International Bioenergy Forum: China –EU Cooperation

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Conference Proceedings (Excerpts)

The International Bio-energy Forum met in Guangzhou, P.R. China from 28-30 September 2003 to discuss cooperative efforts in the field of bio-energy between China, the EU and supporting countries. This forum was organized jointly by the Ministry of Environment of Guangzhou, the Guandong University of Technology, the European Biomass Industry Association (EUBIA) and the Global Network on Bioenergy.

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Updated information on this workshop is available at http://www.bioenergy-lamnet.org.

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THE MUNICIPAL SOLID WASTES (M.S.W): AN ENERGY IMPORTANT BUT ENVIRONMENTALLY PROBLEMATIC RENEWABLE ENERGY SOURCE

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The M.S.W. is a Renewable Energy Source (R.E.S)

Around 60% by weight of household waste is Paper and bio-waste and, as such, their combustion or the combustion of their degradation products is CO_2 neutral.

This means that the energy released by combustion is revived wholly from R.Sources, such as wood and green wastes, that absorb CO_2 whilst they are growing.

So, generation of energy from landfill gas or from the combustion of the wastes reduces the use of fossil fuels and diverts the methane produced, when waste is landfilled, thereby contributing strongly towards greenhouse gas (methane + CO_2) reduction targets.

Table 1. Typical Composition of M.S.W
(Source: Waste Management Paper No 26A, 1992 U.K.)

Constituent	Weight % (as received)
Paper	29.2
Putrescibles	19.0
Textiles	3.0
Unsorted Fines	8.6
Miscellaneous Combustibles	5.8
Miscellaneous Non-combustibles	4.0
Wood	2.2
Glass	8.4
Garden Waste	3.8
Ferrous Metal	8.0
Non-ferrous metal	1.0
Plastic Film	4.2
Dense Plastics	2.8

Moisture content = 33% by weight
Bulk density, uncompressed = 170 kg/m^3
Gross calorific value = 9,260 kJ/kg
Net calorific value = 7,630 Kj/Kg

The Energy, Economic and Environmental problems of E.U.

The Energy, Economic and Environmental problems of E.U. are summarized in the following figures 1, 2 and 3.

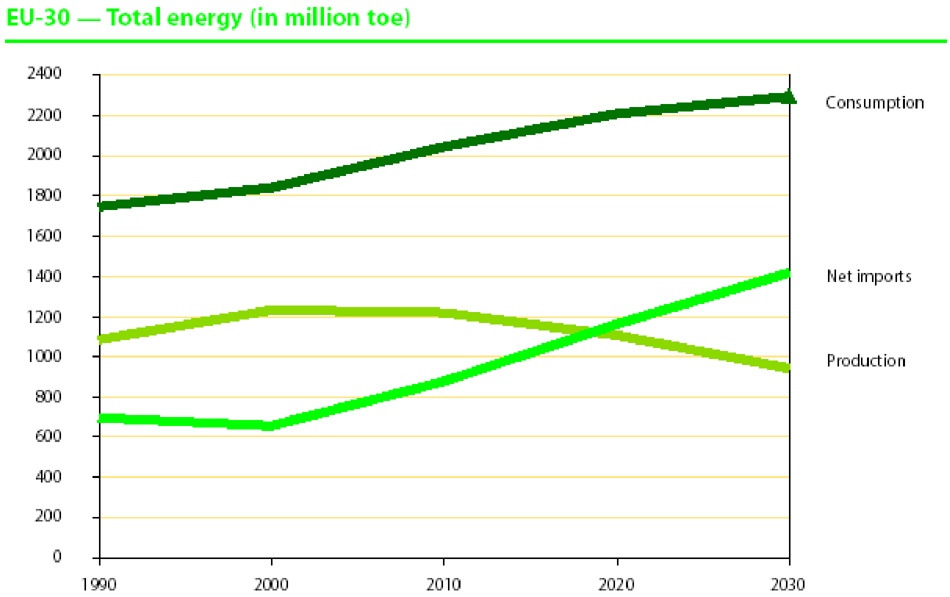

Fig. 1. The Dependency on Energy imports of EU-30. The total imports are composed from Solid fuels, Oil, Natural gas and Uranium.
(From. E. Commission's Green Paper)

