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Biogas energy recovery

Elena Argelich Hesse, Environmental Metropolitan Agency of Barcelona

Introduction:

Environmental Metropolitan Agency from Barcelona

In 1987, a law was passed in the Parliament of Catalonia that gave birth to the Metropolitan Body for Hydraulic Services and Waste Treatment (EMSHTR), also known as the Environmental Metropolitan Agency from Barcelona.

Its competence includes treating and exploiting municipal waste, providing services such as supplying drinking water, wastewater disposal and inspecting and controlling discharges of industrial wastewater.

In this context, the actions of the Body are based on environmental criteria in accordance with the principles of the Letter of Sustainable European Cities and Towns (Aalborg Letter), which the Environmental Control Body is party to, the same as other documents such as the Lisbon Plan for Action and the Rio Declaration.

The territorial scope of the Environmental Control Body includes a total of 33 districts, covering a surface area of 585 km2, which is home to around 3 million inhabitants, or almost half the entire population of Catalonia.

The controlled disposal site of Vall d'en Joan

The controlled disposal site of Vall d'en Joan appears today as an irrefutable exponent of the Environment Metropolitan Entity environmental policy, and it is a clear example of the gradual but meaningful advance of the new approach of the Municipal Residues Management Metropolitan Program (PMGRM), in development since 1997.

In fact the controlled disposal site of Garraf has moved from the old practice of "elimination of municipal residues" to its adaptation to the new emerging paradigms that claim for residues treatment system more respectful with the environment and with the territory.

Precisely for this, the actual controlled disposal site of Vall d'en Joan is of meaningful relevance. We are in front of an infrastructure of elimination in progressive deactivation regime, with a scheduled closing date fixed (2006) and with a simultaneous process of morphological, physical and vegetal restoration. This actuation should enable a wide consensus regarding the selective pick ups and the needed construction -partially achieved already- of new alternative installations of recovering, valuation and treatment of our residues.

The sustainable management

The sustainable management of the Garraf controlled landfill site involves devoting economic, technological and human effort and resources in order to keep the environmental impacts normally associated with this kind of infrastructure to a minimum.

The recovery of the biogas generated by the decomposition of organic waste, the collection and treatment of the liquid waste produced (leachates), and experimenting with new systems of refuse disposal are the three main axes along which action can be taken, with a dual aim to prevent negative effects on the site and the territory and to take advantage of its energy resources.

Also, and in accordance with Directive 1999/31/EC on waste disposal, since some time ago the disposal of biodegradable waste has been limited as the provisions of the PMGRM have been deployed.

Biogas energy recovery

The anaerobic decomposition of the organic matter present in deposited waste generates biogas, a gas which basically consists of methane (CH4) and carbon dioxide (CO2), at approximate percentages of 55% and 45% respectively. It also has other minor components such as upper hydrocarbons, hydrogen sulphide (H2S), ammoniac (NH3), oxygenated and halogenated organic compounds and siloxanes (silicon and hydrogen compounds), among others.
Methane is a gas which contributes to the greenhouse effect, with a global warming potential -or GWP- 21 times higher than CO2; that is to say, the equivalent, in the case of the Garraf landfill site, of 600,000 tonnes of CO2 per year. This is why recovering this potential not only contributes a highly valuable energy yield but also avoids local and global environmental impact.
The amount and composition of the gas generated depend on a variety of factors such as the type of waste, the intrusion of water, the kind of surface cover, the work method applied, etc.
Currently European standards (1999/31/EC on waste disposal) and Royal Decree 1481/2001 oblige the proper collection and treatment of the biogas produced. Thus, once the site is closed, the biogas can continue to be recovered as long as its proportion of methane is higher than 40%, a condition which will be fulfilled for approximately fifteen years after closure, given that as of the time of closure, both biogas production and methane content start to dwindle.
In the case of the Vall d'en Joan site, the biogas, which is considered a renewable energy source, is used to generate electrical energy.
To collect the biogas, there are currently more than 300 wells some 20m deep on average, dug down into the waste mass and uniformly spread across the surface of the controlled tip. These wells are connected to the suction station via a network of collectors that send the collected biogas to the generator groups.
The production and decomposition characteristics of the extracted biogas are checked. Before sending the biogas to the motors, its composition is made suitable by changing the extracted flow so that the richness in methane can be regulated and the concentration of oxygen can be controlled. Moreover, through the use of suitable devices, humidity content can be kept to a minimum. For any surplus biogas that cannot be used by the motors, a suitable flare is fitted that burns it offer at high temperature (over 1,000 ºC).
In this way, the forced suction collecting system (in such a way that the collection wells are permanently subjected to a slight depression), keeps leaked biogas emissions through the surface of the landfill site to a minimum.
It is only possible to appreciate this system with the naked eye in the areas that are pending restoration, as a set of collection tubes and aerial conduits. Conversely, in the areas that have been closed definitively and restored, the biogas collection network runs underground within the bulk of the planting areas, so that access to the regulation valves and measuring and sampling points is done by means of recordable control boxes.
In total, there are twelve sets of motor generators whose combined total power is 12,570 MW and the electrical energy obtained is discharged along a 66 kV electrical line.

The emissions reduction

The biogas generated by the biodegradation of accumulated rubbish contains carbon dioxide (CO2) and methane gas (CH4), which is collected by means of wells and conducted to the cogeneration plant to produce electrical energy. The up to 9,170 m3/h of biogas collected presents a heating value of less than 5 kWh/m3, half the heating value of domestic natural gas.
The recovery of the biogas of the Garraf controlled landfill site helps towards avoiding the emission of between 50,000 and 110,000 tonnes a year of CO2 by electricity power stations burning fossil fuels. This amount of carbon dioxide is the equivalent the amount that is absorbed by the surface of some 1,000 hectares of woodland (the Garraf natural park covers 12,820 ha).
The 100 GWh/year that the recovery plant can produce is equivalent the decorative, roadside

and tunnel lighting for the whole of the city of Barcelona.

Volume of biogas collected (2002-2006)

As mentioned previously, the Garraf controlled landfill site generates some 100 GWh (100 million kWh) of electricity per year from biogas, enough energy to serve a population of about 12,000 inhabitants. Given that the site has been closed since the end of 2006 and, therefore, no more organic matter will be entering it in the future, the biogas that is produced will decrease in the coming years exponentially until it ceases to be useful when it contains very low percentages of methane gas and the extractable flow becomes excessively low.

