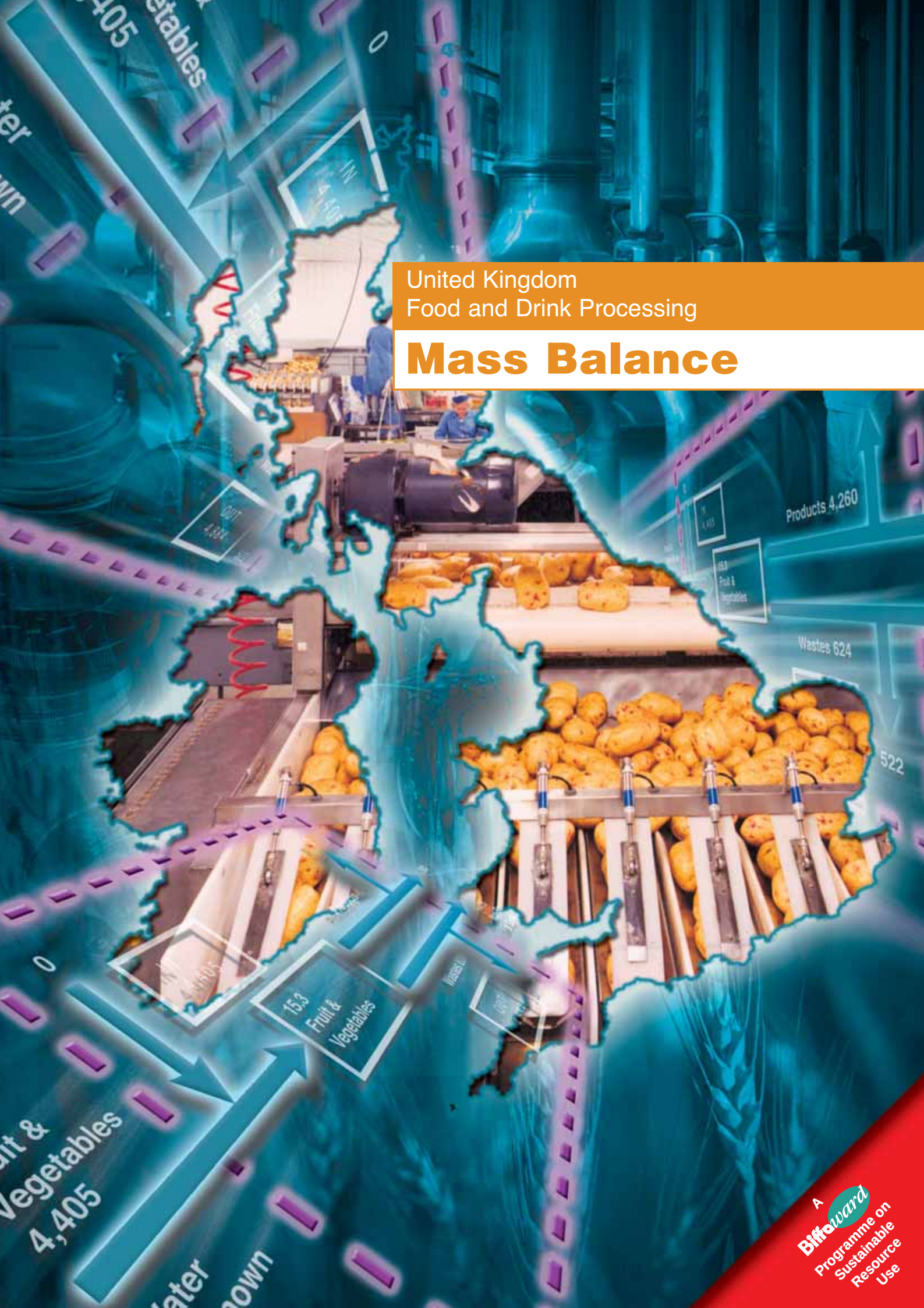
United Kingdom
Food and Drink Processing

Mass Balance



A Biffaward Programme on Sustainable Resource Use

Biffaward Programme on Sustainable Resource Use

Objectives

This report forms part of the Biffaward Programme on Sustainable Resource Use. The Programme aims to provide accessible, well researched information about the flows of different resources through the UK economy based either singly or in combination on regions, material streams and economic sectors.

Background

Information about material resource flows through the economy is of fundamental importance to the cost effective management of resource flows, especially at the stage when those resources become waste. In order to maximise the Programme's full potential, data will be generated and classified in ways which are consistent with each other and with the methodologies of other generators of resource flow/waste management data.

Acknowledgments

C-Tech Innovation Ltd are grateful to the Mini-Waste and Food Processing Faraday Partnerships for their support and assistance in developing the concept of this report, assistance with targeting and arranging field research and the provision of other useful background information on the food and drinks processing sector.

The authors wish to acknowledge the contribution of Sustainable Technology Solutions Ltd in the compilation of data and information pertaining to the fruit and vegetable sector. For further information about Sustainable Technology Solutions, visit their website at www.sustainabletechnology.co.uk or contact

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The analysis of waste contained in this report is substantially based on the findings of the Environment Agency's 1999 National Waste Production Survey. The authors gratefully acknowledge the assistance of the Environment Agency in carrying out detailed interrogation of the Waste Survey data and helpful background discussions. Further details of the Environment Agency's ongoing activity in monitoring waste patterns may be obtained from the Waste Survey web site at

http://www.environment-agency.gov.uk/subjects/waste/315439/302097/
or via e-mail, from alan.bell@environment-agency.gov.uk

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Foreword

For the past 200 years society has become used to quantifying and understanding efficiency in 2 broad dimensions:

- labour and people input,
- financial costs.

Few have paused to think about the efficiency of the way we deliver goods and services in terms of physical resource inputs and outputs. This publication is an attempt to refocus our thoughts in that direction in relation to food processing. Why bother? After all the environment is "free". We can use low cost, non-renewable raw materials such as minerals, carbon or energy at will - it is the application and conversion of those resources that is becoming expensive in the form of traded permits or pollution taxes.

We are now coming to terms with reality - that the profligate use of low "financially" priced resources has resulted in the introduction of large quantities of liquid, gaseous or solid waste into the world at a rate faster than the eco-system can return it to its original state - if at all. Each year it is estimated that spaceship Earth only neutralises around 38% of CO_2 produced. The consequences of this may not necessarily be as cheap as we thought - indeed we are yet to count the future cost in terms of health, climate change and biodiversity loss.

Few in society recognise that our developed economy is consuming in excess of 10 tonnes of raw material resources for every one tonne of output purchased at the point of sale by private individuals. Much the same ratios apply to specific sectors. In 1998 the Government introduced the means by which Biffa could fund work undertaken by those keen to explore the implications of this level of resource inefficiency. The Landfill Tax Credit Scheme has allowed us to commit over £8m in the last 4 years to more than 50 such sector studies which look at the dynamic of resource flows through different regions, industry sectors and resource lifecycles. DTI and DEFRA have subsequently reaffirmed their support in the form of critical resource efficiency indicators.

Environmental impacts come in the form of widespread use of non-renewable materials sourced and disposed of in ways that don't necessarily represent the best deal for society in the long run. For the cynics among us, the dictum that it will be financial costs that drive the process is probably the right one and those costs are set to rise. Landfill Tax has risen at a mere £1 per tonne over the last 7 years and the Chancellor has announced a £35 cap for around 2011 - driven by higher levels of awareness on the workings of environmental taxation in the Government as well as increased pressures resulting from the recent spending round. Additionally, a much wider range of materials being used are about to be reclassified as hazardous with the consequence that they will either be banned from landfill and treated to recover their constituent elements for reuse or designed out entirely. Producer Responsibility, targets and Traded Pollution Permits all add to the emergent tapestry of Environmental instruments driving this process.

The food processing sector is going to have to learn how to trade-off these new economic as well as environmental realities. Apart from the cost-push pressures driven by European and UK legislation/regulation, there are also the demand-pull expectations of the "market place". Product producers are under increasing pressure to develop internal reporting guidelines on all aspects of their environmental track record. Unfortunately this report will create more questions than it answers - but that is always the case with leading edge work. It highlights the chronic absence of reliable data on resource flow generally. This should be no surprise given parallel paucity of data on mainstream areas under management - particularly waste - where policymaking is bedevilled by an absence of an integrated framework or sets of common definitional protocols. Today it is but a dream to believe that a comprehensive overview of resource inputs into and from UK Plc could be obtained at the flick of a button, but the process has started via the Biffaward funded software packages for Municipal WasteDataFlow and REMAT. The former is the Agency/DEFRA recommended national reporting framework for domestic waste whilst the latter is the industrial and commercial sector equivalent.

