of the organic carbon in the landfill for the estimation the expected conversion of organic carbon into $CO2$ during the in situ aeration, for comparison with what expected in the traditional anaerobic landfill.

In the paper some results of preliminary in situ aeration tests carried out in a landfill in northern Italy where landfill mining is foreseen are presented.

2. IN SITU AERATION TESTS

The in situ aeration tests were carried out in order to evaluate the feasibility of the application of in situ aeration in the landfill; moreover, relevant parameters for the design of the full scale plant were ascertained, the radius of influence of air injection and gas extraction wells and the pressure field in the landfill body during the aeration process among others.

In the paper some results of preliminary in situ aeration tests carried out in a landfill in northern Italy where landfill mining is foreseen are presented.

2.1 Description of the field tests

The field test have been carried out in a pilot plant with 4 purposely built air injection wells and 6 monitoring wells, each one of them comprising slotted pipes at various depths in the landfill. A sketch of the field test site is provided in Figure 4. A mobile unit equipped with blowers, air flow meters, manometers as well as a power supply unit was used for the test (Figure 5). Prior to the aeration test landfill monitoring has been carried out for:

- leachate head;
- biogas composition;
- temperature in the landfill body;
- efficiency of the air injection wells.

The tests for the evaluation of the efficiency of the air injection wells provided the data for making the pressure-flow rate diagram shown in Figure 6, where the effects of the heterogeneity of the waste deposited and the subsequent different response to air injection in different points in the landfill are clear.

Due to the high leachate head in the landfill some of the slotted pipes in the monitoring wells resulted to be positioned in the saturated part of the landfill and therefore they resulted useless for collecting biogas samples or for pressure monitoring.

Moreover, the presence of huge quantities of sewage sludge throughout the landfill caused the filling of some aeration wells up to unexpected levels. For this reason, proper pneumatic devices for the extraction of the sludge (as well as of the leachate) from the wells were designed and installed. The extraction of leachate and sludge from the aeration wells was successful and enabled better conditions to establish for the aeration as well as for the landfill mining activities foreseen in the landfill.

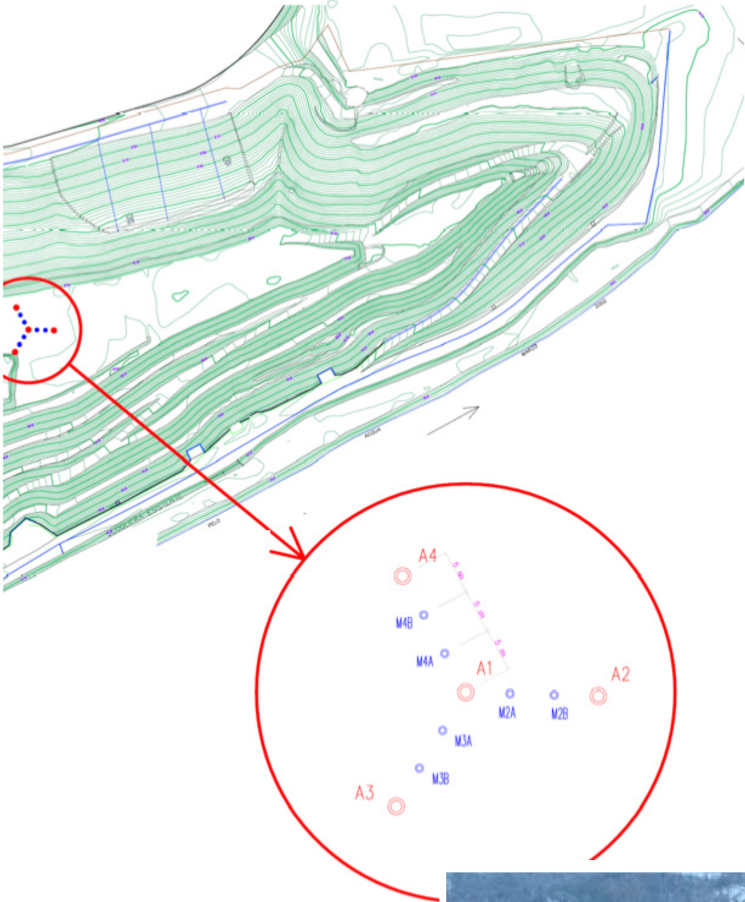

Figure 4. Location of the field tests in the landfill with a sketch of the position of the aeration wells A1÷A4 and of the monitoring wells (Mij).