Diagram of the biogas recovery system in the Garraf landfill

1. Biogas collection wells.
2. General collector transport (355 mm Ø).
3. Blowers to suck the biogas from the wells and conduct it to the motor generators (3 blowers handling 3,000 m3/h each).
4. High temperature safety flare (1,000 ºC) to burn surplus biogas.
5. Motor generator groups for the production of electricity (12 groups in sound-proofed housing whose unit power is 1,048 kW).
6. Transformer to increase tension from 6.3 to 66 kV.
7. Electrical energy drainage line.
8. Leachates tank.

Although in 1979 and 1980 some pilot tests were done to collect biogas, the building of the degasification system for energy purposes began in 2001, and the facility’s commercial debut took place in 2003, with a total budget of 11 M€.

“Biogas programme” a successful model for household energy recovery in Nepal
Shambhu Dev Baral

Biogas technology has become much popular these days in Nepal. This technology is spreading rapidly all over the country. Nepal has high potential to construct biogas plant nearly about 150, 00, 00 numbers but up to now only 175,000 plants has constructed.

Human and animal manure are the major problem in rural Nepal because of the open defecation practice and improper management of animal manure. This is creating several problems in the households as well in communities. The biogas is a best option in the Nepalese context to manage manure scientifically adopting “***waste to energy”*** principle in a decentralize manner is very important because of socio-economic, geographical, environment and culture condition of Nepal. This is an appropriate technology in the context of cost effectiveness, use of local material, simple in construction, maintenance, and operation, reliable, accessible and free from potential disaster.

Biogas has several tangible and intangible benefits to the communities’ people. The most important are economic, health, environment and gender benefits. Out of these benefit economic benefit biogas reduces the expenses on fuel for cooking and produces high quality fertilizer contributing high yield from agriculture, reduce indoor air pollution to minimal, attached toilet improve the sanitation and hygiene condition of the people and reduce the drudgery to the rural women to collect the fire wood from the jungle and saves the 3 hours time a day per family mainly from collecting firewood, cooking time and cleaning the utensils. The bundling the Biogas for the purpose of CDM is another milestone and prestigious achievement in the international community in promotion of renewal energy and economic benefit. This technology is a clean technology has multidimensional benefit to the community supported by government, local government, local communities, and donors’ communities.

This paper analyze the multidimensional aspect of biogas including household economic, opportunity, challenges and strategies and lessons learned could be replicated to other developing countries like Nepal. ,

Key words: biogas, waste, renewable energy, economic, environment, gender, health, benefit

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Challenges and opportunities for composting of solid wastes for reduction of greenhouse gases in developing countries

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Compared to the industrialized countries, developing countries contribute very little to greenhouse effects because they have lesser industrial activities. However, in developing countries the increase of solid waste quantities and their disposal in landfills may lead to the increase of the greenhouse gases.

Emissions of greenhouse gases produced by wastes are essentially methane in landfills. In developing countries the quantity of methane generated in landfills is more important than in developed countries, because of the highest amount of organic matter and of moisture content in wastes.

Composting can be an efficient mean in reducing greenhouse gases, and also to fight desertification. The multiple advantages of composting are:

- the treatment of the principal mass of waste (100% of organic waste and 70 to 80% of municipal waste);
- the elimination by evaporation of the important moisture content (700 kg to 900 kg of water in 1000 kg of waste);
- the attenuation of the greenhouse effect by eliminating methane in landfills;
- the economy of land surface used by the landfill (and therefore the increase in their life spans);
- the regeneration of soils by organic manure and the support to the agricultural activity

However, composting plants (about one hundred) constructed in developing countries during the 1960-1985 show many failures and operational difficulties. It appears that these failures are due to imported "turnkey" technologies, without any mastering of base designs and operation of treatment systems. Moreover, these failures have not been investigated, audited or evaluated properly to determine the reasons for the deficiency.

To avoid these failures, reliable data measurements and analyses must be carried out by specialized solid waste laboratories (we refer here to the concept of an "experimental waste plant") based on methodologies tested in the local context.

In Tunisia, such research is conducted within the experimental waste plant in Borj-Cedria Science & Technology Park. For the success of composting, experimentations were necessary in view to:
- characterize precisely wastes and their aptitude to be composted,
- define the bases of treatment and to set up adapted processes for composting,
- identify the value and the use of compost in agriculture.

In this presentation, we will expose the findings of our research and the arguments for composting, namely:
- the importance of composting as a solution to avoid greenhouse gases in landfill,
- the conditions for the viability (feasibility) of composting,
- the importance of experimental researches to establish the basis of composting strategies (waste characterization, processes and the use of the compost in agriculture).

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Dr Ben Ammar worked as a consultant on national and international projects and assignments, for the Tunisian Ministry of the Environment, the German cooperation (GTZ), the organization of the Nations United for the Industrial Development (UNIDO) and the French agency for environment and energy management (ADEME).

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A computerized volume and mass balance of combustion gases from landfill or MBT biogas.

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The EMSHTR is a Local Authority encompassing Barcelona and 31 other surrounding municipalities, in charge, among others, of municipal solid waste management and water supply and sanitation.

Summary of the paper:

The contribution of biogas from landfills or, in a lesser extent, that from MBT, to greenhouse effect is not at all negligeable. Its major contribution derives, not from carbon dioxide as for general cases, but from methane, which has a potential about 21 times greater. Electrical generation from biogas by means of its combustion in turbo- or motogenerators is, not only an excellent way to convert a waste-derived product into energy but a way to convert methane into carbon dioxide (and water), that is, to reduce the contribution to greenhouse effect above mentioned as well.

In this respect, the Author considers that it is of general interest the elaboration of a computerized calculation algorithm to determine easily the volume and mass balances of that conversion.

The algorithm, starting from the data of : extracted biogas volume, percentual ratio extraction/production, and percentual composition of the biogas (in methane, carbon dioxide and nitrogen), all of them easily obtainable, gives the overall emission of combustion- and unburnt gases (also broken down into its components), expressed in volume and in mass. It also gives the balance between the components of produced and finally emitted gases.

This algorithm, obviously based on physical and chemical (stoichiometric) calculations as will be explained at the full paper, also gives the partial results which allow to derive the final ones described, so giving other data of interest and facilitating to users the comprehension of the algorithm itself and its eventual modifications for adapting it to needs of everyone. In addition, in its Microsoft Excel computerized version (available free of charge at the Author's e-mail), the algorithm contains the detail of the formulae and calculations, so facilitating even more its comprehension and modification.

