Energy from Waste

Summary and Conclusions from the IEA Bioenergy ExCo56 Workshop

This publication provides the summary and conclusions from the workshop 'Integrated Waste Management and Utilisation of the Products' held in conjunction with the meeting of the Executive Committee of IEA Bioenergy in Dublin, Ireland on 12-13 October 2005.

The purpose of the workshop was to inform the Executive Committee and ultimately policy makers and stakeholders about the development of waste management processes and the technical and non-technical barriers that need to be overcome in order to accelerate the expansion of these technologies in the market.

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SUMMARY AND CONCLUSIONS

This publication provides a synopsis from the workshop 'Energy from Waste' held in conjunction with the 56th meeting of the Executive Committee of IEA Bioenergy in Dublin on 12-13 October 2005.

Solid waste derived from the household and commercial waste sectors, commonly referred to as municipal solid waste (MSW), is an important resource. In many countries the majority of this MSW is consigned to landfill where it causes significant environmental damage through, for example the release of greenhouse gases, leachate, and general disamenity. The public sector is closely involved in the diversion of MSW from landfill as it sets the policy for waste management and normally controls the waste stream via contracts to the private sector. Polices on waste minimisation and recycling therefore impact directly on the nature and quantity of residual waste requiring treatment prior to landfill. MSW represents a significant resource for energy recovery either via the recovery of the materials' *inherent* energy, through for example recycling/recovery processes, or through the *direct* recovery of the energy value. The energy recovered from residual MSW can off-set that derived from fossil sources.

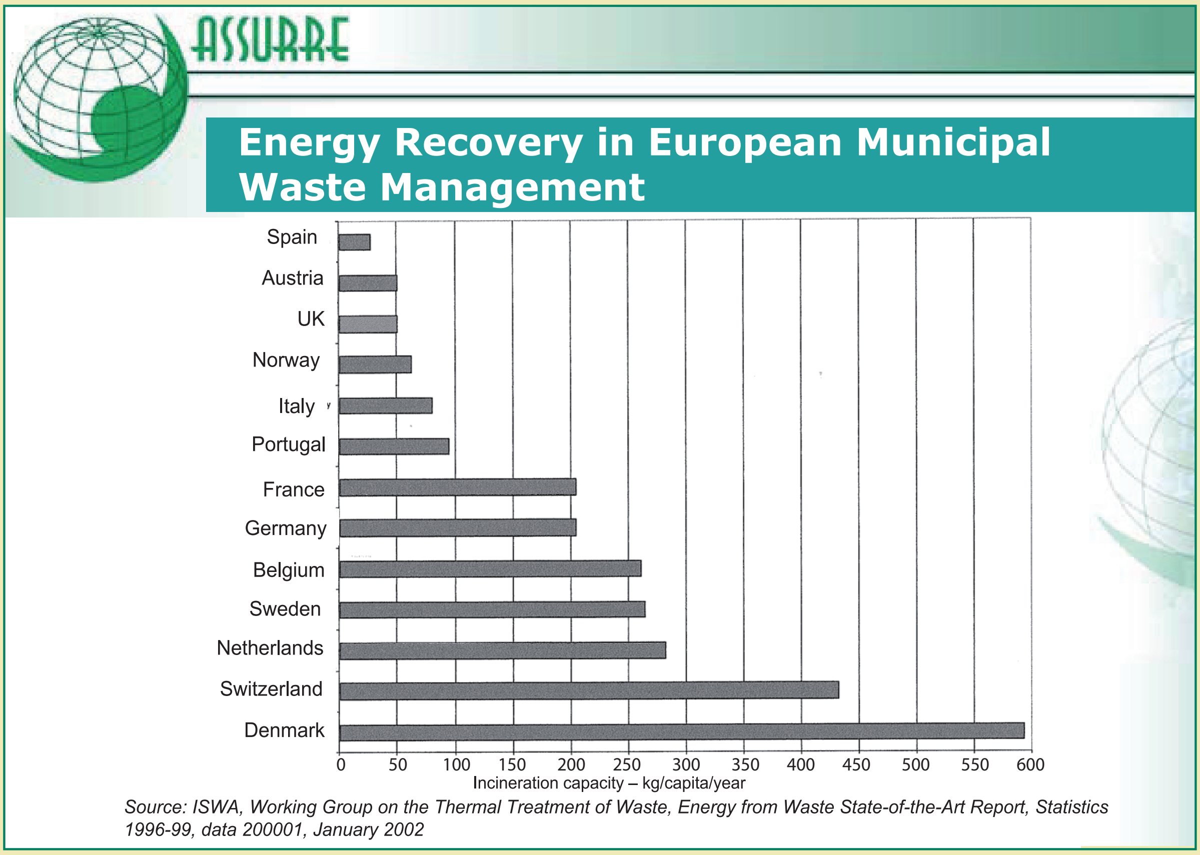
Whilst there are various biological and thermal systems that can be applied to the treatment and recovery of residual wastes many of these still suffer from poor public perception and this negative perception often leads to deployment difficulties. Public bodies sometimes seek alternatives to the proven systems and these alternatives are themselves often unproven and/or technically and environmentally inferior to the conventional systems.

The key barriers to deployment of environmentally sound residual treatment technologies include:

- Resistance to implement existing proven systems in view of public opposition and/or knowledge of system performance compared to alternatives.
- Lack of systematic, reliable information on the performance of various configurations of treatment technologies.

These barriers can be addressed by providing policy makers and developers with:

- Information on systems performance – technology, environmental impacts, cost etc.
- Guidance – to aid policymaking and to assist deployment of systems.
- Reverse logistics – guidance on systems and infrastructure to systematically and incrementally recover resource value from waste.