Aeration tests involved air injection from one injection well at the time and monitoring of pressure and biogas composition in all other wells. Each test lasted approximately 6 hours and it was enough to reach significant O2 concentrations in most of the investigated part of the landfill (see an example in Figure 7).

The results showed that air distribution in the landfill body was satisfactory during the tests, although different behaviour was recorded during each of the tests, confirming the heterogeneity as well as the anisotropy of the landfill. The radius of influence of the wells installed was estimated in the range 10 - 15 m.

Figure 5. The air injection/gas extraction mobile unit used for the tests

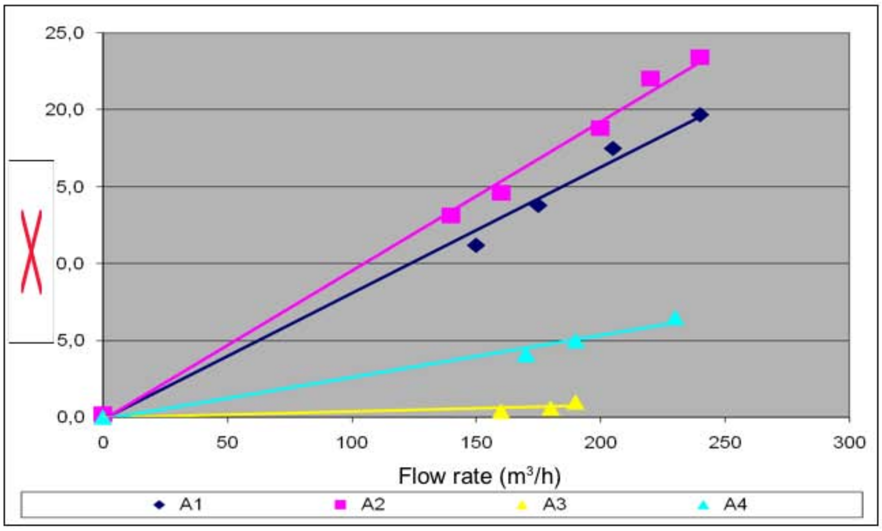

Figure 6. Example of pressure-flow rate diagram during air injection tests in wells A1 ÷ A4.

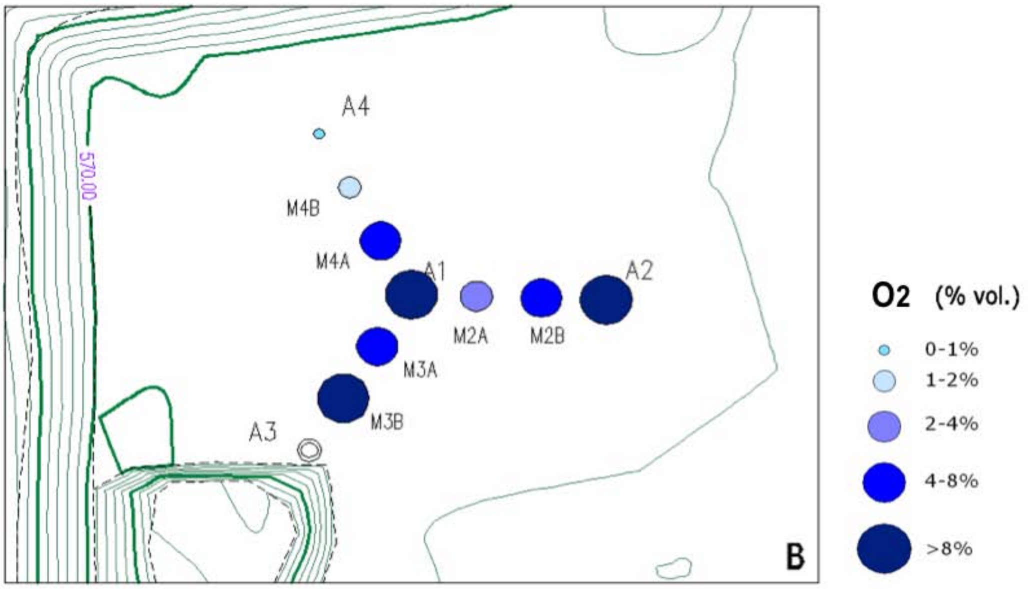

Figure 7: O_2 concentration (% vol.) in the monitoring wells 11 m deep in the landfill and in wells A1, A2 and A4 after a 6-hour air injection test from well A3.