This publication is designed to present the wider picture and inform the debate. If you wish to explore the issues outside your own industry, then find out more about the Biffa Mass Balance Programme on www.massbalance.org and see examples of some of the 50 odd commissioned studies that have reported thus far, or contact me on peter.jones@biffa.co.uk.

Peter Jones
Director - Development and External Relations
Biffa Ltd

Executive Summary

The Food and Drink processing sector is the major consumer of UK agricultural output, and sales of its products are an important contributor to the United Kingdom's GDP and trade balance. The sector also produces around a tenth of the country's industrial and commercial waste. Information on these important resource flows has not previously been available in consolidated form.

This report provides a comprehensive assessment of the major inputs, outputs and wastes arising from UK food and drink processing using the mass balance format. The report also considers the status of relevant UK and EU legislation, and current and future options for waste minimisation and energy and value recovery from the industry's wastes.

> " Stakeholders must act concertedly to drive change in practice and promote waste minimisation. "

The purpose of this report is to inform stakeholders - including food processors, waste management service providers, technology providers, local authorities and central government officials, of key aspects of resource flows in the sector. These include the amount and nature of various streams (particularly wastes), identified needs related to food processing wastes, issues preventing or slowing the adoption of new practices, and case studies of current industrial practice and emerging approaches to waste minimisation.

Mass balances are presented for the nine major sub-categories of food and drink processing as defined by the SIC(92) 15.0 industry classification, identifying net inputs of principal ingredients, outputs of products and bio-degradable wastes arising. Allowance is made for the interdependent nature of food processing and the significant flows of products and co-products from one area of the sector to another for further utilisation. Amounts of non-biodegradable waste are also reported, and where available estimates of water utilisation have been included.

The sub-sector mass balances are consolidated into an overall mass balance for the UK food and drink processing industry. The sector is estimated to consume nearly 56MT of ingredients annually in the production of 59MT of products, including the water content of beverages. Biodegradable wastes exiting the sector amount to nearly 1.9MT, but a further 3.4MT were re-utilised within the sector at the time the source waste data was collected (1999). Other wastes, including packaging derived material, and mixed or uncategorised waste amounted to a further 3.9MT. Deducting the moisture content of beverages from the products allows an estimate to be made of the amount of incoming water paid for as part of the sector's raw materials which does not leave in finished product. This stream is estimated at 8.6MT.

The general thrust of legislation and specific responses to high profile food chain health scares mean that many conventional mechanisms for dealing with food processing waste are under threat or already no longer available. Food and drink processors and the waste management sector serving them face significant challenges in developing the operational practices and understanding, information management systems, collection infrastructure and new technologies required to comply with the new legislative requirements for Animal By-Products, Packaging Producer Responsibility, Landfill restriction, and IPPC compliance. The food and drink industry, waste management companies, and government must act concertedly to drive change in practice, promote waste minimisation and allow available new technologies to significantly contribute to sustainable management of the industry's wastes.

1 Introduction

These are changing times for food processors and how they must handle their material flows. Food and drink manufacturers account for a substantial amount of the UK's annual industrial waste, and in particular its bio-degradable component. Legislative restrictions on landfill disposal will increasingly force the industry to consider new routes to minimise waste and alternative treatment approaches for wastes arising. However these changes also present the industry with the opportunity to take a lead by dealing with waste as part of an overall resource management.

Food waste has the potential for energy recovery, and can be a source of added value speciality chemicals. Cost-effective techniques already exist to enable these sorts of uses to be made of food wastes. Many waste problems could be resolved with a little more attention to segregation of waste streams, and better co-ordinated provision of alternative recovery routes. Innovative processing technology and the application of best operational practice can help producers minimise waste production in the first place. Where there is a will, there is a way.

Government strategy[1] has stated the need to maximise value recovery from waste through better and broader recovery and recycling, and through developing new and stronger markets for recycled products. The food industry has traditionally demonstrated the ability to utilise side streams from one area productively in another, and can now turn that ability to advantage in reassessing current options and opportunities for what is currently consigned to landfill.

> "Food waste is a potential source of energy and added value speciality chemicals."

This report aims to help food processors, waste treatment companies and other stakeholders assess the nature and scale of the challenges and opportunities facing the industry by providing quantified information on resource flows in the sector as a series of mass balances. Waste is broken down for each main sub-sector of food processing by type of waste and its current fate. Additionally the report reviews relevant legislation, options for waste treatment, and emerging food processing technology with the potential to reduce waste.

1.1 Waste and The UK Food Processing Industry

1.1.1 Food and Drink Output and Waste

Food and Drink processing contributes about £70 billion of sales[2] (15% of manufacturing activity) and just under £19 billion of gross added value (2.6% of GDP)[3] to the UK economy. Exports in 2001 were £8.5bn of which 60.6% went to EU members[4].

As a proportion of the overall economy, the Food and Drink sector has declined in the long term as greater affluence resulted in disposable income being spent on luxuries rather than basic foodstuffs.

Figure 1.1
Comparison of UK Food, Drink and Tobacco Industry with Total UK Industry Production Output

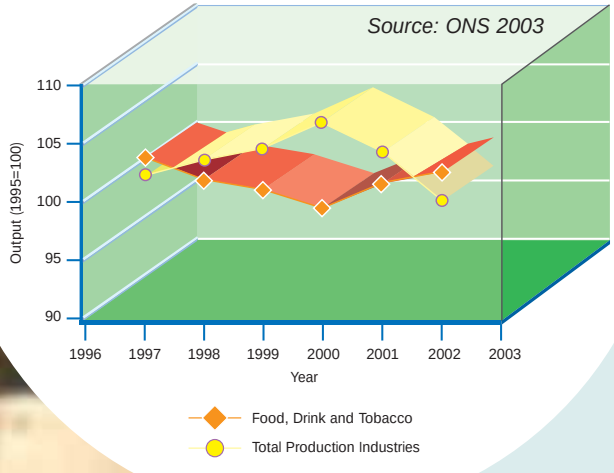
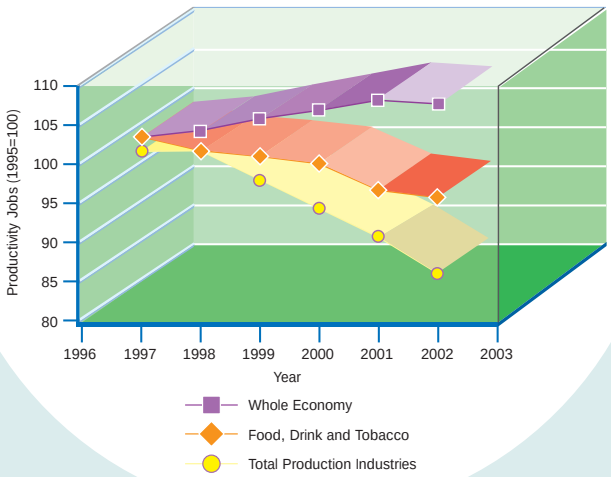


Figure 1.2
Relative Productivity Trends
Source: ONS 2003



Nevertheless the industry remains an important one for the UK economy, providing employment for 455,000 people (1.7% of total employment, over 12% of manufacturing employment) in nearly 8,000 businesses.

The level of output from Food, Drink and Tobacco manufacturing has remained fairly static in recent years, Figure 1.1, although the sector seems to have bucked the trend of the overall production sector during the same period. Output has been maintained against a background of declining employee head count, Figure 1.2, reflecting the general shift in the economy away from manufacturing. This implies greater productivity per job, but as seen in Figure 1.3, the Food, Drink and Tobacco sector lags behind both the economy as a whole and the broader manufacturing base.

Although the overall picture of the industry is fairly stable and mature, there are developing trends, new products and markets. Strong growth has occurred for quality chilled convenience meals, which realise added value by meeting the lifestyle needs of busy consumers with disposable income, but little time to spend in the kitchen. Regional speciality and ethnic foods are also increasingly popular, as the British public becomes more diverse in its make-up and cosmopolitan in its tastes. At the level of the individual operating unit, change is also a constant feature, as product development demands frequent launches and product variants to maintain customer interest and boost added value.