The European Community energy resources will be depleted depends not only on the extent of known reserves, but also on the price of oil and gas on the world market, and on technological progress, as the new extraction technologies may mean that, in time, the recovery rate could rise from 20-40% of deposits, to 60%

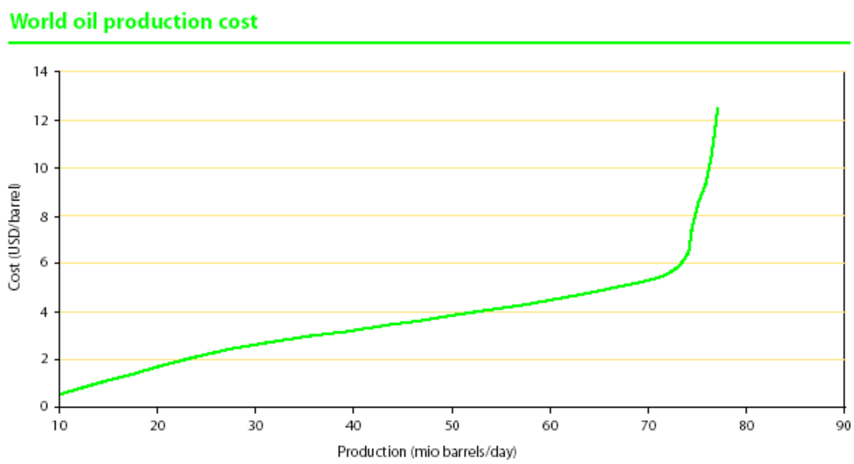

Fig. 2. The evolution of the World Oil Production Cost and quantities.
(From. E. Commission's Green Paper)

The biggest part of CO_2 production is due to the fossil fuels (oil, gas and coal) consumption

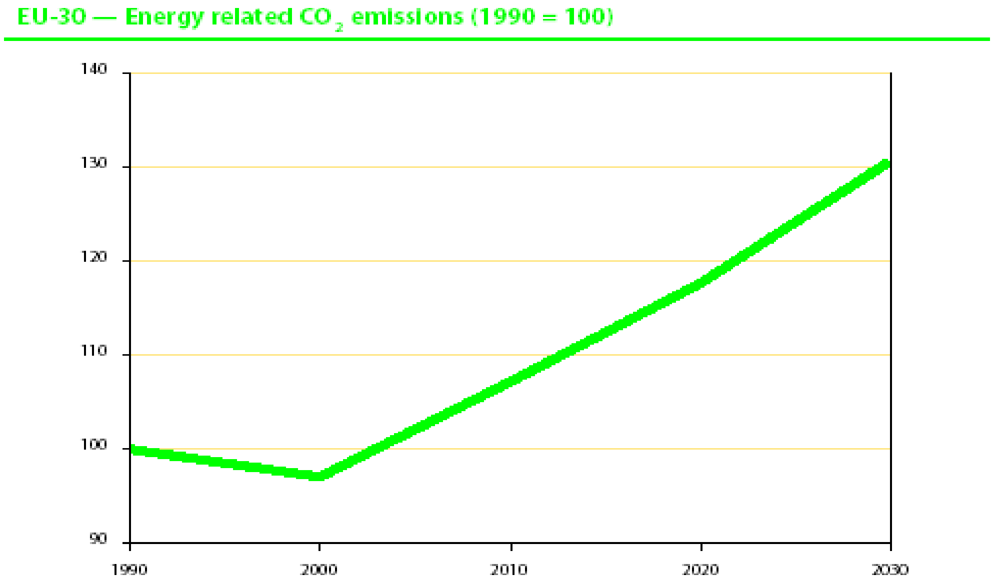

Fig. 3. The EU-30 energy related CO_2 emissions (1990=100) quantities.
(From. E. Commission's Green Paper)

Finally according to the E. Commissions' Green Paper the following three main points are emerging concerning the Energy problem of the EU-30

- The European Union will become increasingly dependant on external energy sources and enlargement will not change the situation, based on current forecasts, dependence will mach 70% in 2030.
- The European Union has very limited scope to influence energy supply conditions. It is essentially on the demand side that the EU can intervene, mainly by promoting energy saving in buildings and the transport sector
- At present, the European Union is not in a position to respond to the challenge of climate change and to most its commitments, notably under the Kyoto Protocol.

