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ENERGY RECOVERY FROM PACKAGING WASTE – THE RESULT OF 12 YEARS´ STANDARDISATION WORK

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INTRODUCTION

This project on Energy Recovery was established in 1990 by a Swedish initiative as an integrated part of a new committee when CEN (Comité Européen de Normalisation) founded and structured its Technical Committee TC 261, Packaging. An incentive for all this came from EU, which had started a preparatory work for a Directive on Packaging and Packaging Waste.

TC 261was organised with four subcommittees (SC), each of them with several working groups (WG). The total number of WGs was 25. In TC 261/SC, 4 different WGs were organised:

- Terminology, symbols and LCA
- Prevention
- Degradability and composting
- Reuse
- Material recovery
- Heavy metals and other dangerous substances
- Energy Recovery
- "Umbrella"/General approach

During the first years of discussions on a draft directive, the document was an item of discussion at each meeting and many comments and proposals were sent to the Commission, *i.e*. DG XI (now DG Environment). The eighth draft was completed on the 20th of December 1994 as Directive 94/62/EC on Packaging and packaging waste (Ref.1).

The environmental aspects are very important parts of the Directive, and in 1996 the Commission mandated work on Environmental packaging standards to TC 261 and its SC 4.

The results of this work were accepted gratefully by the CEN Members, but a few EU Member States reacted negatively. The solution of this impasse ended with a second mandate in 2001, a mission CEN/TC 261 now has fulfilled.

PREVENTION OF THE ENVIRONMENTAL IMPACT OF PACKAGING WASTE

Requirements specific to the manufacturing and composition of packaging are given in the Standard on Prevention by Source Reduction (Ref:s 2, 3 and 4). All packaging, including that for which energy recoverability is claimed, has to fulfil these requirements. This means that the packaging functional unit contains a minimum amount of material. In addition, the amount of heavy metals and other hazardous and noxious substances is minimised, which has implications for the environmental impact of the energy recovery process.

OPTIMISATION OF ENERGY RECOVERY

The energy recovery standard provides the requirements for a packaging to be recoverable in the form of energy. The first Commission mandate asked for a minimum net calorific value to allow optimisation of energy recovery.

Optimisation of Energy Recovery from packaging waste involves the overall system including properties of packaging, waste collection systems, preparation, and storage and energy conversion to provide useful energy as shown in Fig.1. Some steps included in the overall system are not related to packaging itself. Combustion plants and the handling of residues from combustion, for example, are subject to specific regulation.

