Integrated Waste Management – A Pragmatic Case-by-case Approach Optimizing Recycling and Energy Recovery

Dieter Bürkle
Department Plastics and the Environment, Elf Atochem
4/8 Cours Michelet, 92080 Paris la Défense 10, France

Recycling industry has existed for many years, simply for economic reasons. In the case of plastics, long-established, profitable recovery and recycling businesses (such as pallet shrink film, bottle crates, battery cases, etc.) are underestimated by the general public which often sees only one area - consumer packaging. Those large, uncontaminated, relatively easily collectable plastic items are collected and recycled without any legislative pressure.

Often, plastic products are extremely light and hence not worth being dismantled and/or collected. In order to get 1 ton of recycled plastic from yoghurt cups or cheese wrappers, one would need to wash at home, collect and recycle 200 000 or up to 700 000 packages, respectively. For these, an efficient waste-to-energy incineration should be the preferred option. No wonder that successfully recycled plastics come from large items and often go back into the same or similar applications.

Should we ban 9-g "heavy" refill pouches (for 200 g of instant coffee) because they do not contain any recycled material today and will certainly never reach the excellent high recycling rates of glass (package weight 600 g for 200 g of coffee) ? And this in spite of a clear advantage of the ultra-light weight, 0 % recycled multilayer packaging in a life cycle assessment ? We have to recognize that "pre-cycling" is even better than recycling.

More progress in plastics recycling can be predicted, but only a combination of mechanical recycling (probably limited to about 15%, on average), energy recovery and possibly feedstock recycling (on a large scale after the year 2000) will ensure optimum results for our environment and our economy. If recycling is "forced" and uneconomical, one can be reasonably sure that too many resources are used and the environmental balance will be negative.

Concentrating on waste alone could even be totally counterproductive for our environment and for our economy. Packaging, for example, uses only 10 to 15 %, on average, of the total energy needed for food supply. Therefore, minimizing the product loss must be the first priority, not minimizing packaging. No packaging or too large pack sizes can be the worst solution for our environment and our economy.

"Integrated Waste Management" is increasingly recognized as the way forward. The word "integrated" may be understood in three ways:

 CCC 1022-1360/98/$ 17.50

- integrating all available waste management options, with recycling and energy recovery to be chosen on a case-by-case basis
- integrating waste streams other than packaging in order to optimize cost and environmental performance (e.g., newspaper, "green" waste for composting, etc.)
- integrating the whole life cycle of a product and not just one part of it in a global life cycle assessment

1 RAISING ENVIRONMENTAL CONSCIOUSNESS

Independent research /1/ and practical experience show that the concern for our environment is in consumers linked to search of liberation from feeling guilty and to excessive media coverage. It is here to stay: it is not a fashion, but a basic movement.

So far, products produced by industry have had to be efficient ("fit for the purpose"), worth their price ("value for money") and safe. In addition, industry has now to recognize a new criterion for products it puts on the market: an emotional or "feel-good factor" which often may decide whether a product is accepted or not by the consumer.

For many citizens, the issue of domestic and in particular packaging waste seems to be the most important environmental issue. However, minimizing waste in households should not necessarily be the first priority. In a more global view, minimum use of non-renewable resources, minimum energy consumption, and minimum air and water pollution should be achieved. In other words: our objective should be a better global performance in life cycle assessment (LCA) from "cradle to grave". The urgency of the waste problem should not lead to decisions based on emotions rather than on facts. The head of the Waste and Water Department of the German Federal Environmental Agency (UBA) summarizes: "Only 0.5 % of the damage to our environment in Germany comes from waste. The waste sector has only a marginal influence on our environment. We are spending, by far, too much money in this area" /2/.

2 WASTE MANAGEMENT IS ONLY ONE PART OF TOTAL PRODUCT LIFE CYCLE

In a modern car, 100 kg of plastics replace 200 to 300 kg of conventional materials. This leads to a considerable energy saving: approximately 750 litres of gasoline over the car life-span. 87 % of the energy necessary for the system "passenger car" (Fig. 1) is consumed during the use of the car (fuel, lubricants). The total energy recovery potential through recycling is about 6 % (mainly through steel recycling), with 1% for plastics (if all plastic parts were recycled).