Incineration capacity in kg/capita of selected European countries (2002)

INTRODUCTION

The workshop was held in conjunction with the 56th meeting of the Executive Committee of IEA Bioenergy in Dublin on 12-13 October 2005. The purpose of the workshop was to inform the Executive Committee of IEA Bioenergy and ultimately policy makers and stakeholders about the development of waste management processes and the technical and non-technical barriers that need to be overcome in order to accelerate the expansion of these technologies in the market. The workshop was a follow-up of the IEA Bioenergy position paper 'Municipal Solid Waste and its Role in Sustainability'[1]. The full contributions (PowerPoint presentations) of the contributors can be downloaded from the IEA Bioenergy website[2].

BACKGROUND

All societies produce waste. Today, a whole series of technologies and practices are employed in developed countries to optimise the re-utilisation and recovery of waste instead of the past practice of uncontrolled dumping that is still prevalent in many developing countries.

The biodegradable components (e.g., paper and food) of wastes consigned to landfill decompose to emit carbon dioxide and methane – the latter a greenhouse gas 23 times more potent than carbon dioxide. Hence many countries aim to reduce their dependence on landfill for such wastes. The European states in particular have set ambitious targets for the reduction of biodegradable waste destined for landfill; and some have even banned the practice. Despite this, significant quantities of solid wastes continue to be disposed of to landfill largely driven by poor infrastructure, low cost and ready availability.

Many countries have adopted the principles of the waste hierarchy in order to guide their policies for waste management according to the 4 R's: Reduce – Re-use – Recycle – Recovery of energy. Where it is economically viable and environmentally sound recycling materials is preferable to treatment of waste (both for energy recovery or to stabilise for landfill).

Alternatives to landfill disposal allow the resource value of the material to be recovered either through recycling activity, allowing the inherent energy value of the material to be recovered or more directly through energy recovery via a number of means including: direct combustion; fuel production and biogas recovery.

While the composition of solid wastes can be highly variable the removal of materials for recycling and biological treatment tends to leave a residue that has a significant calorific (heat) value making it suitable for energy recovery operations. The heat value of this residual waste from developed countries is in the region of 8 to 12 MJ/Kg (cf. 25 to 30 MJ/kg for coal) making it suitable for a range of conversion technologies of which direct combustion systems are the most common. In some countries (and in particular Asia) the biological fraction (food waste) tends to be considerably greater and the application of bio-treatment technologies generating a biogas for combustion is more suitable.

DRIVERS AND BARRIERS

Within the EU the main driver for diverting the degradable fraction of the waste from landfill is the Landfill Directive[3]. The waste can either be recycled (so recovering its inherent energy value) or energy can be extracted from the remaining residual waste. EU member countries fall into one of two groups: those that already meet the requirements of the Landfill Directive because they have highly developed waste management infrastructure and so consign the minimum to landfill; and those that do not meet the Landfill Directive yet and so provide the greatest opportunity for energy recovery. The former group of countries include Austria, Germany, Denmark, and the Netherlands. The latter group includes the southern European nations, Scandinavia, the UK, and Ireland.

Policy and economic drivers for sustainable waste handling vary among OECD/IEA countries. Canada, USA, and Australia for example have far lower energy costs than European countries which affects the degree of uptake of technologies to recover energy and materials. At the same time they do not as yet have policy measures such as the EU Landfill Directive and therefore continue to rely on landfill. Hence, they rely principally on the economic driver for waste diversion.

The last decade has seen considerable efforts in research work on waste management – including policy development, environmental systems analysis, technology development, and economic drivers. Whilst this has assisted in the development of waste management systems in many cases it has also delayed deployment of energy recovery systems in particular due to confused policy making, lack of public awareness (and therefore opposition) and uncertainty over environmental performance and technology performance. Policy makers require guidance and information on all these aspects if waste and resource management systems that are environmentally and economically sustainable are to be developed. It is an on-going objective of the IEA Bioenergy Tasks working in this sector to promote the utilisation of this resource in the most environmentally sound and cost-effective manner possible.

[1] *www.ieabioenergy.com/LibItem.aspx?id=165*
[2] *www.ieabioenergy.com*
[3] *http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:31999L0031:EN:HTML*

PRESENTATIONS

The workshop consisted of seven presentations from invited speakers drawn primarily from organisations outside of the Bioenergy Agreement. A summary of the main points of each presentation follows. The presentations can be downloaded from the IEA Bioenergy website[4].

Presentation 1: The Thematic Strategy on the Prevention and Recycling of Waste – Christopher Allen, European Commission DG Environment, Belgium.

The EU's Thematic Strategy on the Prevention and Recycling of Waste aims to integrate resource, product, and waste policies throughout the EU Member States. It proposes the application of 'life cycle thinking' into policy making and legislation at the EU and National levels. However, in pursuing this goal the EU is not suggesting a giant life cycle assessment or study but rather seeking to improve the knowledge base of life cycle impacts and reaching consensus on applicable methodologies that inform policy making. The main components of the Thematic Strategy will be:

- a strategy document;
- revision of the Waste Framework Directive;
- action on common standards; and
- action on prevention

An interesting question, currently the focus of wide debate is that of the classification of energy conversion systems as recovery or disposal operations. This has important implications on issues such as meeting recovery targets and on the movement of wastes (or products of waste such as fuel) between Members States. The proposed basis of the classification is that if energy conversion operations achieve a certain threshold efficiency then they will be classed as recovery and may contribute towards targets proposed for recovery. Where they fall short of the required threshold they will be classed as disposal operations (Figure 1).

Presentation 2: Overview of Irish Waste Policy – Michael Layde, Department of the Environment, Heritage and Local Government, Ireland.