The Renewable Energy Policy of E.U.

According to the E. Commissions' Green paper (1), priority must be given to the fight against global warming. The development of new and renewable energies (including biofuels) is the key to change, doubling their share in the energy supply quota from 6 to 12% and raising their part in electricity production from 14 to 22%, objectives to be attained between 2000 and 2010.
In a Study (3) made in the frame of the Altener Programe of E. Commission, the penetration of Renewable Energy Sources for the E.U.-15 could reach 228 TOE by the year 2020. (see fig. 4). In that figure we can see also the estimated biomass energy from the M.S.W., that represents almost 25% of the expected total energy from R.E.S.

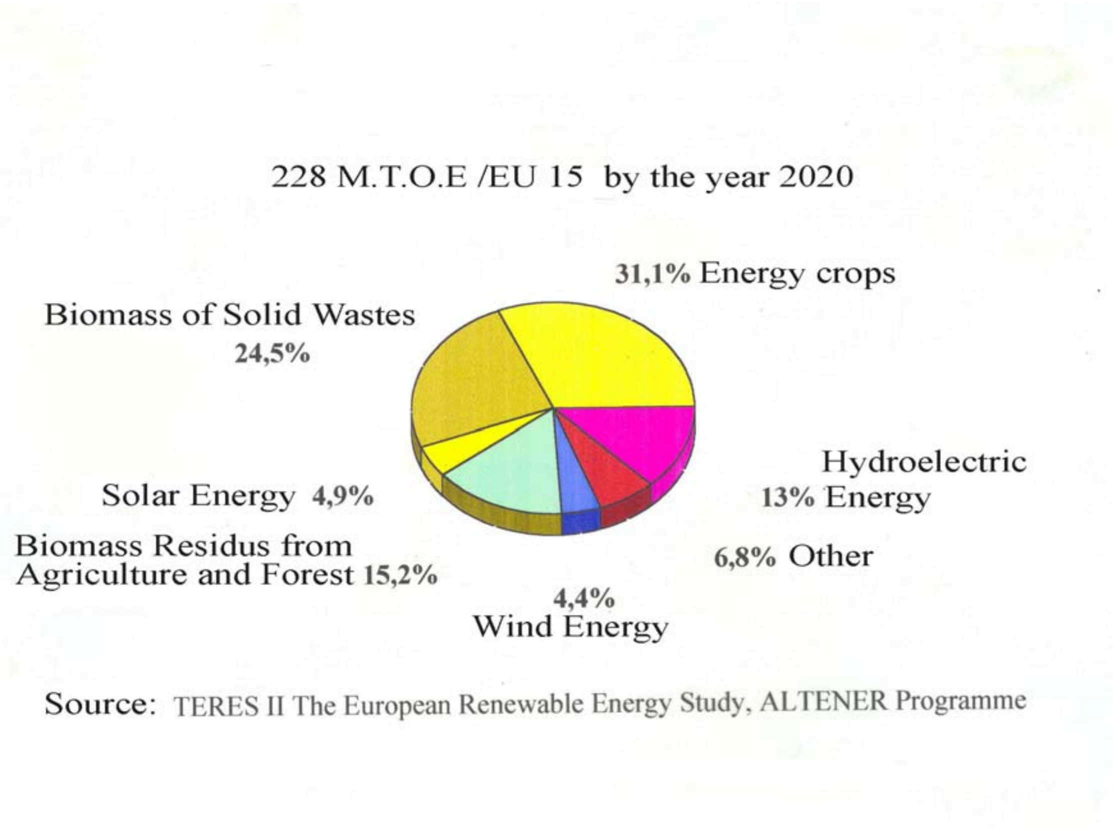

Fig. 4. The possible penetration of different renewable energy sources by the year 2020 in the 15 Countries of E.U.