Table 1.1

Contribution of Food Industry to Industrial & Commercial Waste

Type	Percentage of Total	Percentage of Type	Amount (Mtonnes p.a.)
Industrial Waste	69%		48 - 69
Food, Drink & Tobacco		16%	7.7 - 11.0
Other Industrial		84%	40.6 - 58.0
Commercial Waste	31%		22 - 31
Hotels and Catering		16%	3.5 - 5.0
Wholesale (inc. food & drink)		39%	8.5 - 12.0
Other Commercial		45%	9.8 - 14.0
Total Industrial and Commercial Waste			70 - 100

Source: ENDS Report 294, Environmental Data Services, 1999



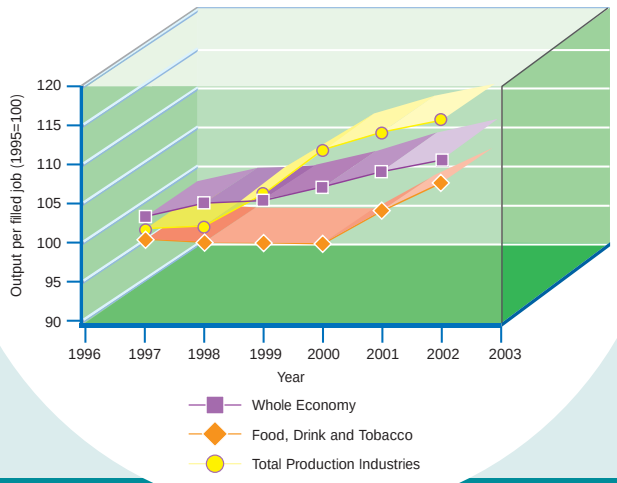
Successful businesses in this important sector of our economy survive by making maximum possible use of the nutritional content of their raw materials, but the food industry remains a significant contributor to UK waste, Table 1.1.

Landfilled waste from food production has been estimated at 2.7 million tonnes per annum,[5] much of which is organic matter.

This is, if nothing else, a potential source of energy, and may also be the source of useful materials for other applications. Most of this value is currently written off as unrecoverable, and paying landfill disposal charges compounds the write-off. As new legislation bites, landfill taxes increase and landfill availability decreases, old disposal practices will no longer be an option for food processors.

"Old disposal practices will no longer be an option for food processors."

Figure 1.3
Relative Output per Employee
Source: ONS 2003



1.1.2 The Bottom Line Impact of Waste

The raw materials of the food industry contain a proportion of inherently non-consumable material. Peelings, offal, husks and so forth must be re-evaluated for potential new uses as old outlets such as animal feeds, landspreading and landfilling become restricted. However new environmental obligations can be financial opportunities if developments in process and recovery technology can be harnessed to minimise waste and realise value from unavoidable waste.

The need to wash and otherwise prepare foodstuffs results in the generation of large volumes of waste water, which either incur cost through treatment or disposal. Reduced water consumption and effluent minimisation can result in a substantial impact on running costs in the food industry.

When considering options for waste reduction, processors need to be aware of the true costs of waste to their business, which go far beyond the direct costs of waste disposal. Cost is also incurred through

- excessive use of raw materials and ingredients
- wasted energy
- water consumption and effluent generation
- discarded packaging, consumables
- waste of human resources in time and effort devoted to coping with waste.

The true cost of waste can therefore be as much as 5 - 10 times the headline cost of disposal.

Long term trends in the retail sector - the emergence of large supermarkets at the expense of independent traders - and increased focus on food safety, quality and traceability, have driven the food chain towards sourcing through preferred suppliers, who are expected to comply with stringent acceptance criteria. Generally speaking, food processors' already tight operating margins have been narrowed further.

The need to demonstrate quality and safety as well as remaining cost competitive, means food processors must address waste minimisation as a matter of business survival as well as one of environmental responsibility.

1.1.3 Policy and Legislation

A policy framework of EU and UK legislation has been constructed in the last twenty years, steering member states towards more sustainable industrial practices across the board. The practical impact of this trend is now becoming a real life issue for the food processing sector as companies have to deal with the requirements of legislation such as Integrated Pollution Prevention and Control (IPPC), the Packaging Waste Directive, restrictions on disposal of biodegradable material to landfill, and Animal By-Products legislation.

While any attempt to legislate always comes with a risk of giving companies additional overhead in achieving compliance, the ultimate effect of waste legislation is intended to be a shift in the economic balance in waste management. This should discourage unsustainable routes and promote emerging technologies, which maximise resource utilisation, minimise waste generation, and recover maximum value from unavoidable waste. A fuller discussion of the relevant legislation is given in Chapter 3.

1.2 Report Objectives

Food processors and industry bodies, waste management and environmental services providers, policy makers and enforcement agencies all need to make informed decisions on the issues surrounding food processing wastes. The main objective of this report is to provide an analysis of resources into and out of the sector which will help stakeholders assess the way forward.

There is currently a lack of overall and comparative quantification of resource flows in the food processing sector. We seek to address this gap by developing mass balances for the UK Food and Drink Processing Industry at the macro level and across major sub-sectors of the industry. The report also identifies relevant legislative drivers for waste in the sector, reviews the key features of food processing and waste treatment options, and considers emerging technologies with the potential for waste reduction in the food industry.

As part of the Biffaward Mass Balance series, this report will add to the overall knowledge base of resource flows within the UK economy. In particular, this study provides further information on the food supply chain, continuing from and building on the data and themes contained in the earlier Biffaward reports on the agricultural sector.[6, 7]

1.3 Scope

The food chain consists of three main links - agriculture, food and drink processing, and the trade and retail sector. A previous report in the Biffaward Mass Balance series, "Agricultural waste mass balance: Opportunities for recycling and producing energy from waste technologies" provides information on the resource balance of the agricultural sector. While considering aspects of the beginning and end of the chain where they influence the processing sector, this report primarily concentrates on industrial production and processing of foodstuffs, from the point of receipt of raw materials through to despatch of products.

Typical wastes encountered in the sector include

- food wastes - peelings, stones, animal by-products, pastry waste etc. in addition to wasted food
- packaging waste - packaging of incoming materials and waste product packaging
- waste water and liquid effluent
- general factory waste.

Food and drink processing is recognised as a major class of economic activity by the Standard Industry Classification 1992, or SIC(92), system, used for official statistical purposes. The main division code for the sector (15) is divided into 9 classes representing the following activities

- 15.1 Production, processing and preserving of meat and meat products
- 15.2 Processing and preserving of fish and fish products
- 15.3 Processing and preserving of fruit and vegetables
- 15.4 Manufacture of vegetable and animal oils and fats
- 15.5 Manufacture of dairy products
- 15.6 Manufacture of grain mill products, starches and starch products
- 15.7 Manufacture of prepared animal feeds
- 15.8 Manufacture of other food products
- 15.9 Manufacture of beverages

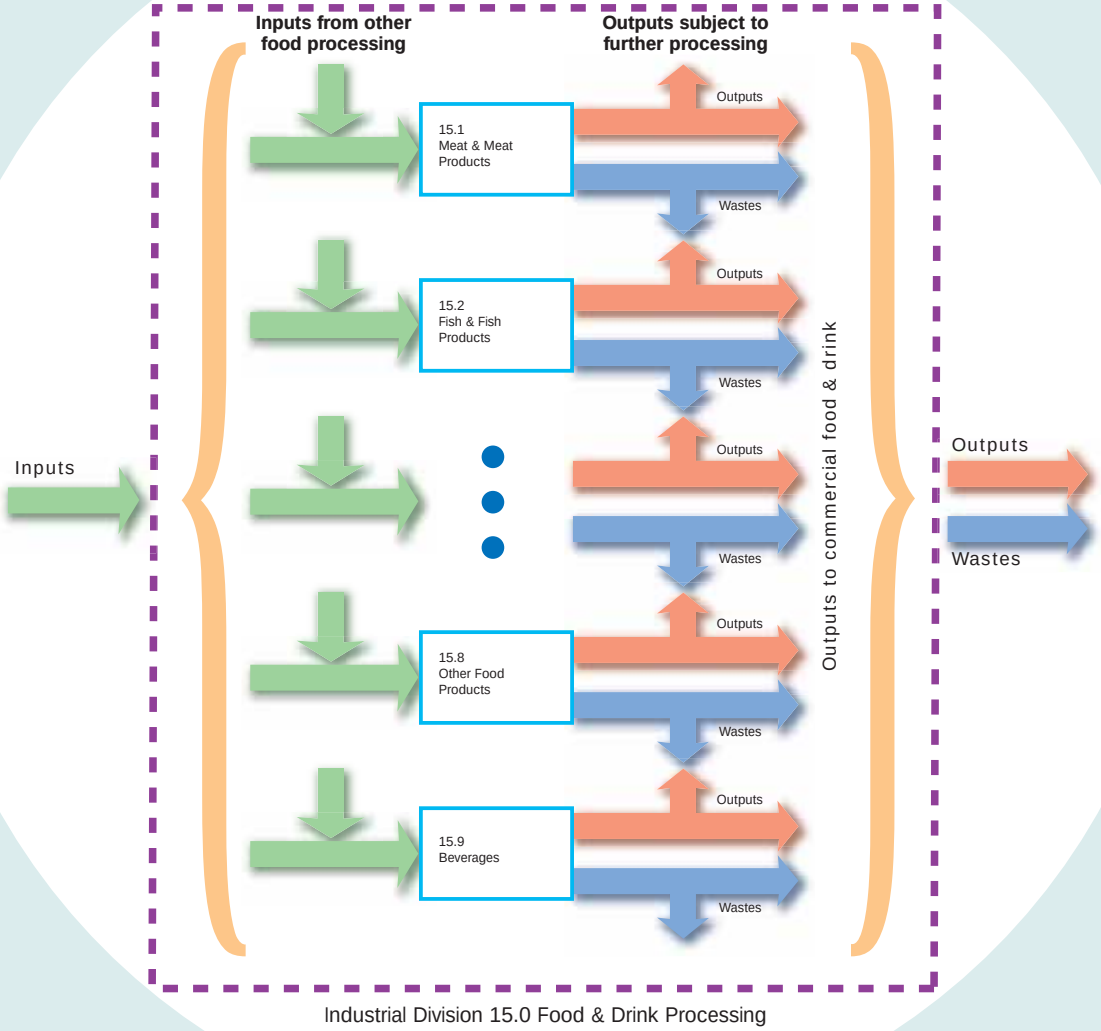
Each of these sub-sectors is discussed further in Chapter 2, and resource flows are broken down for each in the mass balance section, Chapter 4.