Evaluation of the Different Municipal Waste Treatments Versus Climate Change
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EXECUTIVE SUMMARY

Further to the Kyoto Protocol, there has been only a limited reaction across the world for nearly ten years. But recent reports (Al GORE - STERN) have dramatically increased the public awareness and therefore the pressure on Governments and Companies to promote and implement more sustainable development.
As a consequence, it is becoming more and more important to efficiently benchmark the different alternatives, but some tools (e.g. Life Cycle Analysis) are very complex and difficult to use. As a starting point, this paper will address the issue of the "Direct" emissions and the "Avoided" emissions related to the Energy recovered.

In terms of waste treatment, various aspects have to be considered when assessing Green House Gas (GHG) effects :
- What is the biogenic fraction in the waste and how to calculate GHG emission or "carbon footprint" ?
- When energy is generated, how to account for the fossil fuel "saved" (and therefore "Avoided" emissions) and which reference to be used ?
- How to account for GHG which is released today and GHG which will be released in a number of years ?
- How to benchmark the different treatments ?

SUEZ Environment is active in the different kinds of Municipal Solid Waste (MSW) treatments and has developed annual sustainable development reports trying to be as objective as possible. This paper addresses the "direct" GHG and more specifically the Carbone Dioxyde (CO_2) and the Methane (CH_4), provide some overall Carbon footprint for different Waste treatment Processes and some "net" Carbon footprint for the Energy from Waste Plants in relation to different alternatives to supply the same Energy.

The following alternatives have been evaluated:
- Untreated waste
- Landfill (LF) with biogas collection and energy recovery
- Landfill (LF) as "bioreactor" with biogas collection and energy recovery
- Mechanical and biological treatment, with the bio-stabilised part being landfilled and the Refused Derived Fuel (RDF) being burned in a dedicated Plant to generate electricity.
- Anaerobic Digestion of the biogenic fraction of MSW with Landfill of the non biogenic fraction
- Anaerobic Digestion of the biogenic fraction of MSW with combustion of the non biogenic fraction in a dedicated Plant to generate electricity.
- Pyrolysis and carbon combustion.
- Energy from untreated Waste (EfW) with 100% electricity production.
- Energy from untreated Waste (EfW) with 100% Heat production.
- Energy from untreated Waste (EfW) with combined Heat and Power.

The total quantity of GHG emission for each Process has been evaluated, as well as the quantity of Energy recovered. The GHG emissions from alternative fossil fuels and average emissions per kWh produced in different Countries are tabled to be used as reference and determine the quantity of GHG "avoided" when recovering Energy from Waste.

The conclusions are that :

- "bioreactors" are quite efficient to reduce GHHG emissions in particular by reducing the quantity of uncollected Methane, but also by the production of electricity through efficient motors.
- the "Net" emissions of modern Energy from Waste Plants are well below the average emissions of most Countries, therefore contributing to Sustainable Development.

INTRODUCTION

Further to the Kyoto Protocol, there has been only a limited reaction across the world for nearly ten years. But recent reports (Al GORE - STERN) together with the ongoing work of the Intergovernmental Panel on Climate Change (IPCC) have dramatically increased the public awareness and therefore the pressure on Governments and Companies to promote and implement more sustainable development.
As a consequence, it is becoming more and more important to efficiently benchmark the different alternatives, but some tools (e.g. Life Cycle Analysis) are very complex and difficult to use.

The objective of this paper is to clarify the interpretation of a number of parameters so that a consistent approach may be used when evaluating the **"Direct" GHG** emissions and the **"Avoided"** emissions related to the Energy recovered for various Waste Treatment Processes. In this analysis, the Nitrogen Oxyde (N20) has not been considered due to the lack of reliable data and it is considered that the different Process only generate marginal differences.
However, considering the very impact in terms of global warming (310 times worse than CO_2), Suez Environment has decided to launch some specific studies. At this stage the gases which are taken into account in this paper are CO_2 and CH_4.
The "Indirect" emissions generated by the construction of the Plant, transport of waste … as well as the "Avoided" emissions related to the re-use of some material (such as bottom ash) are not taken into account.

- The first step is to look at the Waste composition (in gross weight) in order to determine the biogenic fraction. It is also relevant to evaluate the calorific contribution of the biogenic fraction and understand the origin of the non biogenic fraction and in particular of the combustible part.
- It is necessary to determine the production of GHG for different Waste Treatment Processes, ensuring that the Processes will not generate combustible residues. Energy recovery will be quantified for each Process.
- We will also benchmark the different ways to generate energy in terms of GHG emissions and look at averages for different Countries as a result of different mix of energy generation.
- This will enable to propose some ways to evaluate the GHG emissions saved by the recovery of the Energy contained in the Waste, depending on the Process and the reference used for the substituted Energy production.

WASTE COMPOSITION

In order to evaluate the different Municipal Solid Waste (MSW) Treatments, it is first necessary to have a common understanding of the Waste composition. This of course varies between Countries, urban or rural areas and we show below the different typical analysis split by type of Waste : organic (kitchen and green Waste), paper, cardboard, wood, complex, textiles, plastics, other combustible, glass, metal, other non combustible… Our examples are based on the *MODECOM* analysis prepared by the French governmental organisation ADEME.
Each of these types of Waste contain a fraction of biogenic origin, of inert and of non biogenic combustible. This last part can be considered as "fossil" origin since they derive from various manufacturing processes starting with oil transformation. It is therefore possible to breakdown the biogenic fraction which represents 58% of the MSW in gross weight, a figure very consistent with most approaches in Europe where this ratio varies from 55 to 65%. The "fossil" origin represents 17% and the inert 25%.
We have then looked at the carbon content of the different types of Waste. When combining this with the biogenic and "fossil" origins, the split is then 55% of carbon from biogenic origin and 45% carbon of "fossil".
As part of the debate is to know how much Energy generated from the Waste is replacing Energy produced by other means, we have also worked out the calorific values of the different types of Waste in order to

determine the split of Energy input between the biogenic and “fossil” fractions. It is interesting to note that the ratio are then 55% Energy from the “fossil” fraction, and 45% from the Biogenic fraction.

WASTE TREATMENT PROCESSES

- **Process 1**. For reference purpose we consider that the Waste remain untreated and uncovered similarly the old landfills.