The waste policy in Ireland is predicated on achieving EU objectives for the sector. Thus it adopts an integrated approach for waste management based on the guiding principles of the waste hierarchy. Ireland is starting from a position where landfill practices still dominate but considerable progress has been made in increasing recycling rates from around 9% in 1998 to over 28% in 2003 (Figure 2). This progress has been achieved by considerably enchasing the infrastructure for recycling – 'bring banks' (recycling centres), kerbside collections etc., and the introduction of use-related charges. The Irish waste policy recognises the importance of energy recovery (EfW) as part of the integrated waste management system and proposals to establish these facilities are making good progress. Close coordination of activities between the national government and the local authorities has been seen to be crucial in raising public awareness of the needs for more sustainable waste management practices and in streamlining the approvals processes to attract private financing of the required infrastructure.

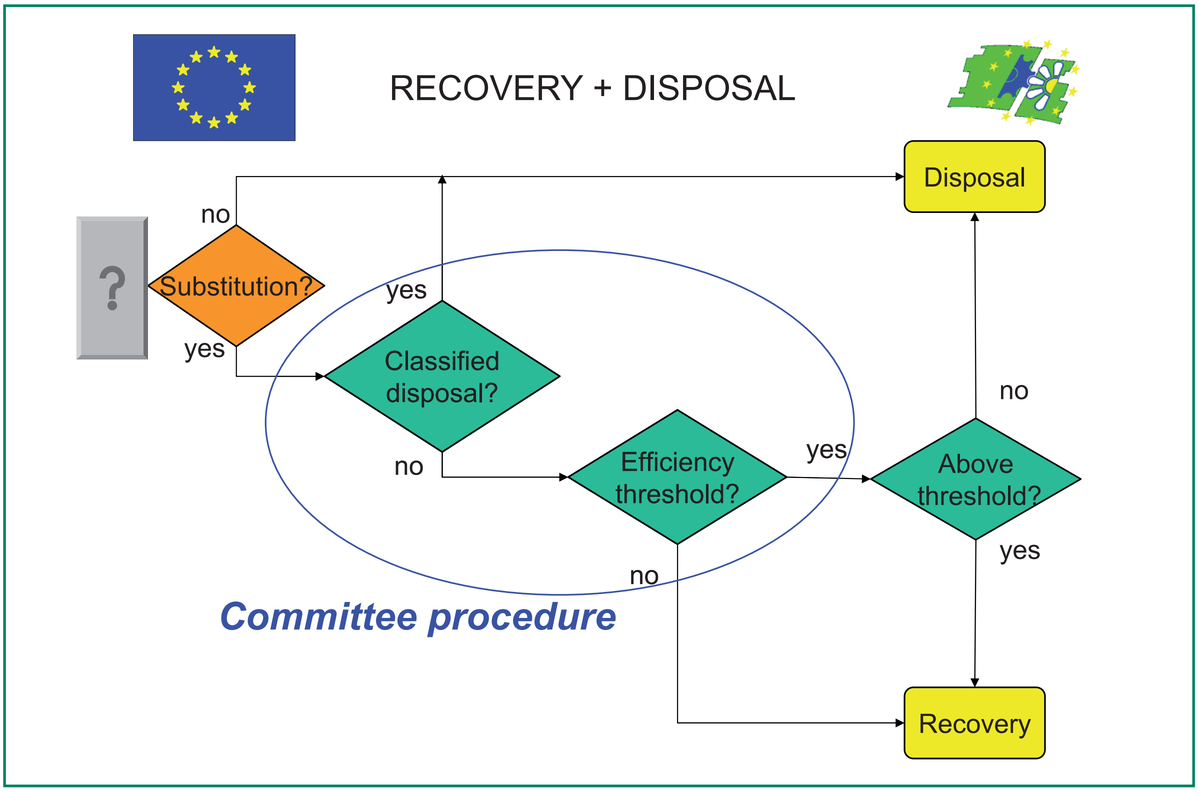


Figure 1: Decision scheme for the classification of waste treatment operations

[4] *www.ieabioenergy.com*

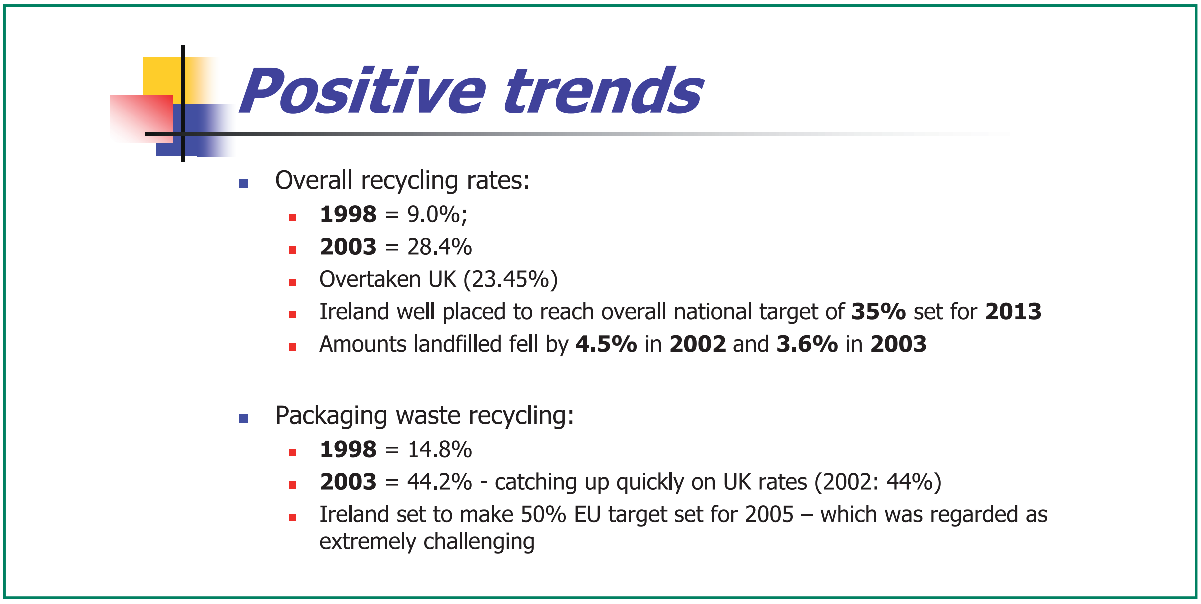


Figure 2: Ireland has made great progress in waste recycling as a first step to meet the EU landfill directive

Presentation 3: Ecobalance of Energy from Waste – Timo Gerlagh, SenterNovem, the Netherlands.