1.4 Model for Mass Balances

The mass balance concept is simple - what goes in must come out. Raw materials - grain, livestock, milk, fruit, vegetables etc. - are converted into foodstuffs through processing activities which may involve other inputs - energy, water, packaging and so forth. However not all inputs consumed result in useful outputs, and the result is waste. The basic structure of the mass balances provided in Chapter 4 is shown in Figure 1.4. Contributory balances for each of the classes 15.1 - 9 are consolidated into an overall mass balance for the food and drink processing sector.

Figure 1.4
Model for Mass Balance





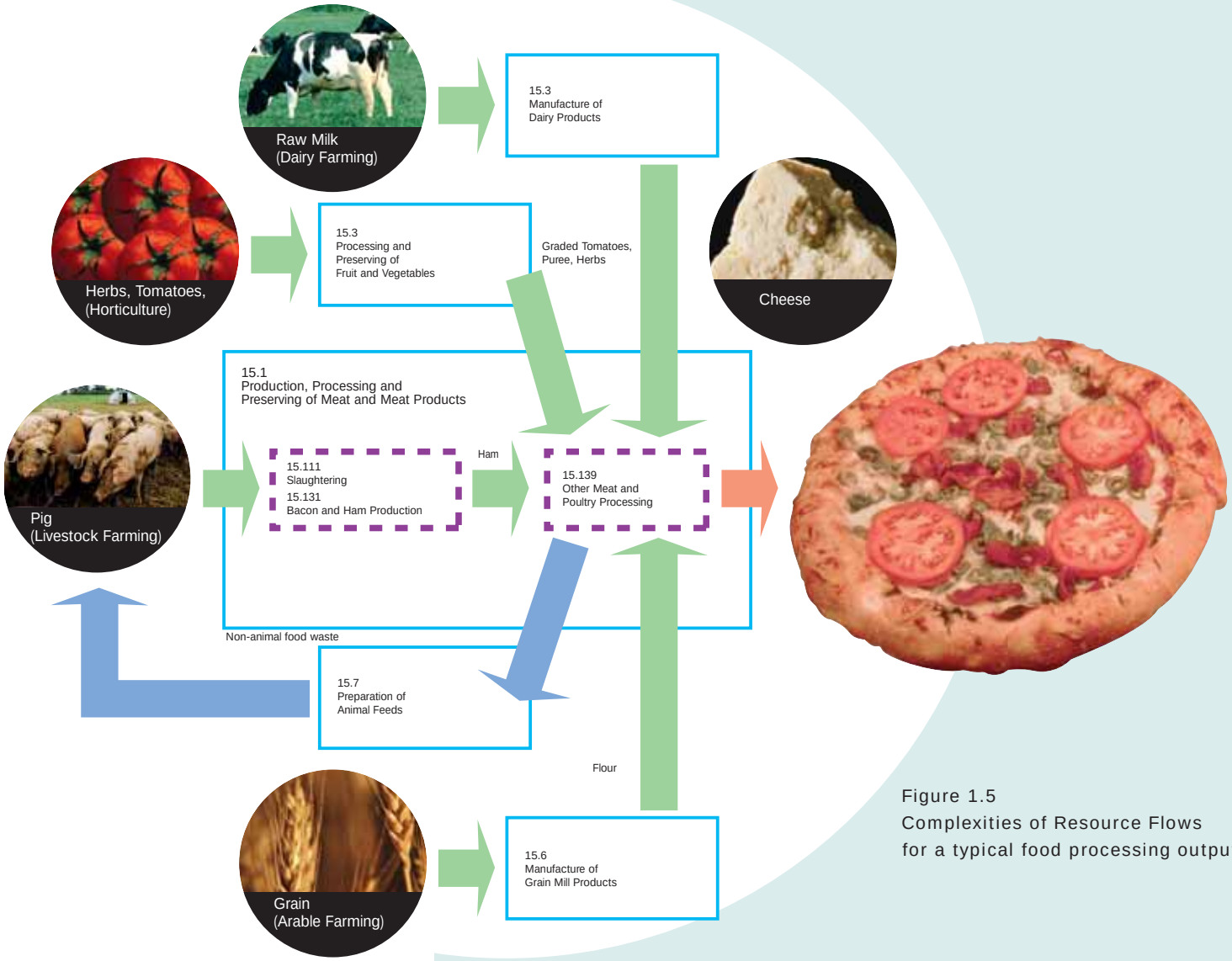


Figure 1.5
Complexities of Resource Flows
for a typical food processing output

1.5 The Pizza Puzzle - Complexities of Mapping Food Resource Flows

The flow of resources through the food chain, and the food and drink processing sector in particular, is highly complex. Wastes are often reused elsewhere in the food chain - spread to agricultural land or fed to livestock - and products from one activity may be the raw materials of another. Pizza production for example involves inputs from several classes of food processing as well as the reuse of some waste in the agricultural sector, Figure 1.5.

Clearly, it would be impractical to map out such complex flows for every process and product encountered in the food processing industry. The main effect of such interdependent processes is to create the risk of double counting certain mass flows when consolidating the data. In the above example, if when attempting to calculate the total output of the Meat and Meat Products sector we were simply to add the total output of ham to the total amount of ham topped pizzas, then the weight of ham on top of the pizzas would be included in both categories and the total output overestimated.

We have dealt with this problem by identifying larger mass flows which support further processing as well as direct supply to the commercial food sector and estimating the split in the output from other sources of information (such as data from trade associations).

Similarly a significant amount of food waste is managed by recovery routes within the food and drink processing sector. The total waste is broken down by its disposal or treatment route which includes some reuse options within food processing. However the more important breakdown is to identify major resource flows where conventional waste management practice is at risk - such as biodegradable material going to landfill.

It should be noted that this approach is specifically not concerned with legal definitions of contentious terms such as waste, by-product, and co-product. Our concern has been to try and provide a picture of how much non-primary product the food and drink sector succeeds in reutilising within its own boundaries, regardless of whether the public or regulatory bodies regard the means of recovery as utilisation of a co-product or treatment of a waste.



1.6 Resource Flows Quantified

The primary product output data used in this study is net of packaging materials, which are not included in output statistics. Information on consumption of packaging raw materials has been obtained by value, but is not directly available by amount. Packaging has therefore not been included formally in the mass balance, although relevant data has been included for information and comparison with the general waste stream from the industry - recognised to be dominated by packaging waste. To ensure a like for like comparison, the wastes included in the mass balance calculations have been limited to those attributable to waste in the food ingredients input. All wastes types and quantities are analysed in more detail following the main mass balance in Chapter 4.

Food processing involves the use of large volumes of water. Raw materials require washing, and many other important unit operations - blanching, steaming, boiling, baking - involve addition or removal of water from the products. Equipment, food preparation and general workspace areas also require extensive cleaning and sterilisation, further increasing the water demand of the industry.