For the system "washing machine", the most important impact on our environment is generated during the washing cycle (Fig. 2). In the case of food, supply (Fig. 3) packaging makes only 11 % of the total energy invested. Energy used for agriculture, in the food industry, during distribution and in households is far more important. If we had not packaging, up to twice as much energy

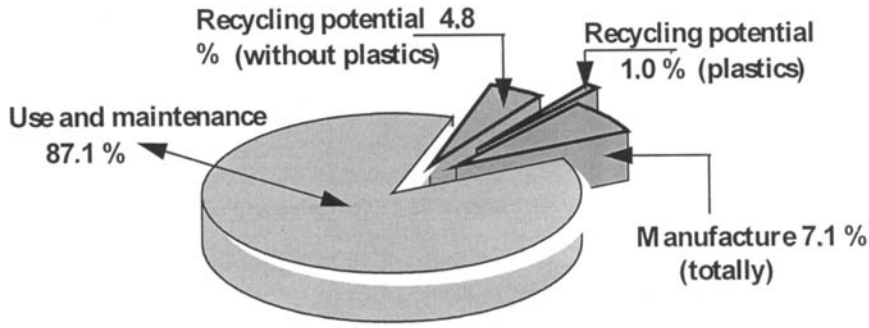

Fig. 1 : Energy Consumption for a Passenger Car
(Source: B. Krummenacher)

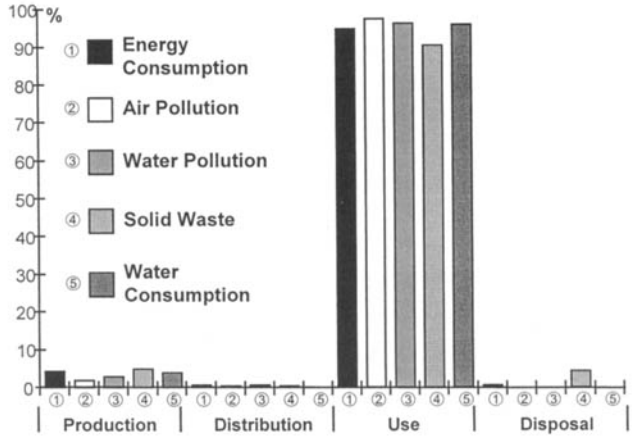

Fig. 2 : Life Cycle Analysis Washing Machines
(Department of Trade and Industry, U.K.)

would be needed to feed people because much more food would be wasted during storage and distribution /3/.

In all cases, the first target for environmental optimization must be the use phase.The choice of waste management options is far less important. In practice, non-recyclable products may often be better for our environment (light plastic car parts, light-weight multilayer packaging).

Hence "recyclable", "contains *x* % of recycled material", "uses only one material = more easily recyclable" are not necessarily identical to "better for our environment", often on the contrary (see following chapter).

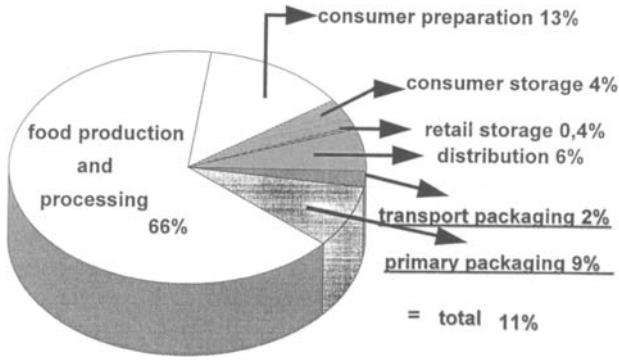

Fig. 3 : Energy use in Dutch Food Supply Systems (average) /3/

3 MODERN PACKAGING – LIGHTER AND MORE EFFICIENT BUT LESS RECYCLABLE

Significant weight reductions of packages (up to 75 %) have been achieved in the last two decades through better raw materials, improved converting techniques and more efficient design /4/. Recently 58 practical examples were described in a document edited by the French Ministry of the Environment /5/ showing industry action improving environmental and cost performance.

Ultra-light weight packaging solutions are developing rapidly although sometimes at the expense of less convenience for distribution or users and more difficulties (if not impossibilities) in recycling: thinner films and bottles, limited or no overwrap, replacement of rigid blisters by plastic pouches, flexible packaging instead of bottles or cans (typical weight reduction of 80 % /6/). In a number of these cases, energy recovery is a better waste management option than recycling.

Theoretically, all materials are recyclable. But, whatever the raw material, it is clear that in practical terms, material recyclability decreases with reducing weight of packaging. Thus, a 6-g plastic refill pouch is clearly less recyclable than the corresponding "heavy" plastic bottle. This is particularly true for thin food packaging film in contact with fatty or oily foodstuffs, with a typical weight of less than 1 to 10 g per pack. This practical aspect and not the variety of packaging materials, is the main obstacle to recycling of very light packaging which should preferably go to modern and efficient waste-to-energy incinerators.