3. CONCLUSIONS

Landfill aeration can be successfully used in the investigated landfill and would provide the conditions for the acceleration of biodegradation processes and the subsequent abatement of the long term pollution potential of the landfill, provided that proper measures are foreseen for lowering the leachate head in the landfill and for the removal of the sludge from the aeration wells.

At the same time the full scale in situ aeration would provide the conditions required for the foreseen landfill mining activities, with the minimization of biogas emissions expected in the excavation area. The enhancement of the biological stability of the waste and the reduction of the moisture content will provide further advantages during the handling of the excavated material and the subsequent treatment processes.

The tests carried out provided the following information (among others):
- O2 distribution in the landfill body was satisfactory during the tests, although different behaviour was recorded in the different points confirming the heterogeneity as well as the anisotropy of the land-

fill. The applicability of the Airflow technology for landfill remediation and as a pre-treatment before landfill mining was ascertained;

- the radius of influence of the wells installed was estimated in the range of 10 to 15 meters. These data will be used for the design of the full scale plant together with the other information obtained during the tests;
- leachate extraction from aeration wells proved to be successful despite the presence, in various spots in the landfill body, of a considerable amount of sewage sludge that migrated into the aeration wells. The system of pneumatic devices installed for sludge and leachate extraction was very effective and the tests provided useful indication for further improvement for the full scale application.

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Paper 10

Factors influencing business models for landfill mining

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Landfilling is a traditional method to dispose waste materials from the society. A rapid population growth and a strong economic development in many parts of the world have given rise to tremendous amounts of waste that need to be taken care of. In developed countries, introduced policies and regulatory measures have often led to a shift in a waste management practices; from landfilling to increased recycling, for instance.

On one hand, there is a number of environmental implications associated with landfills, while, on the other hand, the potential of recovering materials from landfills worldwide is huge. Environmental problems associated with landfills, rise in commodity prices and shrinking market size for landfill operating companies could eventually instigate companies into mining the landfills as their alternative business strategy to offer solutions to these problems. The ideas of industrial ecology could provide a framework for the business opportunities coming from waste generation.

However, a firm needs a model in order to effectively deal with the situation. It requires an identification of various issues which could be addressed while business model is constructed. This article has been aimed at identifying the factors that influence the companies' decision-making with regard to landfill mining as their business strategy. Osterwalder's business model (Osterwalder, 2004) has been selected as a framework and his business model template is used to identify and discuss the relevant issues. It is to be remembered, though, that it is not an aim of this essay to build a business model.

Four key areas and nine building blocks of business model are explained. Attempt has been made to link the issues of landfill mining with the components of business model, and essential factors which influence landfill mining were identified. Some of them were found to be infrastructural set-up, customer identification, cost and benefit, partners and lastly the sustainability attributes of the product and services from landfill mining business.

1. Landfilling and landfill mining

Landfilling is a traditional method to dispose waste materials from the society in open dumps (where waste is disposed without any environmental control measures) and modern sanitary landfills (landfills designed with environmental safety measures). A rapid population growth and a strong economic development in many parts of the world have given rise to tremendous amounts of waste that need to be taken care of and which is generating negative environmental impacts. In developed countries, introduced policies and regulatory measures have often led to a shift in a waste management practices; from landfilling to increased recycling (van der Zee et al., 2004), for instance.

On one hand, there is a number of environmental implications associated with landfills, while, on the other hand, the potential of recovering materials from landfills worldwide is huge. To dump discarded materials in landfills and not recovering them is a massive waste of a resource. In light of this, landfill mining is a proposed strategy to solve the problems and realize the potentials linked to landfills.

2. Landfill mining with business perspective

Environmental problems associated with landfills, rise in commodity prices and shrinking market size for landfill operating companies could eventually instigate companies into mining the landfills as their alternative business strategy to offer solutions to these problems. The ideas of industrial ecology could provide a framework for the business opportunities coming from waste generation.

There are some issues which make landfills a huge problem. First of all, the increasing amount of per capita waste generation, most of which flow into the landfills, is a problem because of scarce land for them. The public hostility towards landfills is another critical issue as no one wants landfills in their neighbourhood due to various health and environmental concerns. But at the top of it, the major environmental hazards linked to landfills are emissions to air and water. Noise, dust, odour, bio-aerosols and landfill gas cause atmospheric pollution, while emission of leachate to water courses and ground water brings negative impacts with it.