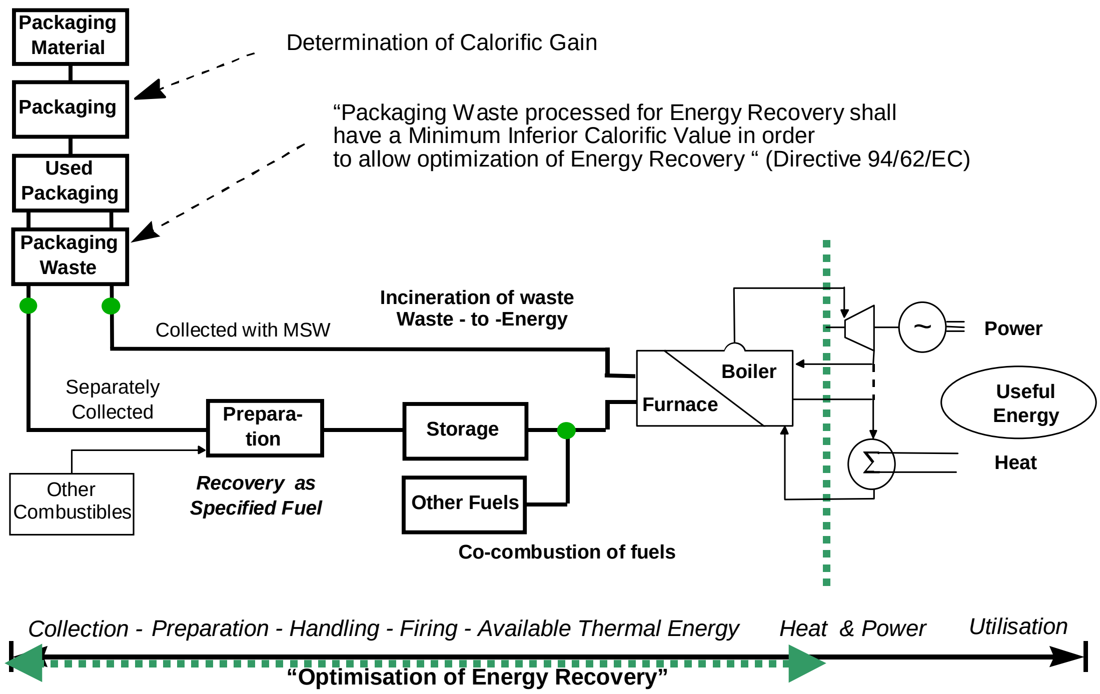

FIG 1 Optimisation of Energy recovery from packaging waste

To allow the optimisation of energy recovery from packaging waste, all steps in the recovery route must, however, be considered. This means that the consideration of energy recovery of packaging waste should include not only packaging materials and packaging design, but also the handling of packaging waste and recovery of the energy, *i.e.* the generation of heat into the flue gases of the furnace and recovery of the heat from gases into the boiler.

The use of this heat is, though, important for the optimisation of energy recovery, outside the recovery route and cannot be influenced by measurements taken by the packaging manufacturer. The standard covers the route from packaging design to the generation of calorific gain.

Figure 1 illustrates the two possible routes for energy recovery of packaging waste. The upper route is conventional incineration of waste. The lower route includes separate collection of packaging waste, preparation of a fuel with specified properties, and recovery of the energy, either as a mono-fuel or in co-combustion with other solid fuels.

For incineration of waste, the Waste Incineration Directive (Ref. 5) regulates the emissions from the plant. For solid fuel combustors, the fuel derived from packaging must meet the specifications of the actual plant.

The standard EN 13431:2000 (Ref. 6a), produced under the first Commission mandate, states that the principal requirement for packaging to be recoverable in the form of energy is that it is combustible under ordinary conditions. The requirement of optimisation of energy recovery was addressed thermodynamically by introducing the concept of *calorific gain*.

To allow optimisation, packaging should be capable of providing calorific gain. This means that the net heat of combustion, q_{net}, of the packaging shall exceed the energy required, H_a, to adiabatically raise the temperature of its combustion products, residues and excess air to the required temperature:

$$H_a - q_{net} > 0 \qquad (1)$$

The conditions specified are those for waste incineration, as regulated in Reference 5, *i.e*. an ambient temperature of 25 °C and a final temperature of 850 °C at 6 % O_2, assuming negligible unburned losses and steady state conditions.

All organic materials and most multi-material, lightweight packaging, containing a major amount of organic material fulfil Equation 1.

The calorific gain concept is a general condition, set for the ideal adiabatic case and independent of packaging material. In real energy recovery processes, there are always heat exchange with the environment and, of course, thermal losses. The available thermal energy in the real processes is, however, larger than the calorific gain of the ideal calculations, even when the losses are considered, due to heat recovery of the hot flue gases.

Waste-to-energy plants are constructed to recover energy from MSW. q_{net} of mixed MSW is of the range of 8-10 MJ/kg. Separate collection of wet bio-waste for organic recovery increases the energy content of the waste-to-energy fraction. The design range of modern incinerators is therefore 11-13 MJ/kg or even higher. This has nothing to do with optimisation of energy recovery but is required to adapt the incineration process to the available waste feed, in order to avoid a thermal restriction to the incineration capacity (t/h) of the plant. Packaging waste, being a mixture of used combustible packaging, represents the energy-rich fraction of the waste stream.