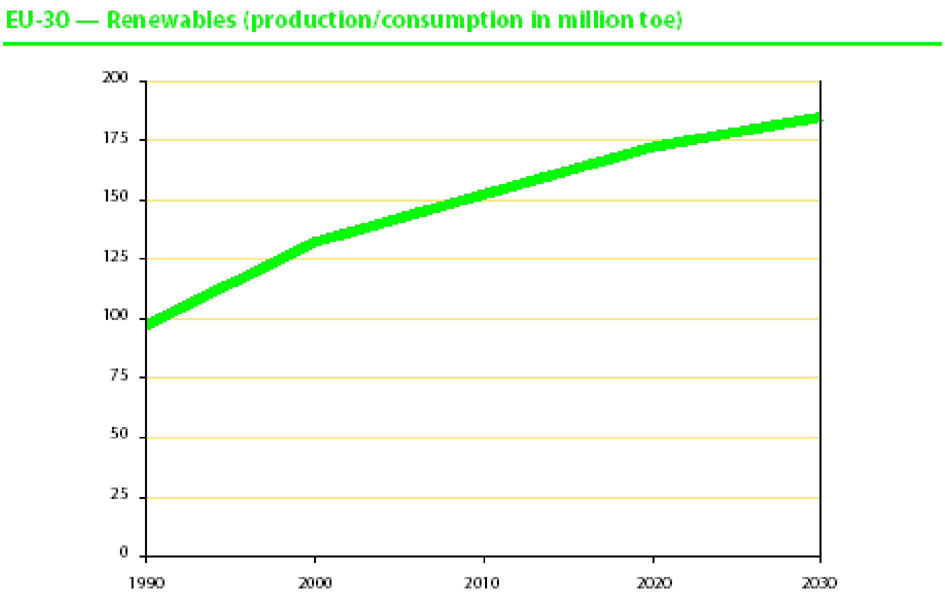

Fig. 5 The Estimation of the E.Commissions' green paper for the penetration of the Renewables to the E.U.-30 Countries

The Energy Content of M.S.W

The energy content of waste can be calculated by a number of techniques, including the modified Dulong equation which is based upon the percentage content of carbon (C), hydrogen (H), oxygen (O) and sulphur (S), and by the use of calorimetry. An equation based upon the percentage (by weight) of food waste, cardboard and paper, plastic, and rubber has also been developed (Khan and Abu-Ghararah, 1991). Using this method, derived values have been shown to be approximately 1-10% higher than values derived using the modified Dulong equation. (It is not necessary to go into the details of these calculation techniques, as it is their results that are of use in this paper). The energy stored within wastes can be utilised in a number of ways. The most common methods are energy from waste (EfW) incineration (with or without energy recovery), and the collection and combustion of landfill gas (in which case much of the stored energy is retained within the methane gas).

Material	CV MJ/kg wet weight (moisture content 20-30%)
Dust and cinders	9.6
Paper	14.6
Vegetables	6.7
Metal	nil
Glass	nil
Rag	16.0
Plastic	37.0
Unclassified	17.6

Table 2 Average calorific value (C.V) of components of M.S.W (2)

The technologies for the energy valorization of M.S.W

Considering the composting of the organic content of M.S.W and the Recycling of other components, as an indirect energy source, there are several technologies for the energy valorization of M.S.W. in practice. From all these technologies in practice we have to look for the Best Practicable Environmental Option (B.P.E.O) in each case, because there is no any technology without disadvantages.
In our days the most applied in practice technologies for ENERGY VALORISATION are the land filling of M.S.W and the incineration of M.S.W (EfW plant).

1. **Landfilling of M.S.W**

According to the European Landfill Directive and RCRA in the U.S.A, a landfill is considered as sustainable if the final quality of the landfilled M.S.W is completed within 30 years, (or in one generation), that means that, waste must be either pre-treated to a state close to final storage quality, or the stabilization within the landfill must be accelerated.
Disposal of M.S.W. to a landfill means that either all the mass of the M.S.W , or part of it is dumped in places with special conditions in order to avoid the leaching of the produced liquids and the emissions of the produced gases and to create anaerobic conditions for the biodegradable elements.