The rise in a commodity prices, metals in particular, could make landfills an alternative mine. The material flow studies suggest that very high proportion of discarded metals is buried in the landfills. For example, 1800 Gg of copper is globally disposed of in landfills in one year in 1994 (Harper et al., 2006). Spatari et al. (2005) calculated that 56 Tg of copper has been accumulated in landfills in North America during the past hundred years. In Europe, 52 percent of 920 Gg of discarded copper is landfilled every year (Bertram et al., 2002). Daigo et al. (2009) estimated the amount of copper dumped in landfills in Japan in 2000 to be approximately 114 Gg which is 34 percent of total uncollected copper. According to Müller et al. (2006), landfills are the third largest iron reservoir in the USA and contain 700 Tg of iron. Globally, 40 percent of discarded iron is disposed of in landfills (Wang et al., 2007) whereas this is 22 percent in case of chromium (Johnson et al., 2006). There are similar studies for zinc and silver as well (Graedel et al., 2005; Reck et al., 2006; Johnson et al., 2005; Lanzano et al., 2006).

Van der Zee et al. (2004) raised and issue of companies operating the landfills. Citing an example from the Netherlands, the decreasing trend in an amount of waste disposal into the landfill due to effective source-separated recycling and regulations led to the shrinking of market size for those companies. In the wake of this, landfill mining could be the alternative business strategy for them.

However, a firm needs a model in order to effectively deal with the situation. It requires an identification of various issues which could be addressed while business model is constructed. This essay has been aimed at identifying the factors that eventually influence the companies' decision-making with regard to landfill mining as their business strategy. Osterwalder's business model (Osterwalder, 2004) has been selected as a framework and his business model template is used to identify and discuss the relevant issues. It is to be remembered, though, that it is not the aim of this essay to build a business model.

3. Business model
According to Osterwalder (2004), a business model is defined as:
"a conceptual tool that contains a set of elements and their relationships and allows expressing a company's logic of earning money. It is a description of the value a company offers to one or several segments of customers and the architecture of the firm and its network of partners for creating, marketing and delivering this value and relationship capital, in order to generate profitable and sustainable revenue streams."

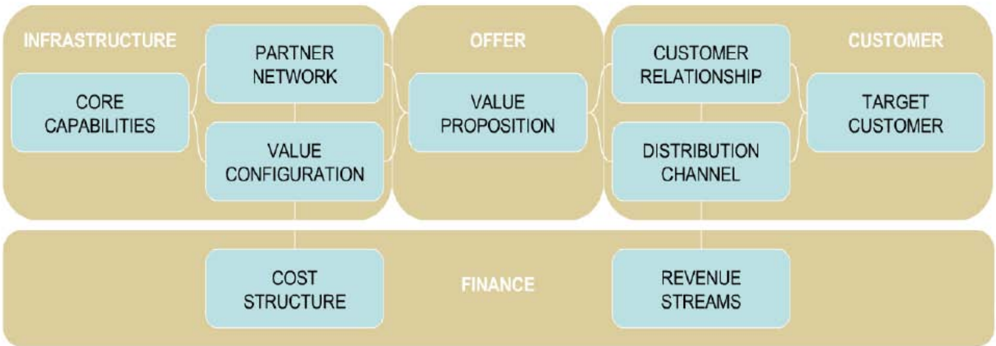

Figure: Business model (Osterwalder, 2004)

According to him, there are four areas which need to be dealt with in order to construct a business model. In his dissertation, he has divided these four areas into nine blocks. The short description (Osterwalder, 2004) of every aspect is provided below:

I. Product: This represents the company's business and its products and value proposition.

II. Customer interface: This defines the target customers, the way to deliver the product and build a strong relationship with them.

III. Infrastructure management: Explains how a company addresses infrastructural issues, with whom and as what kind of network enterprise.

IV. Financial aspects: Here the revenue model and the cost structure is identified.

The nine blocks based upon above four issues are, according to Osterwalder (2004), as follows:
i. Value proposition: Package of company's products and services which is of certain value to the customers.

ii. Target customers: These are the customers to whom a company wants to offer a value.

iii. Distribution channel: Means of getting in touch with the customers.

iv. Customer relationship: A kind of link a company establishes between itself and the customer.

v. Value configuration: The arrangement of activities and resources that is necessary to create value for the customer.

vi. Capability: The ability to execute a repeatable pattern of actions necessary to create value for the customers.

vii. Partnership: Voluntarily initiated cooperative agreement between two or more companies in order to create value for the customers.

viii. Cost structure: This represents money of all means employed in the business model.

ix. Revenue model: The way company makes money through a variety of revenue flows.