The Netherlands have a highly developed waste management infrastructure currently exceeding the requirements of the Landfill Directive and achieving high levels of recycling, composting, and energy recovery (Figure 3). However, the continuing growth in total waste tonnages requires that additional treatment infrastructure is developed, particularly for residual wastes. Gerlagh reported on a study applying life cycle assessment techniques to evaluate four scenarios or options that could be developed for this new infrastructure.

1. Increasing incineration capacity.
2. Composting of biodegradable waste and production of a fuel fraction (RDF).
3. Separation of a plastic rich fraction for co-combustion with fossil fuel along with incineration of the remaining residual waste.
4. Landfill of residual waste.

The study concluded that the two options which include separation of the mixed waste were the best options, with energy efficiency dominating the outcome of the result. Incineration in a high efficiency plant (option 1) could also match the performance of the separation options (2 and 3). Landfill was demonstrated to be the worst option.

The study is contributing to the development of the national waste management plan. The recommendations are to reduce landfill and increase separation capacity including the development of higher efficiency incineration plant.

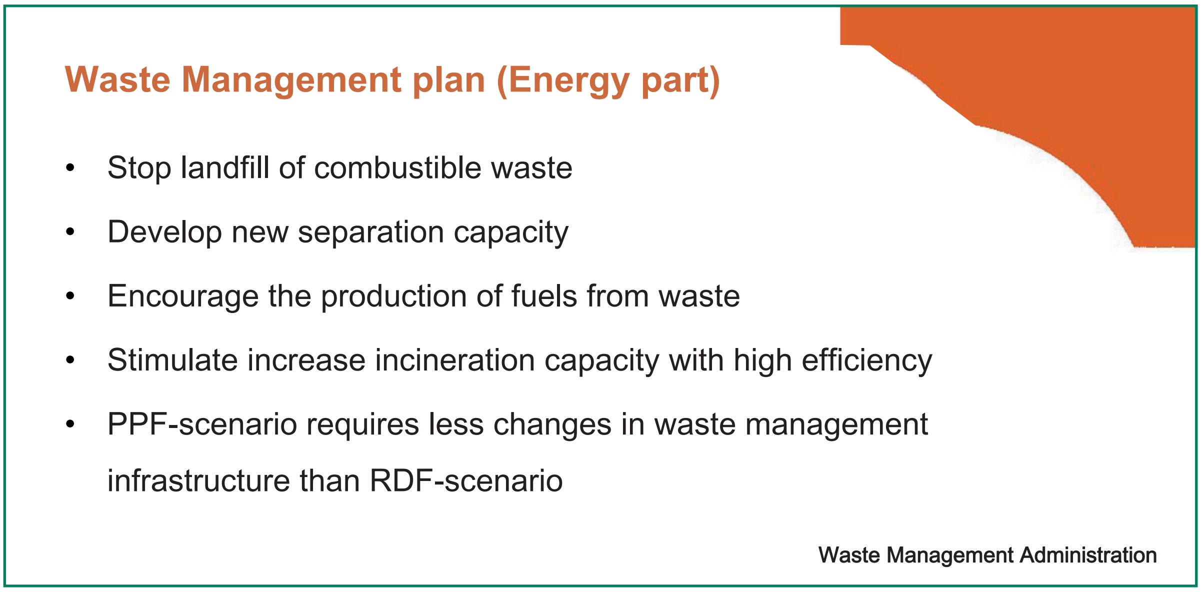


Figure 3: The Netherlands have a highly developed waste strategy exceeding the EU requirements

Presentation 4: Resource Management: looking for Sustainable Solutions – Bill Duncan, ASSURE, Belgium.
Duncan gave a wide ranging presentation summarising the waste management situation in Europe and drawing on a number of studies underpinning the development of EU and national policy. The opportunities to increase sustainable management practices including recycling and energy recovery were highlighted as being driven by the requirement to move waste away from landfill. The intention of EU policy was to move away from a prescriptive to a strategic approach, to align and integrate policy in this sector and to make greater use of life cycle approaches to inform decision making. Various combinations of approaches are available to Member states and the difficulty is in establishing the optimal systems to deliver the required sustainability at a price that is affordable.

Presentation 5: Combating Climate Change: the role of waste to energy – KD Van der Linde, Waste and Energy Company, the Netherlands.
Van der Linde presented a summary of the development of a high efficiency waste to energy facility for the city of Amsterdam (Figure 4). It includes a sewage treatment plant with sludge drying and incineration together with MSW. The incineration plant is designed for maximum electricity production with an expected efficiency of 30%. He emphasised that public acceptance was the key to the development of the plant and that a clear explanation of the need for and benefits of the facility were necessary for successful development. The concept behind the use of the technology is not new but the methods of optimising value recovery are – in order to be implemented in a cost-effective manner. The goal has been to reduce environment impacts (emissions) and to increase efficiency of energy recovery and use of residual materials so creating a closed loop system which can only be achieved in combination with the waste water treatment plant (WWTP). A comparison of this technology to other forms of renewable energy generation such as wind, solar and biomass (in the Netherlands) highlighted the higher availability of energy from waste.