Overall, water is easily the largest resource flow in food processing, however comprehensive data is neither available for water usage nor effluent production within the sub-sectors of food and drink processing. Where possible, available estimates have been provided, including an overall estimate for water use by the sector. Where physical wastes arising from water treatment have been quantified in source data, these have been included as mixed bio-degradable waste.

Some summary information is provided on energy consumption in the sector in the commentary on the overall mass balance. As the primary intent of this report is to map material resources, no attempt has been made to provide a full account of, for example, unnecessary energy consumption or human resources wasted on coping with waste streams. However food producers should recognise that such factors can have a considerable impact on their performance. Headline waste disposal expenditure often conceals a raft of hidden costs, which should be borne in mind when weighing up future policies for waste minimisation.

1.7 Deriving Data

The main sources used to generate the data employed in this study are as follows.

DEFRA Economics and Statistics:
a variety of statistical notices, reports and allied data sets available from DEFRA have been used, mainly to estimate inputs to food processing.

ONS Monthly Digest of Statistics:
consolidated information relating both to major inputs and outputs of the food processing sector.

ONS PRODCOM
(PRODucts of the European COMmunity)
PRA reports for SIC 92 classes 15.1 - 15.9:
main source for derived output estimates. The data are collected via a series of surveys for the Office of National Statistics. The most recent available data within the reports has been used, the majority of contributory figures coming from 2002 and 2001, although in some cases data from earlier periods has been used.



Data has been used without further adjustment, as overall output from the food processing sector has been fairly stable over the period in question.

The Environment Agency (EA)
1999 National Waste Production Survey for England and Wales:
primary source of information on waste. This substantial survey collected data on waste types and amounts from a sample of over 20,000 businesses across the full range of industrial and commercial activities including Food and Drink manufacture. This source has been supplemented where necessary with data from other sources, industry data, and certain classes of outputs from the PRODCOM reports where wastes have some product value. In particular the wastes survey gave a much smaller estimate of wastes arising from the fishing industry than would be implied by industry estimates for edible content of the landed stock. In this case data available from the Seafish Authority has been used in the mass balance in preference to the wastes survey.

Where available, data for Scotland and Northern Ireland has been obtained from the statistical publications of the **Scottish Executive Statistical Services** and **Department of Agriculture and Rural Development (DARD)** in Northern Ireland.

Numerous trade and industry associations and individual companies have been helpful in providing further estimates of inputs, outputs and wastes for particular sub-sectors of food processing. These include data derived from independent output and wastes surveys, company specific experience, and industry summaries of official statistics.

For the purposes of producing a UK mass balance, statistics relating to England and Wales or Great Britain have been scaled up in proportion to the numbers employed in food processing the UK as a whole[8]. This particularly applies to the EA Waste Survey which covered only England and Wales. Outside the mass balance, information from this survey reporting the composition of the waste produced has been used directly (i.e. figures relate to England and Wales only).



2 Food Processing What and Where?

This chapter provides some further background on each of the main sub-sectors of food and drink processing. Principal products, the scale of resource consumption and output, and the nature of wastes arising from the processing of these products are described. Regional variations in the food industry and how it relates to agricultural activity are also considered, along with a short summary of the types of unit operations carried out during food and drink processing.

2.1 Sub-Sectors of Food Processing

2.1.1 Meat & Meat Products

UK farmers supply over 2 million cattle, 10.5 million pigs and 14.5 million sheep annually for processing into meat and meat products. As dietary habits have changed over the last twenty years or so, there has been a slight decline in meat consumption, however meat products remain an important part of the food sector.

According to the Meat and Livestock Commission, wastes from primary processing of livestock vary between 35 and 42% of the incoming animal weight. The majority of this material is treated by licensed renderers, to produce tallow (fat) and solid proteinaceous material, which is ground to meat and bone meal. Different grades of tallow (reflecting from what it has been derived) have different uses and values. Highest grades are used in human and animal foods and soap manufacture. Lower technical grade tallow is utilised in the oleochemicals industry. Total tallow production in the UK is around 250,000 tonnes per annum.

The conventional outlet for meat and bone meal protein - animal feed - has been severely disrupted by the BSE crisis, and this material is currently landfilled or incinerated.

Non-food by-products such as animal skins and hides are sold to leather industry, however the poultry processing industry has had an ongoing issue of dealing with waste chicken feathers. The UK produces 150,000 tonnes of feathers every year, which costs the industry £3 million in annual landfill charges. This waste is not only produced in large amounts, but because of its nature, in large volumes.

Secondary processing to meat containing products - pies, pasties and the like - will typically result in the production of meat contaminated pastry waste, an example of the problematic biodegradable wastes which are typically landfilled at present, but which will in future need to be treated as Animal By-Products.

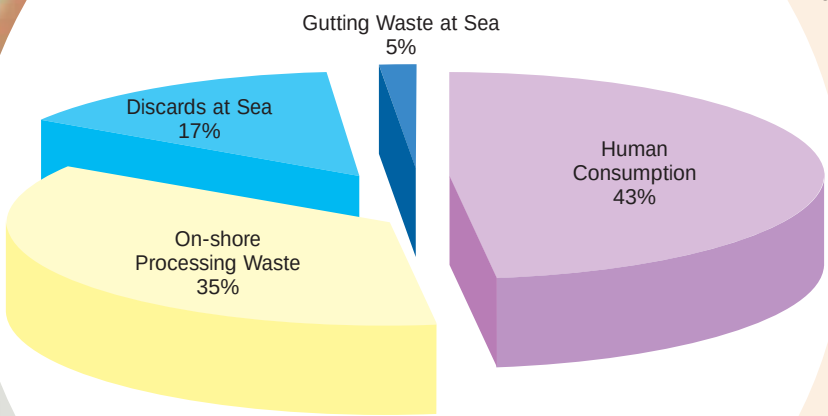
2.1.2 Fish & Fish Products

In 2001, the UK fishing industry landed 738 thousand tonnes with a total value of £574 million. The UK fish processing industry employs 22,000 people in around 550 businesses. Around two-thirds of its output retails through supermarkets, with most of the rest sold through restaurants and take away outlets. A small proportion of the catch is used to make fish oils and animal feeds.

Although it is to some extent a matter of social choice, it is a fact that fresh landed seafood and fish contain a significant proportion of material that cannot be considered for the table. Landing and processing of fish therefore generates sizeable amounts of waste annually.

Figure 2.1
Utilisation of UK Fish and Shellfish Resources

Source: Seafish Industry Authority 2001



According to the Seafish Industry Authority only 43% of fish and shellfish resources (851,984 tonnes) are used as products for human consumption. The remainder is waste, mainly produced on-shore (35% of resource), along with discards and processing wastes at sea, Figure 2.1.

The fish processing industry is mainly located near the source of its raw materials. There are important regional clusters in Humberside and North-East Scotland in particular, but generally processors are found in coastal areas adjacent to major fishing ports. This can present logistical challenges for seafood by-products. For example the South-West of England lacks fish meal and oil processing facilities, meaning that by-products utilised for this purpose elsewhere in the country are consigned to landfill in the South-West.

2.1.3 Fruit & Vegetables

In 2001 the UK horticultural industry produced 5,045 kilotonnes of potatoes, 312 kilotonnes of fruit and 2,703 kilotonnes of vegetables. Taking account of imports and exports, the net totals entering the UK market are 6,254 kilotonnes of potatoes, 836 kilotonnes of fruit and 1,819 kilotonnes of vegetables. About 40% of potatoes and 44% of fruit are estimated to be consumed by food processors (Food Chain Report 1997 and DEFRA), but only around 14% of vegetables are processed. The bulk of the remainder go for pre-packaging or wholesale distribution prior to retailing. The total value of fruit and vegetable produce processed by UK manufacturers in 2001 amounted to £3,773 million.

Average domestic consumption of fruit and vegetables has been fairly stable in the long term at around 9 - 10 thousand kilotonnes, however there have been significant changes in the mix of this consumption. Fresh potato consumption has almost halved to just over 2,000kT since the early 1970s, a reduction only partially offset by an increase in processed potato consumption. Fresh fruit is however more popular than ever before, and consumption of fresh fruit and vegetables is now at a comparable level to potatoes. Over the same period consumption of all processed fruit and vegetable products has slowly increased, reflecting the general consumer demand for packaged convenience foods.



Fruit and vegetable processing typically generates large volumes of effluent and solid wastes. Effluent from washing, blanching etc. can be high in chemical oxygen demand (COD), biological oxygen demand (BOD), and suspended solids, and may entrain residual pesticides. Typical water use per tonne of product[9] is in the range of 2.5 to 9 m^3, although water minimisation programmes can achieve substantial reductions.