Recently, the Flexible Packaging Association of the US launched the slogan "Pre-cycling is better than Re-cycling". Often, using less material from the beginning is preferable to recycling. On the other hand, an efficient "design for recycling" can improve recyclability (e.g. plastic bottles with plastic closures and labels, etc.). The cost of packaging usually decreases with the reduced weight. In the case of packaging for 2.5 l of paint, the cost indices are the following: 9.5 for the metal pail, 5.5 for the plastic pail (260 g) and 2.5 for the ultra-light weight plastic pouch (48 g) /6/. Very often, a

lower cost means less material and energy used. In many cases, ecology and economy go hand in hand.

Are our goods overpackaged ?

Consumers have the impression that some goods are "overpackaged", often due to lack of understanding of the complete transportation and storage chain from the parker filler to the end user. Packaging has already fulfilled many major functions before consumers hold goods in their hands. But some cases of real "overpackaging" may exist .

France is currently setting up its "Conseil National de l'Emballage" announced during the presentation of a document /5/. The objective is to work out a code of "good practice" for packaging and to provide for a forum for discussion of environmental and other issues. This should help to explain better packaging but also to reduce the number of cases of non-optimized packaging solutions.

4 RECYCLING – A PROFITABLE BUSINESS FOR MANY YEARS ALSO FOR PLASTICS

Often, recycling is seen by the public as a moral requirement. However, it should be remembered that a recovery and recycling industry has existed for many years, simply for economic reasons. Large, and (more frequently) small businesses lived from recovery and recycling long before "green marketing" appeared (Table 1).

Table 1 : Examples of long-established profitable recovery and recycling businesses

Material	Benefit from recovery and recycling
Corrugated board	cheap raw material for new paper products (non-food applications)
Steel scrap	cheap raw material for electric furnaces (usually not for cans, but building)
Glass bottles	reduced energy requirement, increased oven capacity
Plastic shrink films	cheap, tough raw material for garbage bags
Plastic bottle crates	new plastic bottle crates (after average lifetime of 20 years)

The amount of existing, profitable plastics recycling is regularly underestimated by the general public, because it often sees only one area: consumer packaging. But 2/3, by weight, and more than 90 %, by number, of plastics consumer packages weigh less than 10 g /4/. Reasonable targets for recovery and recycling in this area, are primarily bottles (typical weight 40 g) provided that a financing mechanism exists for the relatively high extra cost for collection and sorting (provided in France by Eco-Emballages). In many other areas, large, uncontaminated, relatively easily collectable plastic items are collected and recycled without legislative pressure (Table 2 gives examples for France).

Table 2 : Post-use plastics recycling in France (estimates)

Origin of used plastics	Recycled product going to	Amount
Pallet shrink and stretch film, films for agriculture	garbage bags, film for agriculture and buildings, cable ducts	**70 kt/year**
Reusable crates and containers	crates and containers	**20 kt/year**
Automotive parts (battery cases, bumpers, shock absorbers)	wheel arch liners, shock absorbers, bumpers, others	**10 kt/year**
Bottles and other consumer packaging	sewage pipes, profiles, textiles, etc. mixed plastics applications	**18 kt/year** **2 kt/year**
Drums and pails, electric and electronic parts. etc.	pails and other injection-moulded parts	**10 kt/year**
Total post-use recycling		**130 kt/year**

A European survey /7/ found that in 1995, the recovery rates for post-use plastic waste were the following: 7.6 % mechanical recycling, 0.6 % feedstock (or "chemical") recycling and 17 % energy recovery. In addition, recycling rates of more than 90 % are obtained for plastic conversion waste (edge cuts from the film production, neck and bottom scrap from blow-moulded bottles, etc.) and post-conversion waste (film cut-offs, grids remaining after thermoforming, cut-off pieces of tubes and pipes from installation, etc.), with a total amount higher than post-user recycling. Most recyclers are small- and medium-sized companies which have specialized for many years in recycling of conversion and post-conversion (pre-user) waste. In addition, they now recycle more and more post-user waste.