From studying real combustion processes it is seen that calorific gain is obtained in practical combustion processes for fuels having calorific values even as low as 3-5 MJ/kg. The important factor is the optimisation of the combustion process, *i.e*. the adaptation of the fuel to the combustion process (or vice versa). An increase of the calorific value of the fuel does not in itself lead to optimisation (Refs 7 and 8).

THE MINIMUM NET CALORIFIC VALUE

A thermodynamic equation did not, however, satisfy the Commission, who demanded a numerical figure of the minimum net calorific value.

Based on the findings of the energy content of packaging components and packaging functional units fulfilling the concept of calorific gain, a figure of the lowest net calorific value for a “worst case” packaging material was derived.

Fig. 2 is a plot of the calorific gain as function of q_{net} for packaging and packaging materials from Table 1. The line is the extended line of the mean values calculated according to the least square method and extended to $q_{net} = 0$. The extrapolation shows that calorific gain > 0 when $q_{net} > 2$ MJ/kg. Taking the 95 % confidence limit into account, the theoretical minimum value is < 2.5 MJ/kg.

To allow optimisation, *i.e*. taking maltreatment of the fuel, residue handling and eventual extra transportation into account, the practical, real value, $Q_{net,min,real}$ should be larger than the theoretical value, $Q_{net,min,theor}$. Applying a safety factor of 2, commonly used in design and construction of industrial processes, the practical, real, minimum value is set to 5 MJ/kg. For a Q_{net} of 5 MJ/kg, the calorific gain is ≈ 2 MJ/kg, and the calculated available thermal energy in a real process 4 MJ/kg or more. Even when the energy consumption for additional transportation and handling, flue gas cleaning and residue handling are taken into account, the available thermal energy exceeds the energy consumed by these operations.

INORGANIC CONTENT OF PACKAGING

The requirement of calorific gain limits the amount of ash forming substances, since inorganic constituents, except aluminium, give a negative contribution to the calorific gain. The general requirement of provision of calorific gain may, however, allow material combinations that would not be considered energy recoverable, such as a combination of plastic and metal packaging or organic coating applied to metal packaging. Although this packaging may very well enter the MSW stream for incineration and be recovered as material out of the slag, they should not be considered energy recoverable. Therefore, the content of inorganic components is limited to 50% by weight. Inorganic constituents, such as clays and lime, may even be beneficial for the combustion process, and are allowed at higher concentrations, provided $q_{net} \geq 5$ MJ/kg.

REFERENCES

1. 94/62/EC Directive on Packaging and Packaging Waste.
2. EN 13428:2000, Packaging – Prevention by Source Reduction.
3. CEN/CR 13695-1:2000, Packaging - Requirements for measuring and verifying the four heavy metals and other dangerous substances present in packaging, and their release into the environment - Part 1: Requirements for measuring and verifying the four heavy metals present in packaging.
4. CEN/CR 13695-2:2002, Packaging - Requirements for measuring and verifying the four heavy metals and other dangerous substances present in packaging, and their release into the environment - Part 2: Requirements for measuring and verifying dangerous substances present in packaging, and their release into the environment.
5. Directive 2000/76/EC on the incineration of waste.
6. a) EN 13431:2000, Packaging - Requirements for packaging recoverable in the form of energy recovery, including specification of minimum inferior calorific value.

b) prEN 13431, Packaging - Requirements for packaging recoverable in the form of energy recovery, including specification of minimum inferior calorific value. *Revision to be published in 2004.*

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8. CEN/CR 13686:2001, Packaging - Optimisation of Energy Recovery.