Table 2.1

Water Use in Fruit and Vegetable Processing

Product	Water Use (m3/tonne)
Fruit Juices	6.5
Baby Food	6.0 - 9.0
Jams	6.0
Frozen Vegetables	5.0 - 8.5
Canned Vegetables	3.5 - 6.0
Canned Fruit	2.5 - 4.0

Solid wastes include discarded foodstuffs, and the inedible portions arising from peeling, stalking, etc. These materials are often fibrous or woody in nature, but usually have a high nutritional value. Estimates of solid waste production for various fruit and vegetables are shown in Table 2.2.

Table 2.2

Solid Waste Production Rates for Fruit and Vegetable Products

Product	Water Use (kg/tonne)
Apples	90
Cranberries	10
Olives	20
Peaches	180 - 200
Broccoli	200
Carrots	200
Corn	40
Peas	40
Potatoes	40

Source: World Health Organisation, 1993

2.1.4 Vegetable and Animal Oils and Fats

Total domestic usage of oils and fats in the UK is over 3,000 kilotonnes per annum, however the country is less than a third self-sufficient in the supply of this market. The conversion of crude oils and fats to food grade products is a multi-staged process involving a variety of physical and chemical treatments. These are aimed at the removal of undesirable materials and flavours, most of which are present in fairly small to trace levels, but which would otherwise render the products unsafe or undesirable.

Crude oils and fats are obtained from animal and vegetable processing through expelling, extraction or rendering, and may contain seed particles, phosphatides, carbohydrates, proteins, traces of metals, pigments, waxes, oxidation products, polycyclic aromatic hydrocarbons and pesticide residues.[10] Impurities are removed by boiling with water (degumming), alkaline washing (neutralisation), bleaching, dewaxing and deodorisation. Product oils and fats are important intermediary ingredients in further food processing, production of animal feeds, and in the oleochemicals industry.

2.1.5 Dairy Products

The UK is the world's 7th and the EU's 3rd largest milk producer, with domestic production of around 14 billion litres annually, a figure limited by EU production quota. Milk is produced by about 30,000 dairy farms. The main milk producing regions are Cumbria, Cheshire and Devon in England, Carmarthenshire in Wales, Dumfries and Galloway in Scotland, and Antrim, Down and Tyrone in Northern Ireland. Milk is sold directly to processors and through farmers' co-operatives.

There are over 100 dairy processors in England and Wales, ranging from small local dairies and specialist cheesemakers to large national and international companies which supply liquid milk and a variety of dairy products for doorstep delivery and supermarkets. About 86% of the milk processed in England and Wales is utilised by around 20 companies processing more than 100 million litres per annum.

Although 95% self-sufficient in milk, the UK has substantial trade in and out of dairy products, importing cheese from Ireland, France and Germany and butter from Denmark, Ireland and New Zealand.



At the same time the country exports butter, cheese, cream and milk powder, mainly to other EU states and the Americas.

Liquid milk production is relatively waste free provided best practices are adhered to, however maintenance of equipment and workplace hygiene can consume a lot of water, resulting in high COD, fatty residues. Attention to water minimisation and effluent control is therefore a basic requirement for good dairy operation.

The production of dairy products like cheese, butter and cream involves enriching the fat content of products by the removal of water from milk. Cheese manufacture for example typically involves a tenfold reduction in volume from raw materials to product. The balance is whey, a dilute (5%) suspension of lactose, protein and other solids in water. Whey is useful as an animal foodstuff, however this is not a high value market, and often production at the dairy exceeds requirements. In these circumstances land spreading is used as an alternative disposal route. New added value uses as an additive in ice cream manufacture and health supplements have emerged in recent times, however the dilute nature of whey, and lack of investment in the equipment necessary to recover valuable substances can prevent realising the potential of these options.

2.1.6 Grain Mill Products and Starch

The UK flour industry involves over 30 companies operating 68 mills, however the two largest concerns account for approximately half of total UK production. The UK flour milling industry uses over 5.5 million tonnes of wheat each year to produce nearly 4.5 million tonnes of flour, and is the largest single user of domestic wheat. Up to 85% of the industry's wheat supply comes from the UK, a proportion that has more than doubled since the 1970s.

The grain mill industry plays an important role in the food chain, converting primary cereals into a wide range of flour products and other ingredients used extensively elsewhere in the food processing industry. Output from the starch products sector is dominated by glucose syrup, used extensively in confectionery and soft drinks.

2.1.7 Prepared Animal Feeds

The category of prepared animal feeds includes both feeds for agricultural livestock and domestic pet food, but is dominated in tonnage terms by the former. Agricultural feedstuffs are based on a mixture of primary grain products and by-products from agriculture and food processing including wheat feed from flour manufacture, oilseed cakes and meal from the manufacture of oils and margarine, and brewery by-products. The compounding industry is concerned with the preparation of nutritionally balanced foods from these inputs.



From a low point in the late 1980s, the market for compound feedstuffs grew slowly to almost 12 million tonnes in the mid-1990s. Over a third of this is cattle compound, but this is a smaller proportion than in earlier times, as growth has been achieved through compounds for non-ruminants. Prepared compounds have generally commanded up to two thirds of the total animal feeds market, however there has been a trend towards more home-mixing of feeds on farm, using ingredients supplied by feed manufacturers, estimated to be around 40% in the early 1990s.

> " Animal feed is an important outlet for nutritional material not for human consumption. "

The animal feeds industry is an important outlet for material flows from elsewhere in the food processing industry which, while having nutritional content, are not deemed suitable for direct human consumption. It has therefore played, and will continue to play an important food waste minimisation role. However the impact of BSE and the resultant prohibitions on reuse of animal by-products such as meat and bone meal in animal feedstuffs (banned since 1996) has resulted in an organic material flow which can no longer be dealt with by the feed industry and requires alternative strategies. Recent draft Environment Agency guidance relating to the Integrated Pollution Prevention and Control regulations has raised concerns that the redefinition of a range of food chain co-products as waste will imperil the significant contribution made by the prepared feed sector in utilising food chain resources to the maximum. According to the National Pig Association large tonnages of co-products such as brewers grains and yeast,

citrus pulp, distillery co-products, maize gluten, molasses, and potato and sugar beet co-products are at risk of being diverted to landfill if the proposed change in definition goes ahead.

2.1.8 Other Food Products

This division covers a range of products, but is dominated by sugar production, bread, biscuit and confectionery products. Sugar manufacture is a highly controlled industry, split fairly evenly between sugars derived from domestic beet and imported cane. Production of these two types is entirely dominated by the large British Sugar and Tate & Lyle concerns respectively.

At least a quarter of all food processors are in the bakery sector. Bread manufacture is dominated by large bakeries, which account for 80% of market share, with most of the rest being baked by in-store bakeries. Fresh sandwiches, one of the recent growth products in ready to eat and convenience foods, also fall under the “Others” category.

The sugar industry describes itself as “a shining example of sustainability in industry”. A range of useful by-products is derived from the inputs to beet sugar. Spent beets go to animal feed, molasses to fermentation, soil and stones entrained with incoming beet is sold to landscapers, architects and farmers, and lime products arising from the refining process are used as soil conditioners. Cane sugars are primarily imported as raw sugars after primary processing, so cane bagasse (spent cane after extraction) is not a major issue for the UK mass balance.

Bakeries produce wastewater from cleaning operations including cleaning in place (CIP) and equipment and crate washdowns. Fairly high COD loads can arise from entrained ingredient losses picked up by washing, and from cleaning and lubricating agents. Generally the proportion of waste-water produced per unit of product tends to decrease with the scale of the bakery as larger operations allow for more efficient washing, however COD levels can be substantial. An Australian study of a typical bakery[11] found that every tonne of dough produced resulted in 500 litres of wastewater with 1.9kg COD and 1.0kg suspended solids. Lower volume and speciality bakeries tend to produce larger (pro rata) volumes of waste water, but with lower COD.

Given the high level of crossover between straight baking activities and pastry encased meat products, bakery waste finds itself mired in the regulations related to animal by-products. Much pastry waste either results from a process where it is directly in contact with meat, or is processed on sites where meat is also handled, and is thus currently regarded as animal by-products, to be treated only by approved routes. Food waste from bakeries which does not contain or has not been in contact with meat can still go for landfill, but it is of course an example of the sort of biodegradable waste, which will ultimately have to be phased out of landfill disposal.

2.1.9 Beverages

The SIC(92) sub-class 15.9 covers the production of alcoholic beverages and soft drinks, including mineral waters, but not drinks such as tea and coffee, which are part of class 15.8.