Presentation 6: Mechanical Biological Treatment: A must for future waste upgrading technologies – Arthur Wellinger, Leader of IEA Bioenergy Task 37, Switzerland.
Mechanical biological treatment (MBT) technology is well established as a pre-treatment option prior to incineration and/or landfill. Approximately 20 million tonnes of processing capacity is installed worldwide with the greatest usage in Italy, Germany and Spain (Figure 5). It is not a stand alone technology – its objective is to mechanically separate the mixed waste stream for downstream treatments such as bio stabilisation and energy recovery. In most of the plants composting is used as the biological treatment however, the application of anaerobic digestion (AD) instead is increasing. There are some 30 plants in operation with treatment capacities of up to 160,000 tonnes per year.

In industrialised nations with well developed existing waste infrastructure the application of MBT systems may contribute to optimising incineration and/or landfill capacity and might produce a humus rich soil improver that can be applied in arid areas (e.g., Spain, Australia). For developing nations where the bio-waste (food) content is greater and landfill without gas recovery or lining is still common, MBT offers a cost competitive option for the treatment of such wastes to reduce emissions.

MBT is an ideal process to be combined with incineration. If with MBT and biogas production the initial volume of waste going to incineration is reduced and can be replaced by additional MSW, then the total energy recovery is higher than with incineration alone at a clearly reduced price per tonne.

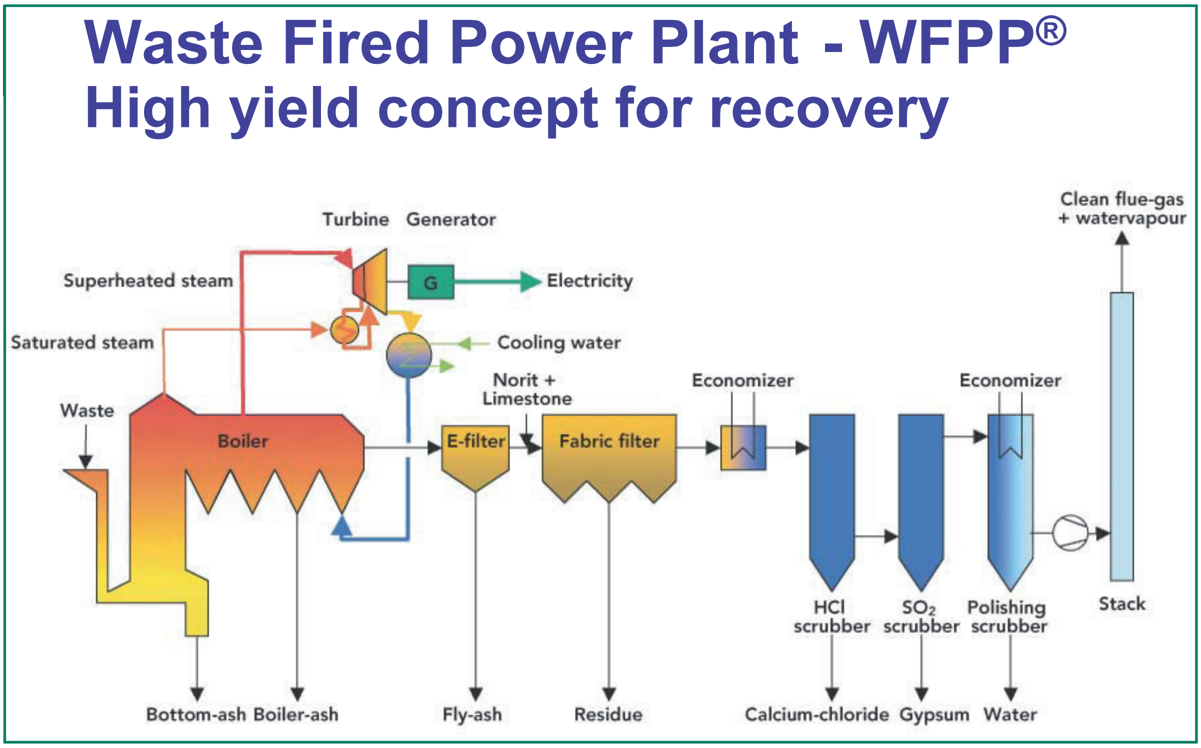


Figure 4: Design of the new Amsterdam waste incineration plant with high electrical efficiency.

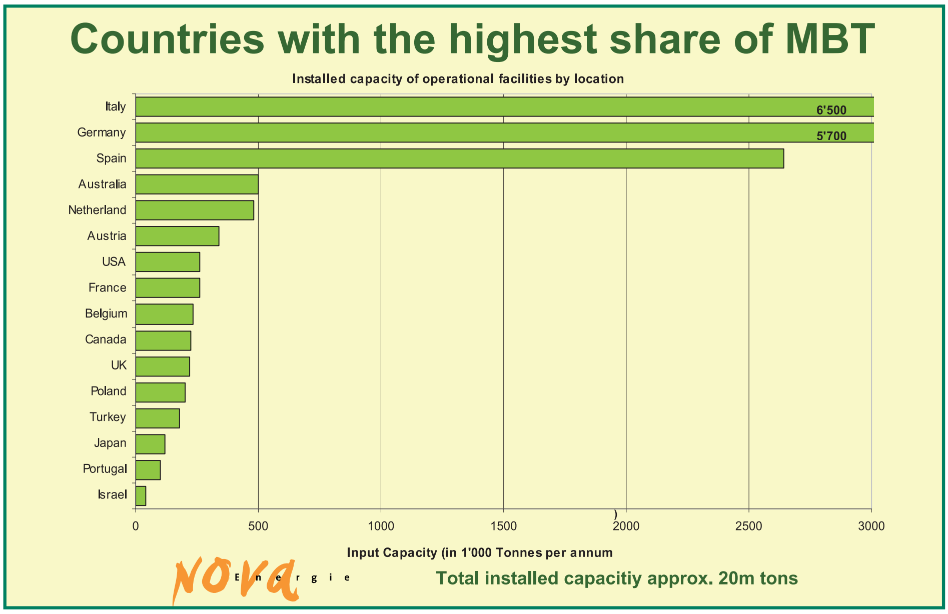


Figure 5: Italy, Germany and Spain cover 75% of the total worlds MBT capacity

Presentation 7: Rendered Animal Fat (Tallow): A Waste for Incineration or a Sustainable Bio-fuel? – Stephen Woodgate, European Fat Processors and Renderers Association (EFPRA), United Kingdom.