5 POSSIBILITIES AND LIMITS OF POST-USER PLASTICS RECYCLING

5.1 Keys to success in mechanical recycling of plastic waste

Based on practical experience, a number of points can be identified which contribute to success:

- cooperation of a raw material supplier, converter, filler with users, waste collectors, recyclers (examples in France: bottle recycling - Valorplast /8/, car bumper recycling, Autovinyle);
- design for recycling /9/ (but without de-optimizing global environmental performance, e.g., with heavier mono-material solutions);
- adding post-user waste to existing production and industrial waste recycling schemes leading to higher volume, reduced cost, and more consistent quality;
- replacing virgin resin in large-volume applications (closed- or open-loop recycling);
- developing quality management systems and standards for recycled plastics and building confidence in recycled material;

- subsidizing recycling schemes can be envisaged for an initial period (low-volume, high-cost). If high subsidies for recycling are needed on a long-term basis, other waste management options such as energy recovery may be preferable (see Chapter 6). High cost is often a sign of poor environmental performance (e.g., high energy requirements);
- collection can be the most significant cost factor, especially for consumer packaging waste. In a number of countries, these costs are paid by "green-dot" companies and hence the consumer;
- another example of an efficient new recycling scheme comes from a big German PVC window producer /10/ recycling today windows and window profiles in a modern, automatic plant: 6000 t/year from installation operations and 1500 t/year (increasing) from demolition of buildings. The operation will become profitable beyond 10 000 ton total per year (1998). The PVC recyclate goes back to new windows replacing virgin PVC in core layers surrounded by virgin PVC.The main problem today is the still limited collection from demolition activities. Other successful plastic recycling operations are described in /11/.

5.2 Practical limits of mechanical recycling of post-user plastic waste

The limit can be estimated on average as 10 - 20 % of the waste stream. Cost/benefit and life cycle analysis should be used for guidance.

A study produced for the Dutch Ministry of Environment /12/ examined five different combinations of waste management options for plastics consumer packaging and concluded that the contribution of mechanical recycling, in terms of maximizing the environmental gain, is restricted to between 13 and 18 % (Fig. 4).

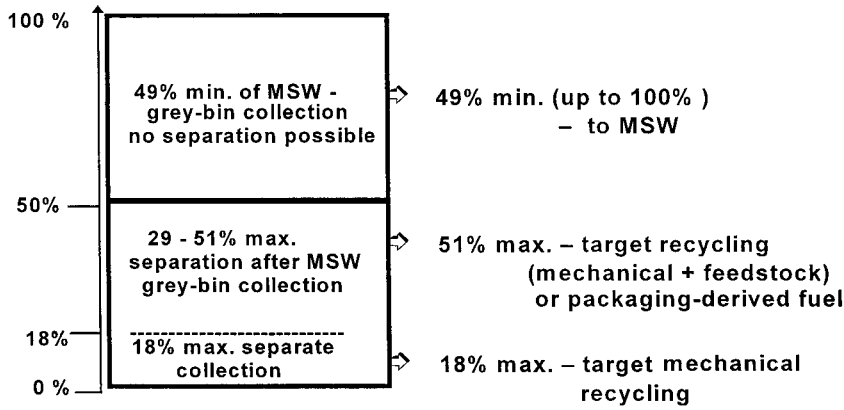

Fig. 4 : Plastics consumer packaging - waste management options /12/

An unpublished 1996 SOFRES study commissioned by the European Commission came to the conclusion that 18 % of the total plastic waste streams (packaging, vehicles, etc.) could be, on average, the maximum target for mechanical recycling in 2005-2010 /13/.

But large variations exist, depending on the type of waste stream. Much higher plastic recycling rates are already achieved today for a limited number of relatively bulky, easily collectable plastic items like shrink hoods (palletizing film), bottle crates (more than 50 % recycling after 20 years of average service life), car batteries and, increasingly, one-way bottles in a number of countries.
However, mechanical recycling of small soiled parts such as 1.4-g cheese wrappers or 5- to 6-g yogurt cups should better be avoided, as all available studies indicate /12, 14, 15/; see also Chapter 6.

This means that there can be no general hierarchy of waste management options, but only a case-to-case approach which has to start with the question "does recycling make sense in this case ?".

5.3 Feedstock recycling ("back to crude oil or other petrochemicals")
Much development is under way in this field in Germany, but also through a consortium of several European petrochemical companies (BP, Elf Atochem, DSM and Enichem, with the support of APME) /16/ and more recently in Japan (Niigata pilot plant, start in 1997). Plans exist in the Netherlands for a demonstration plant producing syngas from used plastics packaging. According to /13/, feedstock recycling could in the next century enable the recycling of another 18 % of the total plastic waste stream in Europe.