4. Discussion
4.1 Product: Since the products from the landfills are wastes, there can be two types of competitors the company can have; one similar to them and other different competitors offering similar product. The competitive quality and price of the product that company can offer are two parameters for them to make decisions.

4.1.1 Value propositions: It is necessary to identify the type of products landfills can offer to the customers. This may vary from landfill to landfill which consequently influence the design of the business model. At the same time, it requires response to the questions such as will our value proposition solve the customer's problems or satisfy our customer needs. Investigations about whether the company's competitors are offering the product in competitive prices and whether they are satisfying the customers well. In general, soil fraction, metals, fuel for waste-to-energy plants and other recyclable materials are the products that a landfill mining company can offer

4.2 Customer interface: This constitutes recognizing the customers, the delivery of the offer and the relationship with the customers.

4.2.1 Target customer: The identification of the target customer is crucial. Depending upon diversity in products, those customers could be landfills, waste-to-energy plants, recycling companies, metal industries and so on.

4.2.2 Distribution channel: The identification of effective distribution channel depends upon definition of target customer. But in landfill mining, most of them are business-to-business customers than business-to-consumer ones.

4.2.3 Customer relationship: Customer relationship strategy needs to be explained. This type of relationship is not given an importance and forgotten in some business models while focuses are on other aspects such as products (Dubosson-Torbay et al., 2002: p8). In order for business to flourish, this relationship can be strengthened through three strategies of acquisition, retention and add-on selling to the customers.

4.3 Infrastructure management: In landfill mining, this corresponds to a technological and logistics aspects of landfill mining as well as the partner companies who work together to create value for the customers.

4.3.1 Value configuration: The key activities of landfill mining have to be categorized so that it could be decided on the potential firms which can take part in the venture. This is because one firm cannot perform too many activities which may result in lack of focus and inefficient operation.

4.3.2 Capability: It is the asset or resource the firm possesses. Here it may refer to a procedure, methodology, technology and skills which are essential for landfill mining operation.

4.3.3 Partnership: Using too many resources internally or performing too many activities is not recommended. To work in unison with different partners and well-defined system could be efficient. Some firm might supply the technological set-up, while some might work on logistics, for instance.

4.4 Financial aspects:

4.4.1 Cost structure: This element in the model could be the most crucial deciding factor in order to initiate the venture. Costs are in key activities and key resources. Fisher and Findley (1995) explored the economic aspects of landfill mining which is dependent on the unique circumstances of the individual landfill. Some of the factors which governs the cost are landfill volume and topography, soil conditions, climate, labor rates, regulatory approval process, contractor's fee, excavation and screening costs and so on.

4.4.2 Revenue model: It is to translate the product value into money and make sure that a firm has an ability to generate revenue streams (Osterwalder et al., 2002:

The factor of success or failure behind landfill mining is the economic performance it generates. One issue will be whether the excavated waste worth the economic returns while in case of potential economic exploits, whether the recovered materials can compete in the market. (Ranjit, 2009: p23) Since the rise in the metal prices has hit the industries badly (www.guardian.co.uk), landfill mining could flourish if it can offer the metals to the industries with the lower price and similar quality. On the other hand, according to one source, the feasibility of landfill mining depends on the price of the commodity. The decline of commodity price made landfill mining less feasible (www.propubs.com).

As explained in Osterwalder et al. (2004: p3), a business model needs to be complemented with the integrity constraint such as "at least one value proposition of the company must be connected to a revenue stream that generates income from a specified target customer segment". This is important when the intent is to establish a sustainable business. For example, the combustible waste fraction could be sold to waste-to-energy facilities, but this is not sustainable for them and consequently they would not be interested in relationships with landfill mining companies. But this problem can be solved by setting up own temporary small-scale plants that directly connects to a grid. The company's customer then would be electricity distributors rather than the waste-to-energy facilities.

5. Conclusion
While some aspects of above discussed areas have been identified and explained, other ones have not been explored in detail. Some areas require much weight than others. With the help of Osterwalder's business model framework, the key factors which influence the business models for landfill mining would be the products from landfills, the infrastructural set-up, customer identification, cost and benefit, partners, identifying distribution channel, establishing customer relationship strategy, categorizing key activities, and lastly the sustainability attributes of landfill mining business. It is recommended to be investigated in detail how these factors influence business models in landfill mining.

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GLOBAL LANDFILL MINING CONFERENCE AND EXHIBITION

Proceedings Index.