Alcoholic beverages provide one of the biggest single contributions to Gross Value Added by the Food and Drink processing sector - over £3 billion of GVA. Adding nearly another billion of GVA from soft drinks emphasises the major contribution of beverages to the overall sector. This area is a huge contributor to the UK’s export economy - Scotch whisky accounts for more than 20% of UK food and drink exports, and supports 1 in 50 jobs in the Scottish economy. An important precursor activity to the production of beers and spirits is the malting of barley. Winter (brewing) and spring (whisky) malted barley consume nearly 2.5 million tonnes of the annual UK barley crop.

The UK brewing industry is estimated to use 34 Mm^3 of water every year, over 70% of which is ultimately discharged as trade effluent.[12] 1997 figures for the volume of water used per volume of beer produced averaged at a ratio of 6.1 parts water to one part product. The best companies operated at 3.4, and the worst at over 20.

Brewing wort (the malt infusion prior to fermentation) is rich in sugars and vitamins, and excess material can be sold for animal feed. If excess wort is produced and discharged to drain the COD level is increased substantially (wort has a COD of 100,000mg/litre). This also represents a waste of the grain used to make up the wort in the first place. To realise the reuse value of fermentable waste like wort it must not be mixed with surplus yeast (which is itself of value to food manufacturers).

Significant quantities of distillery and brewery by-products such as brewers and distillers dried grains are used in animal feeds. Pig farmers can use yeast (which contains over 40% protein) as an animal feed supplement, preferably pressed to less than 20% moisture for ease of handling.

From the point of view of preparing a mass balance the alcoholic beverages industry is different to most of the rest of food processing in that it relies on a chemical reaction rather than a physical change, namely the conversion of sugars to alcohol with the release of carbon dioxide as a by-product.

	$C_6H_{12}O_6 \rightarrow 2C_2H_5OH + 2CO_2$		
Formula Mass	*180*	*46*	*44*

Thus every 92kg (2 x 46kg) of pure alcohol produced through fermentation will have consumed 180kg sugar and will result in the generation of 88kg carbon dioxide. The mass balance therefore allows for an estimated carbon dioxide emission based on the pure alcohol output reported in output statistics. In 2001, we estimated the pure alcohol output of the UK Drink industry to be around 730 kilotonnes, resulting in the evolution of nearly 700 kilotonnes of carbon dioxide. Some of this CO_2 is recovered for utilisation in the carbonation of beverages and other uses of the gas, but the remainder is discharged to atmosphere.



2.2 Regional Aspects of Food Processing

The food processing industry shows distinct regional variations throughout the United Kingdom, often reflecting the close relationship of the sector to the agricultural sources of its raw materials[13], see Figure 2.2. Factors such as the proximity of waste treatment facilities (or potential clusters for reusing wastes) to the source of the wastes can play a large part in determining both the economic and environmental soundness of a waste handling solution.

Table 2.3 shows the number of local units operating in agriculture and food and drink processing in the regions of the United Kingdom. Most agricultural sites are operated by very small numbers of employees. For food and drink processing operations the nation-wide distribution of size of operating units shown in Figure 2.3 is more or less repeated across the regions.

The food supply chain itself tends towards increasingly consolidated operations the further through the food chain one goes - tens of thousands of farms supply thousands of food processors who supply hundreds of wholesale and retail customers. Practical solutions for food chain wastes will have to reflect the logistical implications of these sorts of numbers.

Table 2.3

Regional Distribution of Agricultural, and Food, Drink and Tobacco Local Units 2003

Region	Agriculture	Food, Drink & Tobacco
Scotland	18,765	1,340
North East	3,540	425
Yorkshire & Humberside	10,470	1,035
East Midlands	10,325	775
East of England	11,805	815
South East	10,660	815
London	685	870
South West	21,010	955
Wales	15,975	470
West Midlands	11,100	695
North West	10,430	1,225
Northern Ireland	16,845	540
United Kingdom	141,610	9,960

Source: ONS Size Analysis of United Kingdom Businesses 2003, PA1003.

Figure 2.2 Regional Features of the UK Agricultural and Food and Drink Industries



Northern Ireland

Food and drink provides almost 2.5% of Northern Ireland's gross value added, 21% of manufacturing sales and 19,000 jobs. Large markets in Great Britain and the Republic of Ireland. Major outputs include beef, sheep, pig and poultry meat, dairy products, and beverages.

Scotland

Food & Drinks Industry is important domestically and internationally, with £6.4 billion turnover, £1.5 billion exports, and over 54,000 jobs. The whisky industry is a major export business and is highly consolidated, whereas food products tend to be more domestically targeted and produced by smaller operations.

North East England

Cereals are 80% of regional crops, beef cattle and breeding ewes 11.5% and 12% of the English totals respectively. Major food processing activity in dairy and red meat products processing.

Yorkshire

Yorkshire has a similar profile to the North East with the addition of strong activity in seafood processing on the Humber Coast.

North West England

Diverse food processing and agricultural activity across most classes of activity, employing 63,000.

East Midlands

Home to much of the UK's domestic sugar beet crop, significant food processing clusters in South Lincolnshire and East Northants. 52,000 jobs regionally in the sector. 90% of companies employ less than 100 people.

Wales

Agricultural land accounts for 80% of available land in Wales, with predominantly live-stock based agri-economy. Assembly support to promote organic foodstuffs to 10% of output by 2005.

East of England

Agriculture and food processing are important sectors of the regional economy. Food processing and distribution generate around 5% of regional GDP and 39,000 jobs. The Cambridge and Lincolnshire fens food processing cluster provides 450 companies. 12,000 jobs and £500 million of added value to the region.

West Midlands

Food processing activities include bakery, dairy and eggs, meat, alcoholic beverages, and sugar beet processing.

South East & London

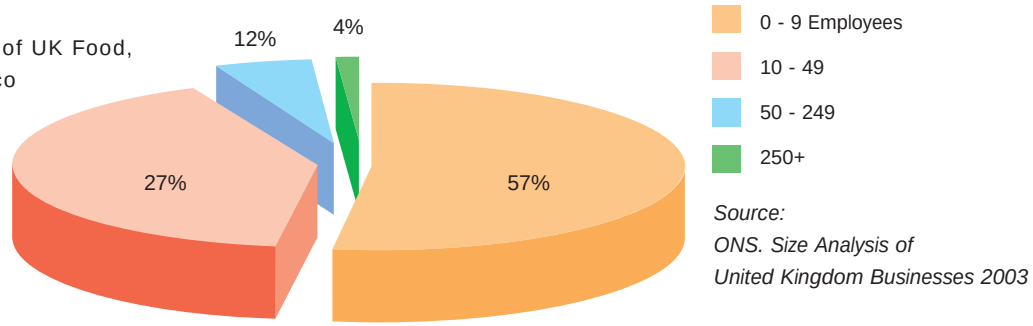
Important horticultural activity, and proximity to the London conurbation. While not a major seat of food processing, the affluence, and cosmopolitan nature of the area positions it well to exploit added value markets for foodstuffs.

Sources:
DEFRA England Rural Development Programme
DARD "Size and Performance of the Northern Ireland Food and Drinks Processing Sector 1999".
Scottish Executive

South West

Important role in the production of alcoholic beverages and non-alcoholic fruit and vegetable juices, meat production and preservation, dairy and cheese making. Low proportion of food processing to agricultural employment.