However, today these new technologies are still expensive, and they are far from being technically optimized. Much more research and development is necessary before the construction of large-scale plants could be envisaged. The first use of plastic packaging waste as a reduction agent in a commercial-size steel furnace started late 1996 in Germany.

6 INTEGRATED WASTE MANAGEMENT – RECYCLING AND ENERGY RECOVERY MUST BE PART OF THE EQUATION

"Recycling is not always necessarily the preferable waste management solution since it is limited by the Second Law of Thermodynamics and obeys the law of diminishing returns. Other options such as prevention, reuse, and recovery of energy can offer ecological or economic advantages over recycling according to the application area. In this light, the growth of the recycling industry is not a necessarily desirable policy target. The point is to perform recycling at its optimum rate, both from an economic and an environmental point of view." /17/.

These are conclusions from a report produced by European Commission services for the Environment Commission of the European Parliament. They are in favour of a combination of all available waste management options, with a decision on a case-by-case basis ("Integrated waste management"). Since several years, countries like the Netherlands (see also Fig.4), Denmark (Table 3) and Switzerland (Table 4) have developed both recycling and modern waste-to-energy incineration for not easily recyclable waste in parallel.

Table 3 : Packaging waste in Denmark /18/

Material	1995					Plan 2000	
	Consumer Packaging kt	Transport Packaging kt	Total kt	recycled	recovered (recycled + energy recovery)	recycled	recovered (recycled + energy recovery)
Glass	170	-	170	62%	62%	62%	62%
Paper + board	113	282	395	43%	90%	57%	95%
Plastic	100	40	140	6% *	90%	17% *	95%
Metals	27	8	35	29%	29%	40%	40%
Total	410	330	740	39%	81%	50%	85%

* exclusively from transport packaging (no collection of consumer pack.)

Building large-volume incinerators does not necessarily lead to less collection of recyclables, as the impressive figures from Swiss BUWAL (Ministry of Environment) show in Table 4 /19/.

Table 4 : Waste Management in Switzerland /19/

Recycling (in general collection through the bring systems)

60 % newspaper, paper, cardboard — 75 % plastic bottles

83 % glass bottles — 83 % aluminium cans

Energy recovery of residual municipal solid waste

80 % in 30 incinerators (total capacity 2.5 Mt/y) in 1996, 20 % landfill

100 % in 34 incinerators (total capacity 3.4 Mt/y) in 2000, 0 % landfill

In addition, increasing quantities of automotive shredder residues (ASR) are added in incinerators (more than 50 % of Swiss ASR in 1997) /19,20/

In many cases, building modern incinerators became an integral part of local plans for improving the quality of air. In Lausanne, Switzerland, less NO_x and other pollutants are produced thanks to the new incinerator replacing 10 000 individual burners and thanks to its location close to the city, which results in reduced traffic for transporting the waste /21/.

Co-combustion tests in Karlsruhe with up to 12 wt.-% of different types of electric and electronic waste added to municipal solid waste lead to an improved burnout of bottom ashes without increasing air emissions /22/. This confirmed earlier results from the Würzburg incinerator where an addition of plastic packaging waste (including PVC) to the municipal solid waste did not produce any measurable increases in production of dioxins and furans /23/. Modern incinerators are dioxin-destruction facilities, rather than dioxin generators /24/; see also data from the Vienna-Spittelau incinerator reported in /25/.

The mayor of Copenhagen is also in favour of integrated waste management: "Incinerators have become power plants using waste as fuel..... [Our] waste management strategy has stressed recycling of materials which have only a small combustion value and which, at the same time, are feasible for recycling.... Incineration is definitely here to stay. Whatever happens, energy production from waste will be an important strategy in our energy policy of tomorrow" /26/. In France, about 1 million t of crude oil equivalent was saved in 1995 through incineration of 8 million t of municipal waste (40 % of the total) /27/.

Citizens want to participate in recycling where it makes sense (glass and plastic bottles, newspapers, garden waste for composting). Therefore, understandably, waste-to-energy incineration will only be accepted by local residents if it is combined with recycling and composting efforts in the same area. A good example of such integrated waste management in Hampshire, UK is described in /28/.

An increasing part of the large amount of energy needed for the production of cement comes from the waste used as an alternative fuel. Plastic waste can make a significant contribution to replace fossile, non-renewable energy sources such as coal. In a number of European countries, severe competition already exists between the cement industry and operators of incineration plants producing energy: both are competing for the use of waste as an alternative fuel.