The **biodegradable** elements of waste disposed to landfill are vegetable matter, paper and cardboard and to some extent, textiles. The composition of municipal refuse varies from country to country and will vary from season to season. In the developed world it typically contains about 60% carbohydrate, 2.5% protein and 6% lipid, the balance being comprised of "inerts" and plastics. Carbohydrates therefore comprise approximately 85% of the **biodegradable** material within municipal refuse, the overall breakdown of which can be represented by the equation:

C6H1206 > CH4 + CO2 + Biomass + Heat
(Carbohydrate) > (Methane) + (Carbon dioxide) + (Bacteria) + Heat

Methane gas is a high-energy fuel with approximately 90% of the energy stored in carbohydrate being retained in the methane. The conversion of carbohydrate to methane is therefore a highly energy efficient process, and much of the energy stored in the carbohydrate is contained within the methane gas. **Because of the high-energy value, the methane can be used beneficially as a heating fuel and for other energy production.**

Table 3. Typical Composition of landfill gas

Component	Typical Value (% volume)	Observed Maximum (% volume)
Methane	63.8[1]	88.0[2]
Carbon Dioxide	33.6[1]	89.3[1]
Oxygen	0.16[1]	20.9[1,3]
Nitrogen	2.4[1]	87.0[2,3]
Hydrogen	0.05[4]	21.1[1]
Carbon Monoxide	0.001[4]	0.09[2]
Ethane	0.015[4]	0.0139[2]
Ethene	0.018[4]	-
Acetaldehyde	0.005[4]	-
Propane	0.002[4]	0.0171[2]
Butanes	0.003[4]	0.023[1]
Helium	0.00005[4]	-
Higher Alkanes	<0.05[2]	0.07[1]
Unsaturated Hydrocarbon	0.009[1]	0.048[1]
Halogenated Compounds	0.00002[1]	0.032[1]
Hydrogen Sulphide	0.00002[1]	35.0[1]
Organosulphur Compounds	0.00001[1]	0.028[1]
Alcohols	0.00001[1]	0.127[1]
Others	0.00005[1]	0.023[1]

1 Data taken from Waste Management Paper No 26
2 Published data supplied by Aspinwall & Company
3 Entirely derived from the atmosphere
4 Taken from Guilani, A J "Application of conventional oil and gas drilling techniques to the production of gas from garbage" American Gas. Association Transmission Conference, Salt Lake City, Utah, 5-7 May 1980
5 Landfill gas is usually saturated with water vapour, up to 4% by weight, depending on the gas temperature. At 25^{0}C a value of 1.8% by weight is typical
6 When undertaking initial confirmatory analysis by gas chromatography, the first five compounds listed above are usually identified when looking for the presence of landfill gas.