- **Process 2**. Landfill with biogas recovery and Energy generation through gas engines.

- **Process 3**. Landfill “reactor” with biogas recovery and Energy generation through gas engines : the difference compared to the previous case is a “sealed cover” reducing the GHG emissions by improving the quantity of recovered biogas.

- **Process 4**. Mechanical and Biological Treatment (MBT) and Landfill : the objective is to reduce the quantity of organic material being landfilled. The principle is therefore to have a waste separation between fine (with high organic content) and coarse fractions. The fine fraction is “stabilised” (aerobic “composting”) and subsequently landfilled (or used as compost if allowed), as well as the coarse fraction.

- **Process 5**. MBT and Refuse Derived Fuel (RDF) combustion : this is typical of the recent German approach with the implementation of the “TA SIEDLUNGSABFALL” (TASI) regulation forbidding the landfilling of Waste having a LCV above 6 MJ/kg. The principle is therefore to have a waste separation between fine (with high organic content) and coarse fractions. The fine fraction is “stabilised” and subsequently landfilled, while the RDF is burned and Energy is recovered. The split between the 2 fractions will depend on the upfront preparation, with or without shredding. In our analysis we have considered no shredding.

- **Process 6**. Anaerobic Digestion (AD) and Landfill : this is an alternative to Process 4 where the fine fraction feeds an Anaerobic Digestor. Energy is recovered from biogas through gas engines, and the solid residues are “stabilised” and subsequently landfilled (or used as compost if allowed). As for Process 4, the coarse fraction is landfilled.

- **Process 7**. AD and RDF combustion : this is similar to Process 6 except that the coarse fraction is burned and Energy recovered.

- **Process 8**. Pyrolysis and Carbon combustion : the waste is first adequately prepared to suit the Pyrolysis Process requirement (generally shredded and metal removed). The syngas generated is burned in a separate system and Energy recovered. The solid residue with high carbon content is also burned in a separate system with Energy recovery (this could be a cement kiln when available).

- **Process 9**. Energy from Waste (EfW) : this is a “conventional” mass burning facility with all the Energy recovery generating electricity to meet the threshold of the new Waste framework Directive (0,65).

- **Process 10**. EfW with all the Energy being sold as Heat.

- **Process 11**. EfW with a mix of Heat and Power, such as to meet the “Good Quality CHP” threshold required to obtain “ROCs” in the UK.

GHG EMISSIONS AND ENERGY PRODUCTION FROM DIFFERENT WASTE TREATMENT PROCESSES

GHG Emissions : The 1st diagram attached in ANNEX 1 indicates for each of the 11 selected Processes the way the different Carbon fractions are converted and which kind of GHG is generated with the related proportions. These are all related to 1 ton of Municipal Solid Waste with 57% of biogenic Carbon and 43% of “fossil” Carbon.

For the different Processes involving some landfilling, it is considered that all the Carbon will eventually be converted to CO_2, and the fact that such conversion is not done within the same time frame is not taken into account. We have therefore indicated that the CO_2 emissions related to the "fossil" portion is "delayed" as opposed to the "instantaneous" degradation of the biogenic fraction or the combustion. However, some people consider it is beneficial to delay the emissions, some consider that this accumulates additional GHG emissions for the future generations … See the 1st picture in ANNEX 3 the "lifetime" of the different types of Waste.
In the case of combustion of solid Waste, there is a small percentage of "unburned" Carbon for which the conversion to CO_2 is also "delayed".

The evaluation of the GHG generated by Landfills is quite controversial. A number of models have been developed for the annual reporting of GHG emissions, but they are not consistent between themselves nor with actual measurements. See the Poster related to the evaluation of GHG from Landfills prepared by Didier Rallu and his colleagues from Suez Environment for this congress. The models also highlight a number of assumptions which should be taken into account as described in a Guide issued in 2003 by ADEME in France to calculate the Landfill GHG emissions

- "Evolutivity" of the Waste which indicates its ability to generate CH_4. We consider MSW.

- Number of years of the Waste in the Landfill. See in ANNEX 3 typical curves of different GHG emitted.
- Efficiency of CH_4 collection which mostly depends on the type of Landfill cover as confirmed by the study of Didier Rallu.

- Oxidation through the Landfill cover which is considered as 10% for all types of covers, as agreed by the Intergovernmental Panel on Climate Change.

- It is considered that no CO_2 nor CH_4 remain captured in the waste.

- Evolution of Landfills towards « bioreactors » with limited return on experience.

Energy Production : We have also tried to evaluate the "CO_2 equivalent" for the different Processes with the above assumptions. This takes into account the conversion factor between CO_2 and CH_4 of 21 as defined further to the Kyoto protocol. This value is currently reviewed by the IPCC in its 4th Assessment report "climate Change 2007 and will become 23 but this is not yet "official". The ratio of mole masses between the 2 gases lead to an actual equivalence of 1 mole of CH_4 being equivalent to 7,6 moles of CO_2.
Let us now review the different Processes and comment their different impact on GHG emissions, the Energy production being summarised in the 2nd diagram attached in ANNEX 1 :

- **Reference** : total potential CO_2 emissions by the carbon contained in the Waste. In case the total Carbon is oxydised (no generation of CH_4), the total quantity of CO_2 produced is constant but the production does not take place within the same time frame depending on the Process. Considering the split between the biogenic and the "fossil" fractions, the quantities of CO_2 are 500 kg and 380 kg CO_2 respectively, which represent a total of 880 kg CO_2 per tonne of Waste.

- **Process 1** : Since there is no biogas recovery, we indicate on the graph that the biogenic fraction generates a fraction of CO_2 (1/3) plus a fraction of CH_4 (2/3).The total GHG footprint is therefore much higher (2 830 kg eq CO_2). However, it is very difficult to provide meaningful figures due to the uncertainties mentioned above. Also this approach should not be considered as a reference for Landfill.

- **Process 2** : The difference compared to the previous case relates to the recovery of CH_4 : it is considered here that the cover of the cells is "semi-sealed" which enables to recover 65% of the CH_4 . The recovered CH_4 being subsequently burned to generate some electricity is then converted in CO_2 . In that case, the production of CO_2 equivalent becomes 1 530kg CO_2 . The Energy production is evaluated up to 150 kWh/ton of Waste.