The Swiss BUWAL did create a common working group with both competitors in order to work out a strategy for the reduction of air emissions in Switzerland thanks to an optimized use of the different waste streams in municipal solid waste incinerators and cement kilns. The results of this remarkable initiative were presented to press in early 1997 /29/.

Even within the German UBA (equivalent of EPA in the USA), it is now recognized that "recycling at any cost" does not make sense: "Demands for higher and higher recycling quotas may be popular but when they are considered a little more closely. they often prove to be technically difficult and economically and ecologically senseless... There are many cases in which energetic recycling is very sensible and even essential... Recovery must never be regarded as an end in itself. It must be used sensibly for the replacement of other raw materials or fuels." /30/.

REFERENCES

1. T. Raccaud, Centre de Recherches et de Documentation dela Consommation (CREDOC) Seminar IIR, Paris, October 1993.
2. J. Schmitt-Tegge, Waste Management Forum, Saarbrücken, Germany, April 1994.
3. J. Kooijman, Environmental Impact of Packaging in the U.K. Food Supply System,
4. Industry Council for Packaging and the Environment (INCPEN), December 1996; Packaging Technol. Sci. 7, 111 (1994).
5. D. Bürkle, Int. Recycling Congress R'93, Geneva, January 1993.

6. Catalogue for the Prevention of Packaging Waste, Min. de l'Environnement, Paris, September 1996.
7. D. Bürkle, Specialty Plastics '95, Zürich, December 1995.
8. SOFRES, Information System on Plastic Waste Management in Western Europe, February 1997.
9. D.Bürkle, Recycling of plastics packaging: optimizing the French "Eco-Emballages/Valorplast" scheme, R '97, Geneva, Switzerland, February 1997.
10. Association of Plastic Manufacturers in Europe (APME), Design for Recycling of Rigid Plastic Containers, Brussels, May 1993.
11. H. Uhlen, Behringen, Germany, June 1996.
12. D. Bürkle, GLOBEC 96, Davos, Switzerland, March 1996.
13. Disposal of Plastics Household Waste: Analysis of Environmental Impacts and Costs, Centre for Energy Conservation and Environmental Technology, Delft, Netherlands, 1994.
14. SOFRES Study, March 1996, cited at European Recovery and Recycling Association (ERRA) – Université Catholique de Louvain (UCL) Symposium, Brussels, May 1996.
15. "Ökobilanzen zur Verwertung von Kunststoffabfällen aus Verpackungen". Fraunhofer - Institut, München, Technische Universität Berlin, Universität Kaiserslautern - Koordination TÜV Rheinland, Bonn, September 1995.
16. Sundström, Plastics Recycling - to Material or Fuel ?, Miljöbalans Press Conference, Stockholm, January 1996.
17. D. Bürkle, Journée Recyclage Eco-Emballages/Valorplast, November 1996.
18. L. Bontoux, F. Leone, M. Nicolai, D. Papameletiou : The recycling industry in the European Union: Impediments and prospects, Institute for Prospective Technological Studies, European Commission Joint Research Centre, Seville, Spain, December 1996.
19. I. Larsen, Agency of Environmental Protection, Copenhagen, EUROPEN - Seminar, Brussels, October 1996.
20. H.P. Fahrni, M. Tellenbach, R '97, Geneva, Switzerland, February 1997.
21. H.P. Fahrni, "Entsorgung von RESH (automotive shredder residues) in Kehrrichtverbrennungs-anlagen", Letter from Bundesamt für Wald- und Landschaftsschutz (BUWAL), Bern, Switzerland, January 1997.
22. G. Völgyi, Reducing emissions in an urban environment, Seminar "The future of European thermal waste treatment", Paris, September 1995.
23. J. Vehlow, T. Wanke, B. Bergfeldt, F. Mark, A. Jean, R '97, Geneva, February 1997.
24. APME summary report, Brussels, November 1994.
25. J. Vehlow, Euroforum Waste Management, Paris, September 1995.
26. H. Löffler, Thermal treatment of residues in Vienna, Austria, Madrid, October 1996.
27. C. Ammundsen, Waste Meeting, Copenhagen, March 1995.

28. A. Cabanes, Conference of Association de Mairies Operant un Réseau de Chaleur et d'Electricité (AMORCE), Pollutec Lyon, France, October 1996.
29. G. Tombs, European Recovery and Recycling Association (ERRA) Members' Symposium, Brussels, April 1997.
30. Kooperation statt Konfrontation in der Abfallwirtschaft (documents from press conference), Bern, Switzerland, February 1997.
31. E. Willing, Umwelt 26 (7/8), 36-37 (1996).