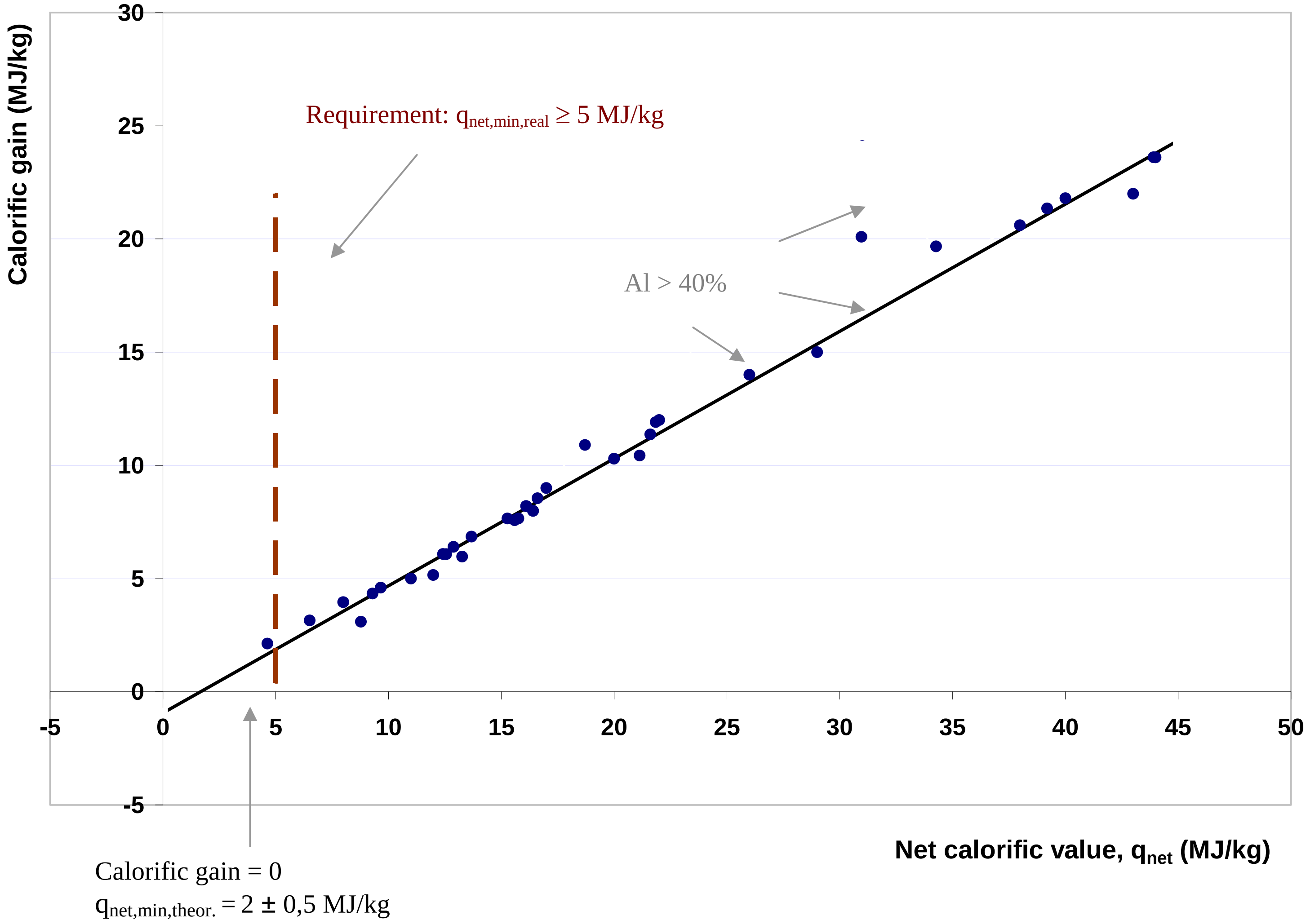

Figure 2. Calorific gain as function of q_{net} for constituents, components and packaging from Ref. 6b. The line is calculated according to the least square method and extrapolated to q_{net} = 0. (Note: the three points well above the line represent examples containing more than 40 % aluminium (by weight). Thermodynamically, aluminium does not behave like organic materials, and these data are excluded from the calculations.)