- **Process 3** : As a further development, Landfills can now be converted into "bioreactor" whereby the cover is 100% sealed with a geomembrane. This enables to recover a higher (95%) percentage of the

CH_4 . In that case, the production of CO_2 equivalent becomes 980 kg CO_2 . The quantity of biogas collected being around 50% more, the Energy production could reach 400 kWh/t Waste.

- **Process 4** : It is considered that the "stabilisation" will enable to oxydise the largest portion of the biogenic Carbon into CO_2, with only small traces of CH_4 which are not quantified.

All the subsequent Processes will not generate any CH_4. Their total Carbon footprint will then be equivalent to 880 kg CO_2/ton of Waste, reflecting the complete oxydation of the Carbon contained in the Waste.

- **Process 5** : The RDF will contain nearly all the "fossil" carbon and a small part of the biogenic fraction. Its Low Calorific Value (LCV) will therefore be 20 to 30% higher than unprepared Waste. However, the RDF will represent around 60 to 70% of the total energy input in the unprepared Waste, and the total Energy production will therefore be in the same proportion, i.e around 420 kWh/ton of waste.

- **Process 6** : The AD will collect a large part of the biogas which will be burned to generate Energy. The amount indicated reported on various Projects is 230 kWh/ton of Waste. The solid fraction being stabilised will generate only CO_2.

- **Process 7** : The combination of Processes 5 and 6 in terms of Energy recovery enables to reach a total production of 600 kWh/ton of Waste, which is equivalent to the Process 9 "conventional" EfW.

- **Process 8** : It is important to note that some presentations of pyrolysis or gasification processes mention that the carbon footprint is significantly lower than other Processes. The main reason for such results is that no treatment is foreseen for the solid residue with high carbon content. This residue will be converted to CO_2 a way or another and such CO_2 has to be taken into account in the equation. In terms of GHG it is important to analyse the complete treatment of the Waste and its residues to avoid unjustified claims of lower Carbon footprint. The Energy production is penalised by the various heat losses through the different systems and by the fact that the solid residue is soaked wet at the outlet of the pyrolysis part. It is estimated around 450 kWh/ton of waste.

- **Process 9** : Some enhancements are made compared with "traditional" design to reach the future threshold of the Waste Framework Directive under negotiation in the EU. The Energy production is therefore evaluated to be 600 kWh/ton of Waste.

- **Process 10** : As a comparison, 100% heat supply to a District Heating enables to considerably increase the Energy recovery to 2 000 kWh/ton of waste since there are no losses anymore in the Turbine and Condenser. This should definitely be the favoured Process but the existence of networks and non acceptability of Plant in urban areas make such a scheme rather theoretical.

- **Process 11** : A "good quality CHP" enables to have an Energy recovery between Processes 9 and 10 and is more realistic than 100% District Heating.

GHG EMISSIONS GENERATED BY ENERGY PRODUCTION

In order to evaluate the "Net" GHG emission of EfW (Process 9), it should be considered that the Energy generated by the EfW Plant replaces the same amount of Energy produced by an alternative method and therefore enables to "avoid" some GHG emissions. The 1^{st} table in ANNEX 2 indicates the different emissions of CO_2 depending on the type of power generation : coal, oil, gas. We have also indicated the "Energy mix" of different European Countries which show great discrepancies, in particular France which has approximately 80% of the electricity produced "CO_2 free" (nuclear plus hydro). In this table, the GHG values for EfW relate to the "fossil" carbon only, since the biogenic fraction is considered as neutral in terms of climate Change.

Depending on the approach / objectives, each of these values could be used as "reference", the "EU" mix being probably the most adequate.

The 2nd table in ANNEX 2 show the “Net” GHG emission of EfW when comparing with some of these “references”. It is interesting to note that the figures range from + 620 kg CO_2/MWh in the case of France to – 110 kg CO_2/MWh in the case of coal being used as “marginal” source, with + 290 kg CO_2/MWh for the “EU mix”, which is more favourable than any fossil fuel.

CONCLUSION

This study demonstrates if need be the complexity of any comparisons between different Processes or scenario, but reflect interesting tendencies, confirmed in the IPCC 4th Assessment Report and different studies in progress in the United Kingdom and the Netherlands :

- Modern Landfills designed as “bioreactors” achieve quite a good performance in terms of Carbon footprint but the “Net” GHG emission remains significant due to a limited although quite significant quantity of Energy recovered.

- Modern EfW qualifying for recovery according to the future waste Framework Directive has a “Net” production of CO_2 well below the average of most European Countries. Any increase in the Energy efficiency will further decrease the carbon footprint.

- This overall balance has not been considered up to now in the communication themes of Waste Treatment but could be used to demonstrate the contribution to the Sustainable Development for example during permitting procedures.