Rendered fat (or Tallow) is a product derived from the treatment of animal by-products (see Figure 6). About 70% of tallow has applications in the food (animal feed) and cosmetic (soap) industry. The remaining 30% can be applied in the energy sector as a fuel substitute. Tallow has 95% of the calorific value of fuel oil and can be used directly in steam boilers and power stations or indirectly – after esterification - as a biodiesel.

Woodgate highlighted a problem caused by EU legislation in the use of tallow as a fuel due to its classification as a 'waste' rather than a 'product'. As waste, any application for energy recovery falls within the definition of the Waste Incineration Directive (WID) and this requires that the emission standards of WID must apply. In practice this means that the use of tallow for energy recovery becomes in many cases uneconomic. In 2004 of the 2.6 million tonnes of tallow produced, 700,000 tonnes was used as a fuel – displacing 2 million tonnes of carbon dioxide emissions from fuel oil. However, this contribution is under threat if the requirements if the WID are fully enforced. Woodgate made a case for greater integration in policy making to recognise the contribution of products such as tallow and to amend regulations to allow the continued exploitation of tallow as a renewable biofuel.

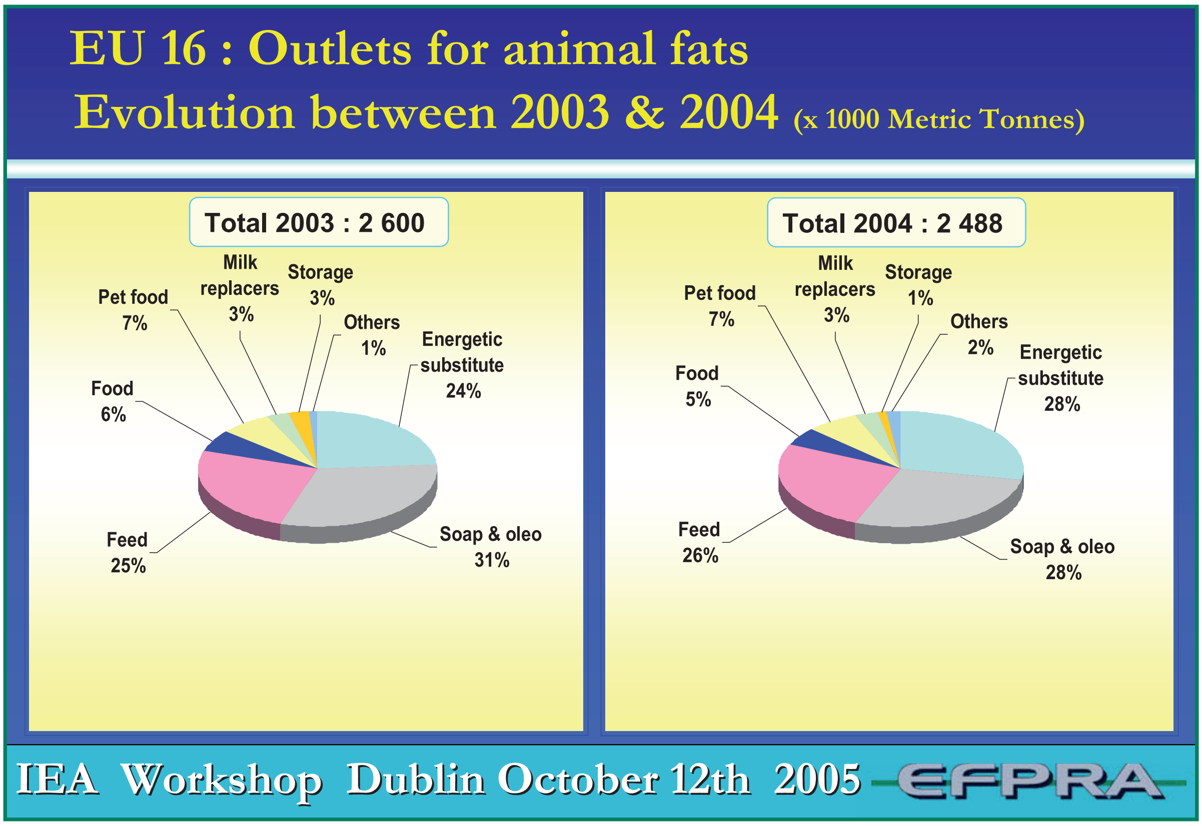


Figure 6: The utilisation of animal fat in the EU 16.

DISCUSSION

The conclusions of the presentations and the subsequent discussions may be summarised under the following headings.

Waste Composition

It is obvious that by its nature mixed solid wastes are heterogeneous and the individual component compositions vary considerably, particularly when compared between industrialised and developing nations (Figure 7). These variations in composition have implications not only on the technologies that can be applied for treatment but also on the policy measures that need to be in place to manage the waste stream most effectively.

The historical mission of waste management practice in developed nations has been to secure hygienic conditions for mixed waste – largely achieved through modern collection and treatment practices. The driver now is for more sustainable measures and the exploitation of wastes as a resource. This is not much different for developing countries, only that their need to improve recycling and reduce emissions is much more pronounced. Above all, their sanitary conditions and the local odour problems have to be resolved quickly.