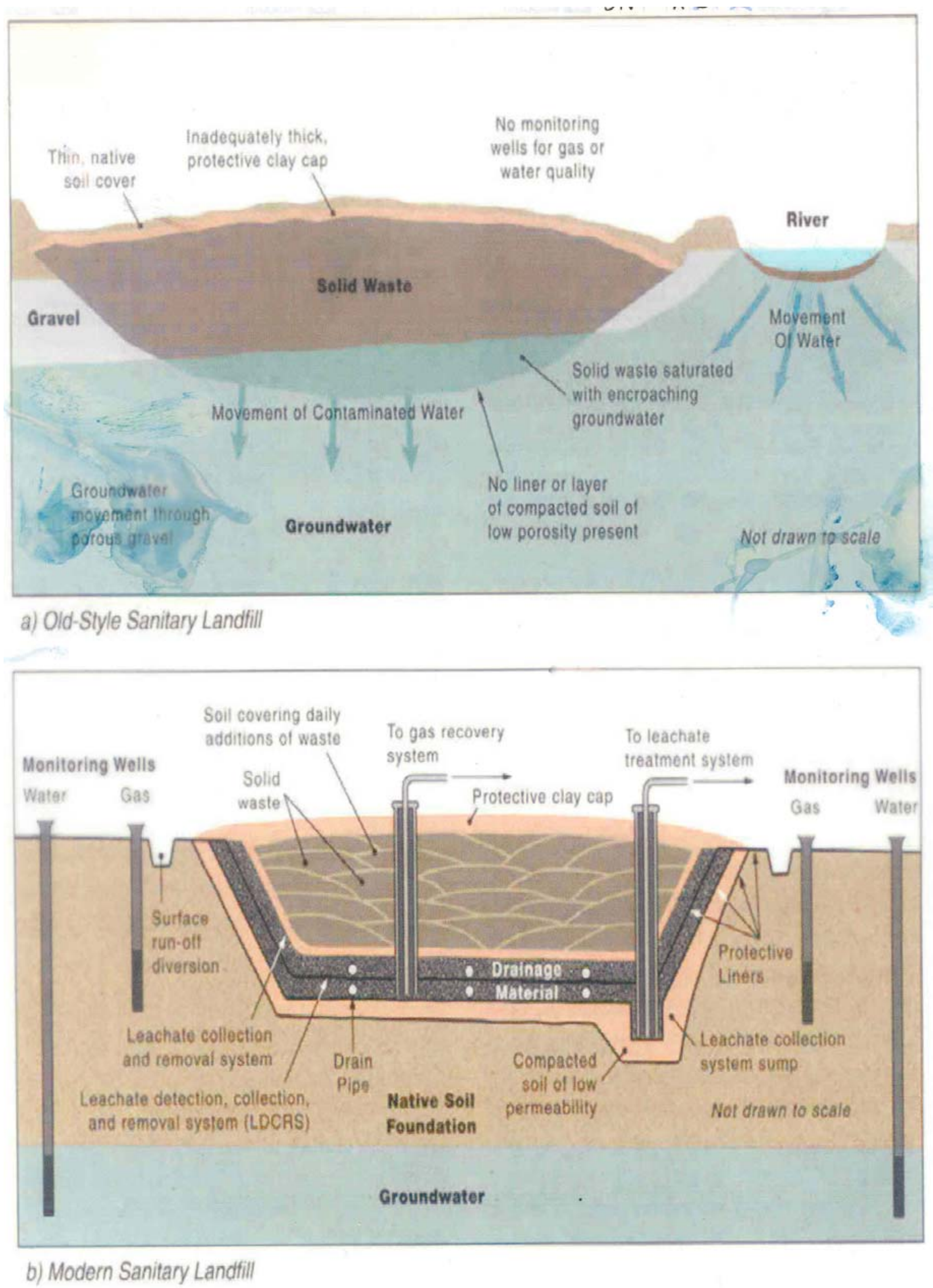

Fig. 6. Characteristics of two different Landfill sites (4)

Table 4. Typical Composition of Leachates from Domestic Wastes
(fig. In mg/l except PH)

Determined	Fresh Wastes	Aged Wastes	Wastes with high moisture contents
pH	6.2	7.5	8.0
COD	23800	1160	1500
BOD	11900	260	500
TOC	8000	465	450
Volatile acids (as C)	5688	5	12
NH_3-N	790	370	1000
NO_3-N	3	1	1.0
Ortho-P	0.73	1.4	1.0
CI	1315	2080	1390
Na	9601	300	1900
Mg	252	185	186
K	780	590	570
Ca	1820	250	158
Mn	27	2.1	0.05
Fe	540	23	2.0
Ni	0.6	0.1	0.2
Cu	0.12	0.03	-
Zn	21.5	0.4	0.5
Pb	0.40	0.14	

Source: Waste Management Paper 26A (DoE)

In a modern Landfill considering as sanitary, we have to control the Leachate and the Cases.
The control of the Leachate can be obtained by Natural Liners (like argile, bentonite etc.) and by Geomembranes. (plastics)

For better results we use a combination of natural liner and geomembranes and we collect the penetrated (by accidents or by other means) liquids.

The control of landfill gases can be partially avoided by

- controlling waste inputs
- controlling the processes of biodegradation
- controlling the migration process (reduce pressure, barriers etc)

We distingue the **passive control**, opening gas wells, and putting vent trenches and the **active control** installing array of vertical and horizontal pipes and blowers.

The Energy Production in a landfill

In practice (2) only a little more gas than 100 m^3/t is collected, but the production is much more.
For effective utilisation in gas engines or turbines, the methane content of landfill gas should be approximately 50%. However, where gas collection is used primarily for the control of migration and the protection of `sensitive targets, then the methane content of the gas is often much less than 50% in order to maintain a flame at the gas flare. For this reason, **it is important to clearly identify at the outset whether the gas collection system is for gas control or energy generation**. Local site conditions may require the use of both types of system where, for instance, peripheral wells are used for gas migration control and central wells are used for collection with subsequent utilisation for electricity production.