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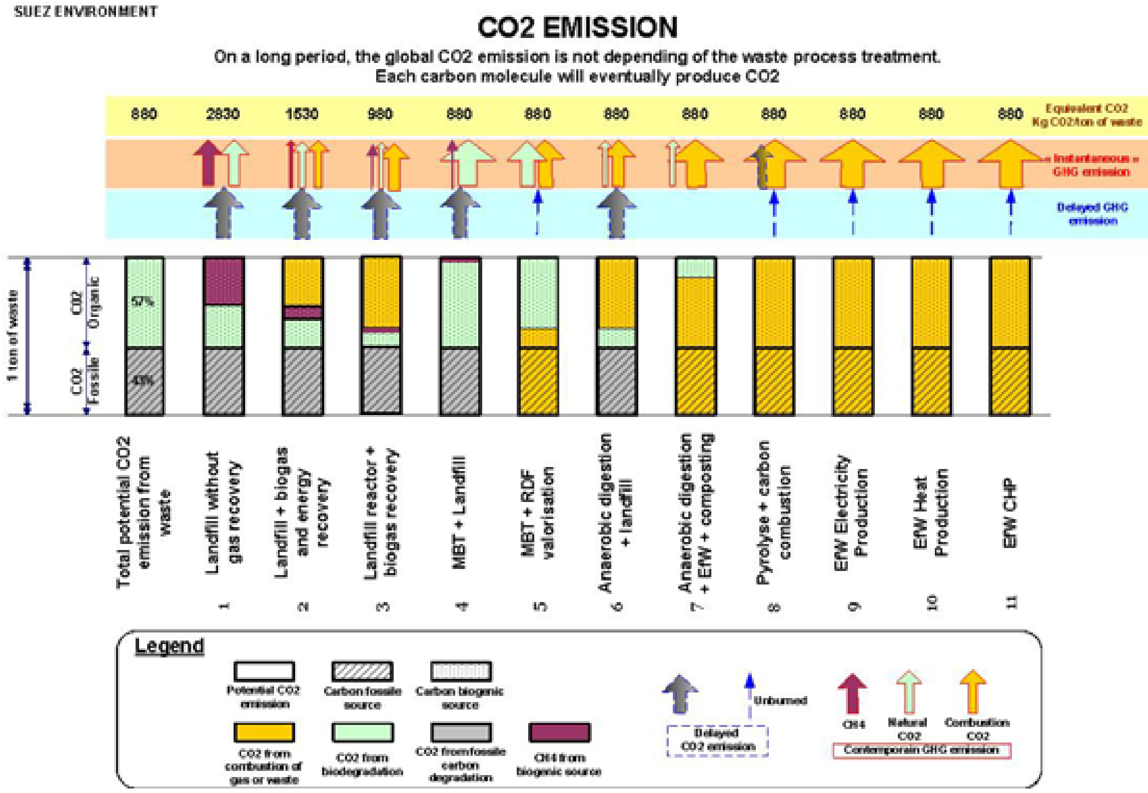
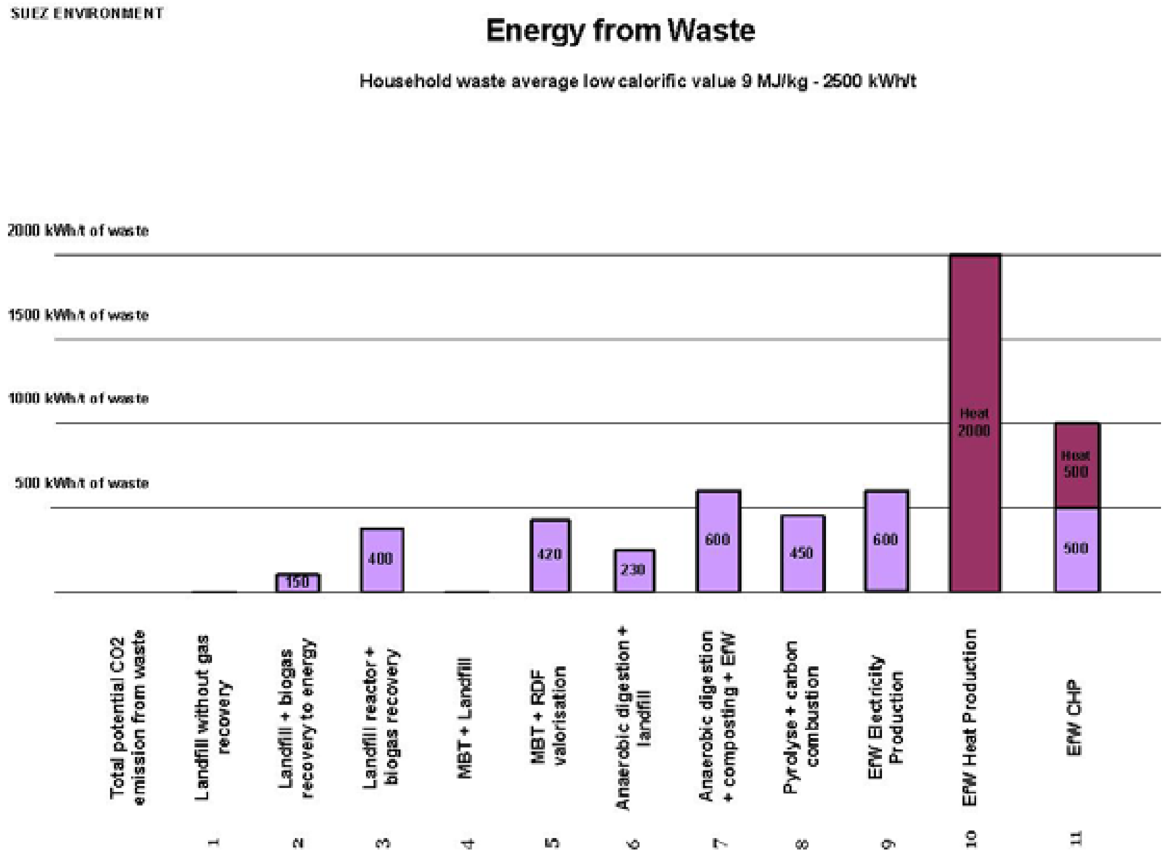
Mathilde Labaye, José de Freitas, Frédéric Duong, Mélanie Bonjean (Suez Environment)