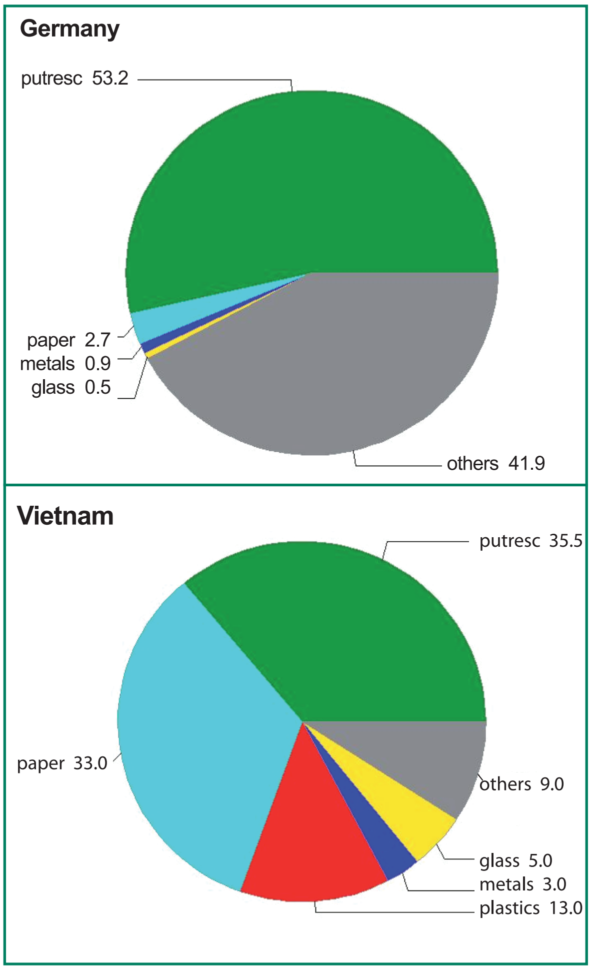


Figure 7: Waste composition for Germany and Vietnam.
Source: J Vehlow, Presentation to Bioenergy Australia, 2005

Technology

There are numerous conversion routes for mixed waste (Figure 8). Basically, these involve thermochemical processes (such as incineration, gasification and pyrolysis) and biological processes (such as anaerobic digestion and aerobic composting). All process routes for energy recovery in dedicated or co-combustion units, with the exception of mass burning or incineration systems, require the production of a specified fuel fraction. This can be accomplished either by separation at source followed by simple mechanical treatment such as size reduction, or by extensive mechanical treatment where source separation is not comprehensive.

The component technologies are to a large extent well proven. For example mechanical biological treatment and incineration with subsequent stack gas cleaning have been established technologies for more than 30 years. Gasification and pyrolysis are still in the process of development (Table 1).

Table 1: Status of waste treatment technologies

	Pyrolysis	Gasification	Combustion	MBT
Years in operation	30	10	75	30
Number of installations	< 10	< 100	> 1.000	> 500

Biowaste accounts for 30-45% of MSW across Europe. Wherever possible, source separation of the organic fraction of MSW (kitchen, yard and food industry waste) should be introduced. Its collection, treatment, and disposal pose unique challenges. The material is intrinsically fermentable, which makes it less than ideal for landfill, while its high water content decreases its efficiency during energy recovery. This is especially problematic in Asian countries where heat capacity of waste might be too low for incineration without fuel addition.

Where source separation is not available then processing systems can be configured to prepare a fuel (sometimes referred to as refuse derived fuel or RDF) for dedicated combustion plant (fluidised bed) or co-combusted in existing facilities (cement kilns and power stations). Here the barriers to exploitation include;

- Technical – feasibility of co-firing or dedicated combustion (there are few full-scale commercial operations but many at small commercial or pilot scale).
- Environmental – regulations governing co-firing are less well developed.

The challenge is making the appropriate selection of all combinations that will deliver the optimum environmentally sound and cost-effective system.

Policy Making

The management of wastes within the EU is almost entirely regulated by EU Directives. The Waste Framework Directive provides general guidance and advice on waste disposal

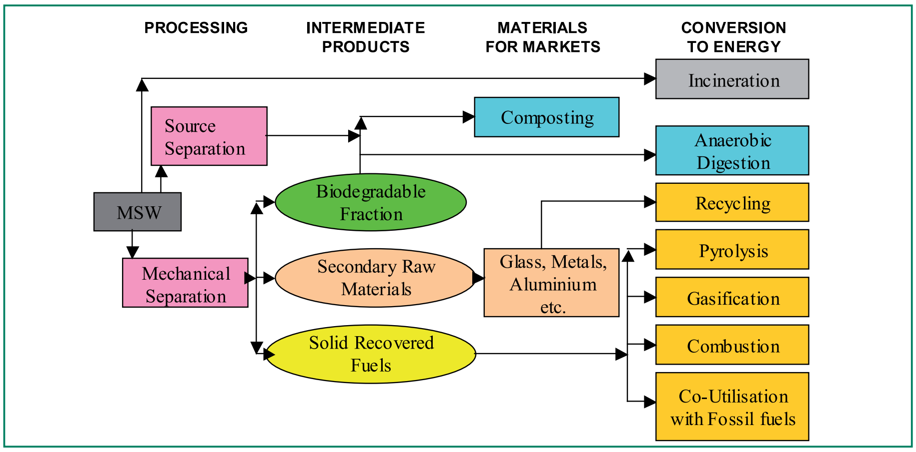


Figure 8: Conversion routes for source segregated biowaste and residual MSW.

of the material and where this is not practicable then direct energy recovery can be applied. A hierarchical approach has been promulgated to put all these systems into practice.

Some countries even go beyond the legal requirements. Austria banned the organic fraction in 2000 as did Switzerland. They were followed by Denmark and Sweden.

and directives regulating specific waste streams have been developed under this umbrella. The fundamental aim of these policies is to harmonise the regulations operating in the waste sector and to encourage more sustainable waste management practices.