It is also possible for wells to be designed and built to accommodate both systems and to be switched from one purpose, to the other, when the situation demands. In this case, the cost of such a system will be much higher than a simple system and this must be accounted for when calculating the **economic feasibility**.
The high moisture content of landfill gas and the presence of trace corrosive gases requires that the collected gas should be pre-treated before combustion in a gas engine.

The future of Landfilling of M.S.W

Today we consider that there is no future of Landfilling of M.S.W and so there is no future of Landfill Gas, because of the:

- limited Void Space
- E.Commission Landfill Directive
  - biodegradables to landfill (75% in 5 years, 50% in 8 years, 35% in 15 years)
  - gas collection on all sites is an obligation
  - pre-treatment before land fill is an obligation
  - packaging waste regulations

2. Waste – Incineration

The combustion of waste as a fuel is more and more seen in Europe as a preferable alternative to landfill, where appropriate, and is receiving much support as a waste treatment. Especially after the E. Commission" decision to prohibit gradually the landfilling of the organic part of the M.S.W., incineration is the Most Practical Environmental Option (M.P.E.O.)
On the other hand, the today progress of the technology reducing the release of the toxic and other emissions (Dioxins, Heavy metals, No_x, So_x etc) from the incinerated M.S.W., gives may be to the EfW plants the unique B.P.E.O today.

A better solution, environmentally speaking, is the recycling of several materials before the incineration.

Wallis and Watson (1995) had estimated that recycling materials can save 2-5 times the amount of energy recoverable by incineration. However recycling is not always feasible, for reasons of material contamination (e.x. heavy metals into compost), or because of the lack of interest in the market. (ex. glass)

The reality in practice is that, if all combustible waste were incinerated, it could provide as much as 5% of western Europe's domestic energy needs. Russotto (1996) and ETSU (U.K.) has calculated that electricity – only schemes from M.S.W. will reduce fossil carbon emissions by 29% and for CHP schemes 78%.

Recycling prior to incineration does not mean that the energy content of M.S.W. per Kg is not interest anymore, see fig. 7.

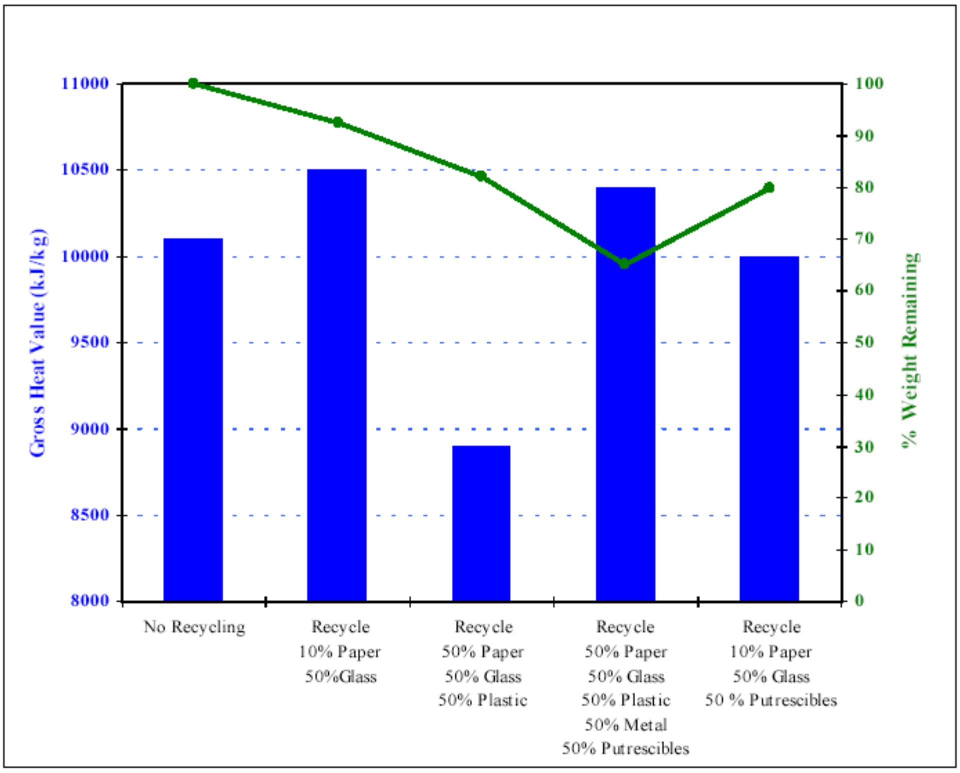

Fig. 7 Recycling scenarios and Heating Value of the remaining part of M.S.W (2)