ANNEX 1

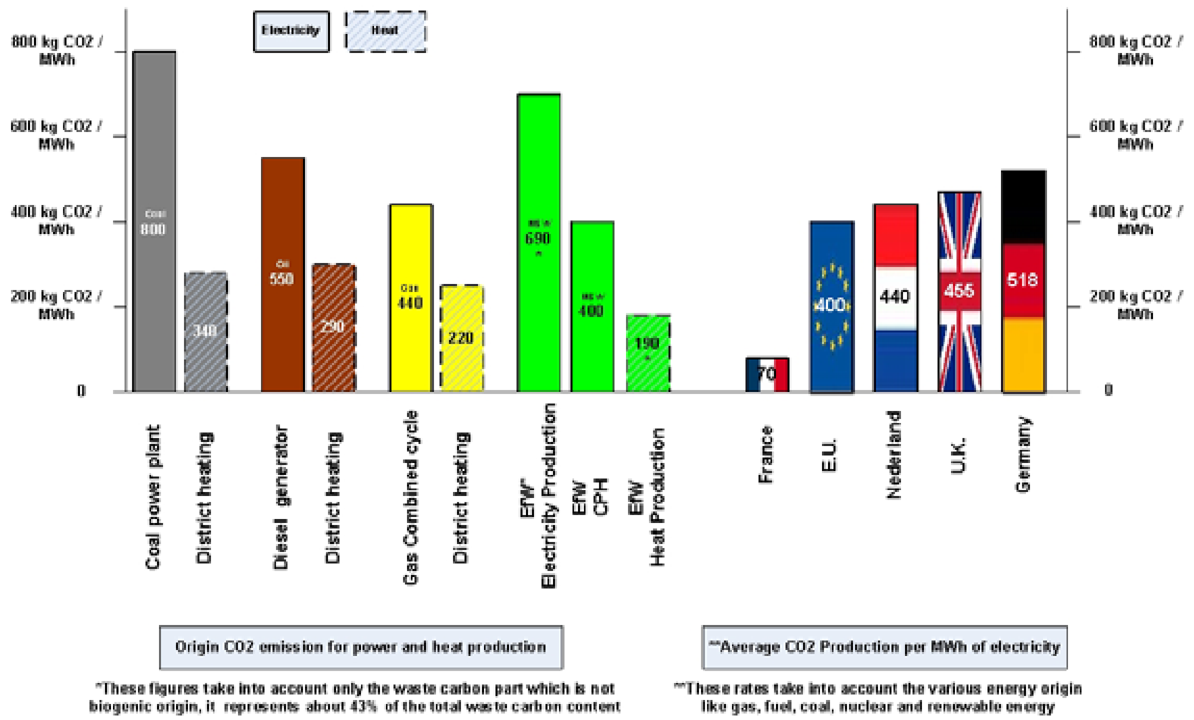

SUEZ ENVIRONMENT
CO2 EMISSION
On a long period, the global CO2 emission is not depending of the waste process treatment.
Each carbon molecule will eventually produce CO2
880
2830
1530
980
880
880
880
880
880
880
880
880
Equivalent CO2 Kg CO2/ton of waste
« Instantaneous » GHG emission
Delayed GHG emission
1 ton of waste
CO2 Organic
CO2 Fossile
57%
43%
Total potential CO2 emission from waste
1 Landfill without gas recovery
2 Landfill + biogas and energy recovery
3 Landfill reactor + biogas recovery
4 MBT + Landfill
5 MBT + RDF valorisation
6 Anaerobic digestion + landfill
7 Anaerobic digestion + EfW + composting
8 Pyrolyse + carbon combustion
9 EfW Electricity Production
10 EfW Heat Production
11 EfW CHP
Legend
Potential CO2 emission
Carbon fossile source
Carbon biogenic source
CO2 from combustion of gas or waste
CO2 from biodegradation
CO2 from fossile carbon degradation
CH4 from biogenic source
Delayed CO2 emission
Unburned
CH4
Natural CO2
Combustion CO2
Contemporain GHG emission


SUEZ ENVIRONMENT
Energy from Waste
Household waste average low calorific value 9 MJ/kg - 2500 kWh/t
2000 kWh/t of waste
1500 kWh/t of waste
1000 kWh/t of waste
500 kWh/t of waste
150
400
420
230
600
450
600
Heat 2000
Heat 500
500
Total potential CO2 emission from waste
1 Landfill without gas recovery
2 Landfill + biogas recovery to energy
3 Landfill reactor + biogas recovery
4 MBT + Landfill
5 MBT + RDF valorisation
6 Anaerobic digestion + landfill
7 Anaerobic digestion + composting + EfW
8 Pyrolyse + carbon combustion
9 EfW Electricity Production
10 EfW Heat Production
11 EfW CHP

ANNEX 2

SUEZ ENVIRONMENT

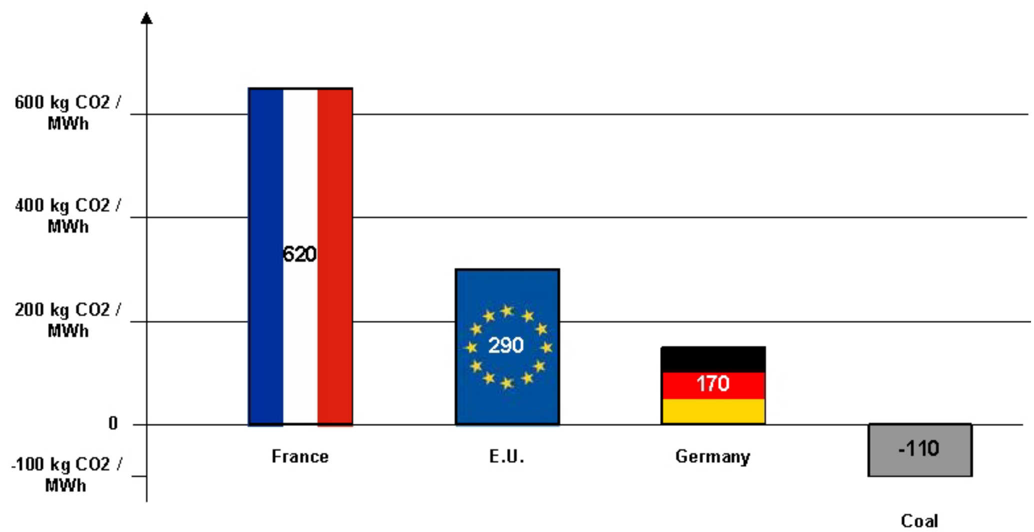
CO2 EMISSION FROM ENERGY ORIGIN
Electricity or heat production