The Landfill Directive is of fundamental importance and is the chief driver for reducing the reliance on landfill. Member States have introduced various policy measures to achieve this including the introduction of taxes to raise the cost of landfill disposal and complete banning of organic matter deposition (Figure 9). These regulations offer a considerable opportunity for sustainable energy management systems to be introduced. Recycling of materials recovers the inherent value

Now, a further refinement of this is to introduce a life cycle approach into determining policy. For residual wastes i.e. after recycling operations, life cycle studies assessing the major environmental impacts (or sustainability indicators) have shown the positive benefits to be gained from integrating energy recovery into the process.

These gains are in the form of:

- Reduced greenhouse gas emissions.
- Reduced acid gas emissions.
- Reduced depletion of natural resources (fossil fuels and materials).
- Reduced impact on water (leaching).
- Reduced land contamination.

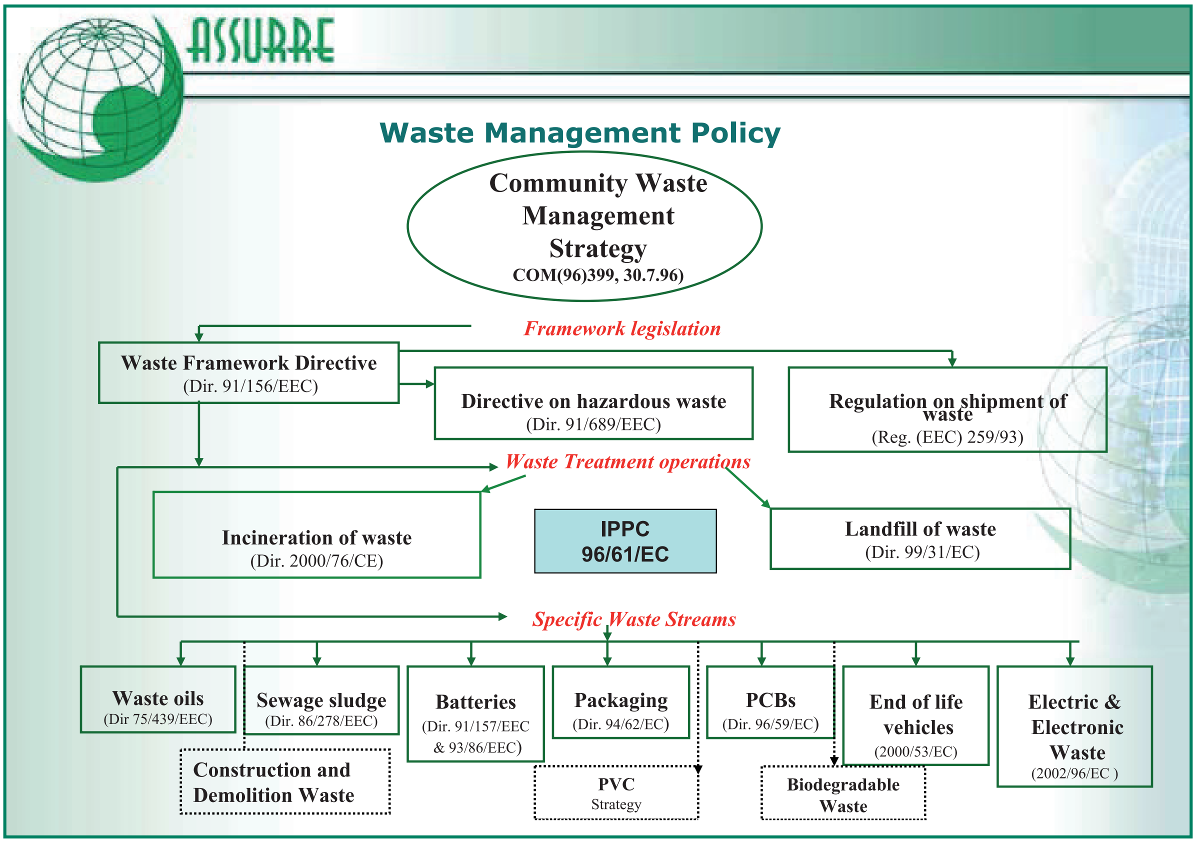


Figure 9: EU waste management policy

IMPLICATIONS FOR BIOENERGY

General

The opportunity to recover energy from municipal solid wastes (MSW) is inextricably linked to a country's policy on waste management. Thus in North America for example, where the main driver is economic and landfill is generally widely available, it is difficult to establish energy from waste projects. Typically, such projects are developed at relatively large-scale (up to 500,000 tonnes/year capacity) in order to make them economic. By contrast, in Japan where landfill is at a premium there is a greater driver to develop systems for residual waste treatment incorporating energy recovery. The situation in the EU is between these two extremes: there is a policy driver (the Landfill Directive) that over the next 15 years will provide a significant opportunity to develop further residual treatment capacity – at least in those countries that still consign more than 50% of MSW to landfill. Thus the opportunity to incorporate environmentally sound and cost-effective energy recovery systems is significant and can add to the current levels of renewable energy generation from solid waste.

Technology

The component technologies for residual waste treatment are largely well developed. However, the lead-in times for the implementation of such systems continues to be drawn out and complex due to the need for decision makers to take account of various legislative, technological, environmental, commercial and social considerations. On technology we can conclude that:

- Proven systems are available for direct treatment of residual MSW, largely based on grate-fired combustion plant.
- Technologies such as pyrolysis/gasification have yet to be fully demonstrated at commercial scale (outside Japan).
- Energy recovery systems with mechanical biological treatments are proven systems. The increased legal requirements on full stabilisation in some countries like Austria and Germany create new challenges for the technology.

Market Development

Even though the environmental and energy advantages of energy recovery systems are fully proven, their market introduction is still slow. The main barriers to further market deployment include:

- Public acceptance of 'new' technologies for residual wastes.
- The lack of systematic, reliable information on new technology combinations and their environmental and economic performance.
- Disjointed policy and decision making at national and local level.

FURTHER READING

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