The Energy from Waste incineration

According to Porteous (1997) the main energy properties of M.S.W. can be summarized to the following table:

CV	10,600 MJ/kg
Moisture	31.2% w/w
Combustibles	44.6%
Inerts	24.2%

Incineration is a thermal oxidation process in which carbon is oxidised to carbon dioxide and hydrogen is oxidised to water:

C + O2 = CO2

2H + ½ O2 = H2O

The Relative Atomic Mass (RAM) of each of the elements involved is shown in the following table.

The relative atomic masses of carbon, oxygen and hydrogen

Element	RAM
Carbon	12
Oxygen	16
Hydrogen	1

This means that 12g of carbon require 32g of oxygen and produces 44g CO_2. Therefore 1g of carbon requires 2.67g (=32/12g) of oxygen and produces 3.67g (44/12g) of CO_2.
Also, 1g of hydrogen requires 8g of oxygen to produce 9g H_2O

From the ultimate analysis (table) MSW contains 24% carbon and 3.2% hydrogen by weight i.e. 1g of MSW will contain 0.24g of carbon and 0.032g hydrogen.

0.24g carbon requires 0.24 x 2.67g = 0.641g oxygen

0.032g hydrogen requires 0.032 x 8g = 0.256g oxygen.

But there is 0.159g oxygen already present (from the ultimate analysis in table 5) and hence the amount of oxygen required to complete combustion = (total required)-(oxygen already present) = (0.641g + 0.256g) - 0.159g = 0.738g (per g MSW).

Now air comprises 23.15% oxygen and 76.85% nitrogen by weight and hence the air equivalent to 0.738g O_2 is 3.21g. So 3.21g air is required to burn 1g MSW.

From Porteous (1997): if we assume 100% excess air (i.e. twice as much air present as is needed) then 6.4g air will be required to burn 1g MSW and therefore the total input will be 7.4g material. The output from the combustion of MSW is shown in Table 5.

Table 5. Outputs from M.S.W incineration (Porteous 1997)

Material	Mass (g)
CO_2	0.881
H_2O	0.288
O_2	0.738
N_2	4.9
HCl	0.007
Ash residue	0.242
Water vapour (from MSW)	0.312
Total output (rounded off) = 7.4	

The advantages of M.S.W incineration are:

a. <u>Energy from waste</u>**:**

- Provides an alternative energy source saving finite resources by replacing fossil fuels (every 3 tons of MSW burned saves 1 ton of coal)
- Extracts value as energy from materials that are not recyclable
- Sterilises waste enabling safe disposal of residues
- Offers an efficient and cost-effective method of recovering materials such as metals for recycling

- Destroys contaminants and pollutants in waste allowing for more easily controlled monitoring and measuring of these products
- The today Dioxin removal technologies and the technologies and methods for the Heavy Metals neutralization meet by far the E.U. directive for the M.S.W. incineration (89/369/EEC).
- Reduces the volume of waste by 90% and the weight by 70% saving landfill space and transport costs

b. Other Products from the M.S.W incineration

From the incineration of 1 t of M.S.W. it could be obtained on average:

- 225kg bottom ash
- 23kg ferrous metals
- 20kg fly ash from the flue gas cleaning equipment
- 1kg non-ferrous metals (mainly copper and aluminum)
- 15kg air pollution control (APC) residues

Other M.S.W. Management options

Some of the most promising technologies for the M.S.W. Management are:

- Recycling and Treatment of cellulose for Levulinic Acid production and other Chemicals production from hemicelulose
  This technology developed in U.S.A. (presidential award), has succeed to reduce by more than 90% the cost of the Levulinic Acid production in comparison with the known procedures.
- Recycling and Composting
  This technology can be run in parallel with the combustion and recycling. It is considered as the most **green** option if the final product (compost) is clean from toxic elements (this can be reached only in a part of the organics)
- Plasmolysis

This technology is under investigation in the Research Laboratories

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