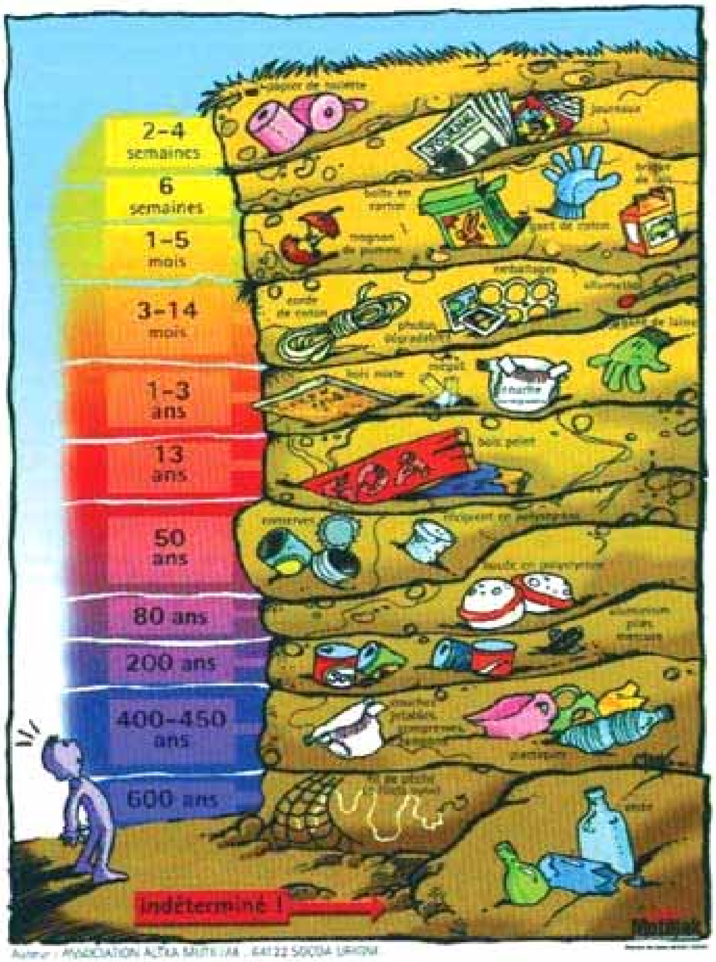
SUEZ ENVIRONMENT

Efw with 100% Electricity Production

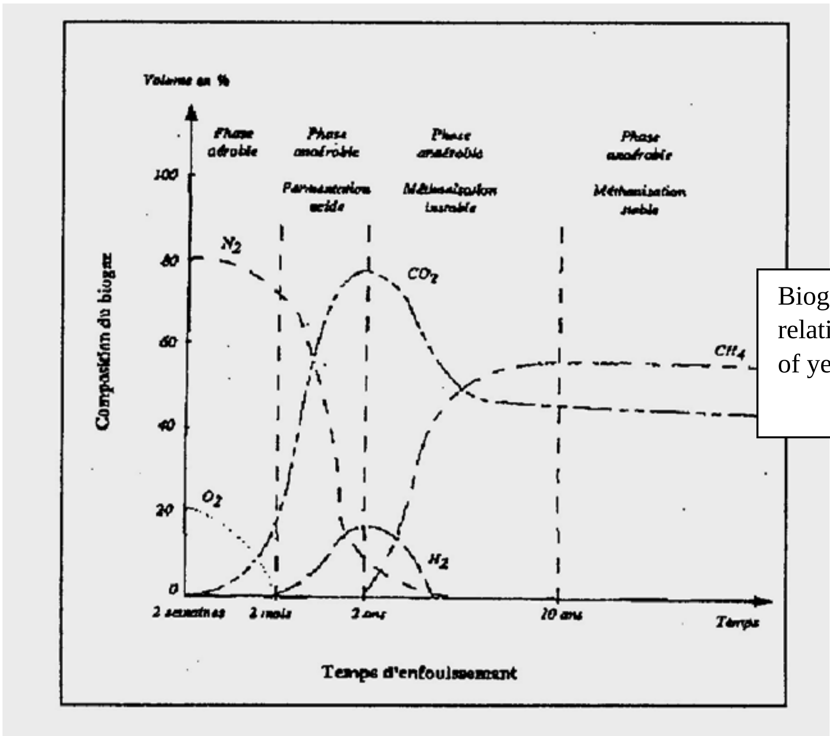
Net CO2 production depending on the reference for alternative energy production



ANNEX 3



« Lifetime » of the different types of Waste



Biogas production in relation to the number of years in a Landfill

Light on GHG reduction potential through JI in waste management in Romania and Hungary
Green Partners, Romania

www.greenpartners.ro

Biodegradation of accumulated waste at landfills results in biogas production. Biogas contains typically between 50 to 60% methane. Methane has 21 times higher global warming potential than carbon dioxide. Therefore extracting and utilizing landfill gas at old landfills have become popular CDM and JI projects. These projects, unlike most other CDM/JI projects are stand-alone projects. That is, given a certain landfill size and waste composition, the projects are profitable relying solely on income from the sale of emission reductions.

Starting with the year 2000 there was considerable interest from the part of project developers to invest in this type of projects. In spite of all the efforts and the positive market research studies by buyers and financing institutions, there are no implemented and functioning landfill gas extraction projects in Hungary and Romania financed through JI. The present paper takes a closer look at why these projects have been successful or have not worked out, what were the main barriers and the main misconceptions regarding these projects:

Incompatible Kyoto and EU financing schemes
In the case of waste management projects, income from emission reduction is an operational income, while EU is typically investment financing through ISPA or cohesion funds. It is often the case that the EU, robust, integrated waste management project includes some landfill closure projects. Theses projects typically include the cover of the landfill and ventilation of biogas. Technically speaking, extracting the gas and utilizing it, would add economic and environmental value of the project. Nevertheless, developing a JI project under these circumstances is hardly possible.

The reason for this in a nutshell is as follows: the EU financed projects are the result of several years of preparation, proposal writing and administrative coordination of tens of municipalities of a region attracting tens of millions of Euros with a considerable co-financing required from the municipalities. At the same time the JI projects are single-task oriented, smaller projects that put no financial burden on the municipalities. One of the rules of EU financing is that it is given to governmental organizations and not to private, profitable businesses. As soon as a municipality would agree to add to his technical landfill closure project the JI LFG extraction project, it could be argued that the JI project is part of the Integrated Waste Management System project, or at least is building on it, and the whole region would risk loosing the EU financing. The risk outweighs the extra benefits the JI project would bring along to the Municipality.

Legal uncertainties
The legal uncertainties are manifold and they often directly impact the budget of the project. For example in Romania new legislation pertaining to landfill closure was introduced in 2005, which turned upside down the budget of a 1.6 million ERU deal between Romania and the Netherlands. The new legislation was requiring EU standard cover on landfills which costs about 10 to 26 times higher than the cover system practiced at the time of the development of these projects. Similarly changes in legislation impact legal additionality issues. What is additional today may not be additional tomorrow. Other examples related to legal risks of JI landfill gas extraction business developers pertain to tendering issues, change of allocation of obligations in waste management between various levels of administration and/or operators, etc.

Inflated expectations
The last but equally important barrier that I like to discuss is the risks related to inflated expectations. Because there have been so many proposals from various buyer and project developer representatives the level of expectation relating to the profitability of JI landfill gas extraction projects has raised enormously among the landfill owners and operators. This result is tightly linked with waste being a very political business, and landfill gas extraction being a relatively new technology.

CONCLUSION

For the reasons listed above the risks and therefore the project development costs for investors outweigh the incomes of this type of projects, and therefore Romania and Hungary has been unable to reap the benefits of JI financing in the field of waste management thus far. These countries have not been able to benefit from the potential of this type of projects to improve waste management practices, reduce GHG emissions, to improve local social and economic conditions and to attract the financing that the Kyoto flexible mechanism was meant to enable.