Figure 2.3
Size Distribution of UK Food, Drink and Tobacco Local Units 2003



Source:
ONS. Size Analysis of United Kingdom Businesses 2003

2.3 Sources of Waste: Unit Operations in Food Processing

Wastes from the food processing industry derive from the unit operations and operational practices of the industry. Table 2.4 summarises the main classes of unit operation in use in food processing, specific examples of unit operations and the sorts of wastes which arise from them.[14]

Table 2.4 **Food Processing Unit Operations and Associated Wastes**

Category	Operations	Example Wastes
Ambient Temperature Processing		
Raw Materials Preparation	Cleaning, Sorting, Grading, Peeling	Cleaning water effluent (BOD or COD), peelings, hair, feathers, grit, blood, contaminated foodstuffs
Size Reduction	Chopping, cutting, slicing, dicing, Milling of Solid foods, pulping, Emulsification and homogenisation of liquids	Poor quality (too coarse / fine) product with loss of nutritional / sensory characteristics. Dust Agglomerates. Waste off-cuts. Fat bearing effluents from colloidal products (e.g. dairy). Risk of pathogenic contamination in emulsification (e.g. dairy).
Mixing and forming	Mixing, forming malformed pieces.	Wrongly proportioned batches, poorly mixed ingredients,
Separation and Concentration	Centrifugation, Filtration, Expression, Solvent extraction, Membrane concentration	Separated solids (e.g. after clarification of liquids), press residues (e.g. fruit juice extraction)
Fermentation and use of enzymes	Fermentation, Enzyme technology	Spent biomass.
Other	Irradiation Pulsed electric field, High Pressure, Pulsed light, Ultrasound	
Processing with Heat Application		
Preservation / stabilisation	Blanching, Pasteurisation, Sterilisation	Under blanched food wastage, Effluent, Thermophilic bacterial contamination, Heat spoilage, heat transfer surface film build-up Product loss due to unsuccessful treatment
Evaporation and Distillation	Evaporation, Distillation	Heat transfer surface film build-up, distillation residues.
Extrusion	Extrusion	Strip down residues
Dehydration	Hot air driers, Heated surface driers, Rehydration	Heat transfer surface film build-up
Baking and Roasting	Direct and indirect heating ovens, Batch and continuous ovens	Write off of oven contents if process interruption exceeds product buffering capacity
Frying	Shallow frying, deep-fat frying	Contaminated fat, particulates
Direct and radiant heating	Dielectric heating, Ohmic Heating, Infrared heating	
Processing with Heat Removal		
Chilling	Fresh Foods, processed foods, Mechanical refrigerators, Cryogenic chilling, Chill storage, Modified and controlled atmosphere storage and packaging	Spoiled food in equipment failure
Freezing	Freezing	Spoiled food in equipment failure, thaw water
Freeze drying and concentration	Freeze Drying, freeze concentration	
Pre & Post-Processing Operations		
Coating and enrobing	Battering, coating, dusting	Over / under coated product, appearance failures
Packaging	Packaging	Packaging waste
Filling and Sealing	Filling, Sealing	Product give-away, spoiled goods if seals fail
Handling, storage and distribution	Raw materials and ingredients, Waste management and disposal, Storage, Distribution	Losses due to transit damages, mismatch of forecast to actual demand.

3 Policies and Legislation

3.1 Definition of Waste

This chapter aims to give a concise overview of the main thrust of policy and the resultant legislation which relates to waste and the food and drink processing industry. It is not a definitive statement of the position of any agency, nor should it be used to try and answer specific questions in the legalities of waste handling. Rather it is intended to be a starting point for further information which may be obtained from expert sources. A suggested next stop for information relating to legislation is the Environment Agency's online NetRegs service, at www.environment-agency.gov.uk/netregs.

EU policies and directives, enacted through UK legislation, are steering environmental practices across industry in general towards lower environmental impact and greater sustainability. The food processing sector is no exception, and must adopt new approaches in order to achieve the targets set. Under the right legislative pressure, waste minimisation, recycling and energy recovery will become not simply more attractive, but increasingly necessary components of sustainable waste management approaches.

In the short to medium term however, changes in the legal status of a number of material arising from the food processing industry means that some processors already cannot or very soon will not be able to use conventional means to deal with waste, and yet do not have other sustainable routes readily available to transfer to. Most notable in this regard are the constraints placed on the handling of animal by-products in response to the BSE crisis. Although these allow the lowest risk Category 3 material to be disposed of by approved routes, the UK does not have approved treatment capacity for our animal by-products stream.

Table 3.1, summarises the main UK and EU legislation of relevance to the food processing industry, described in more detail in the rest of the chapter.

Definition of Waste

The basic definition of waste applied in England and Wales - "any substance or object which the holder discards or is required to discard" - derives from Article 1 (A) of the European Community directive 75/442/EEEC on waste. Waste whose management and disposable are subject to the constraints of waste management or other related regulations is referred to as controlled waste. Where specific additional controls apply, a waste is considered to be special waste. The EU has issued a hazardous waste list and hazardous characteristics which will determine whether a controlled waste is special.[15]



3.2 EU Policy and Legislation

Article 2 of the Treaty on European Union[16] sets the achievement of balanced and sustainable development among the objectives of the Union, and prudent and rational utilisation of natural resources features among the objectives of European Community environmental policy[17].
To effect this vision, the EC has issued a number of Directives relating to the management and disposal of waste, many of which impact directly or indirectly on the food processing sector.

Framework Directive on Waste, 1975 and 1991[18]

In this legislation, member states are directed towards the setting up of adequate waste control regimes and waste management plans. As revised in 1991 it deals with the regulatory framework for the implementation of the European Commission's Waste Management Strategy of 1989, covering waste avoidance, disposal and management.

Table 3-1 **Selected European and UK Waste Related Legislation**

European	Main Features	United Kingdom	Main Features
Framework Directive on Waste 75/442/EEC (91/156/EEC)	Waste control regimes and waste management plans. Regulatory framework for 1989 Waste Management strategy.		
		Environmental Protection Act 1990	Waste management licensing. Integrated Pollution Control (IPC). Waste producer's duty of care. BATNEEC.
Hazardous Waste Directive 91/689/EEC	Definition of hazardous waste. Wastes requiring special disposal.	Special Waste Regulations 1996	Implementation of Hazardous Waste Directive. Storage, treatment and disposal of hazardous controlled wastes. Definitions and lists of special wastes, including several food related categories.
		Environment Act 1995	Environment Agency (SEPA in Scotland) as primary enforcement body. Producer responsibility for waste.
Integrated Pollution Prevention and Control 96/61/EC	Prevention of waste at source, "Polluter Pays" principle, BAT.	Pollution Prevention and Control Act 1999	Phased in enactment of IPPC Directive including major food processing and agri-operations.
		The Pollution Prevention and Control (England and Wales) Regulations 2000	
		Pollution Prevention and Control Scotland) Regulations 2000	
Landfill Directive 1999/31/EC	Proscription of landfilling of certain hazardous wastes. Reduction targets for biodegradable municipal waste.	Landfill (England and Wales) Regulations 2002	Designation of Landfill Directive in England and Wales.
		Pollution Prevention and Control (Designation of Landfill Directive) (Scotland) Order 2003	Designation of Landfill Directive in Scotland.
Packaging and Packaging Waste Directive 94/62/EC	Reuse, recycling and recovery targets for packaging and packaging waste.	The Producer Responsibility Obligations (Packaging Waste) Regulations 1997 and subsequent amendments.	Implementation of Packaging Directive and amended (increased) targets for recovery and recycle levels.
Animal By-Products Regulation	Categorises animal by-products in three categories with stringent disposal requirements.	Animal By-Products Order 1999 (Amended 2001)	Limitation on use of materials of animal origin to prevent disease entering the food chain.
		Water Resources Act 1991 Water Industry Act 1991	Water and effluent management, consents and charges.

Hazardous Waste Directive, 1991[19]
This directive provides commonality in the definition of hazardous waste and seeks to align its management across Europe. It also lists hazardous waste types and factors determining classification, such as composition and properties of the waste.

Integrated Pollution Protection and Control (IPPC) Directive, 1996
The IPPC directive[20] describes measures to prevent, reduce and eliminate pollution at source, and establishes the principle of the polluter paying for the costs of the environmental damage they have caused. The Directive allows the use of "Best Available Techniques" (BAT) where the environmental benefit of a course of action is weighed against the cost of installation. IPPC covers emissions to air, soil, and water from traditional heavy industries, but includes many food processing related activities such as

- Slaughterhouses with greater than 50 tonnes per day production,
- Food products from raw animal materials other than milk (more than 75 tonnes per day), and vegetable raw materials (more than 300 tonnes per day),
- Processing of milk (more than 200 tonnes per day),
- Animal carcass and waste disposal or recycling (more than 10 tonnes per day).

Landfill Directive, 1999
The Landfill Directive[21] severely reduces the latitudes for landfill as a disposal route, banning some hazardous and liquid wastes outright, and setting ambitious reduction targets for others including biodegradable municipal waste, which must be reduced to 35% of 1995 figures by 2014, with intermediate targets also specified. The UK is permitted a four year extension to the timeframe of the Directive, since it currently sends over 80% of biodegradable municipal waste to landfill.

Although focussing on municipal waste, the Directive is undoubtedly a lever intended to force a major change in attitude to the handling of biodegradable wastes from the food chain, and will promote the viability of more sustainable treatment technologies which can also find application in food processing.

Packaging and Packaging Waste Directive, 1994
The Packaging Directive[22] is intended to minimise the impact of packaging and packaging waste on the environment, and promote reuse (for original purpose), recycling (of materials for original or other purposes) and recovery (of specific materials from the waste).
Five-year targets (from the date of national implementation) in the Directive were 50-60% recovery of packaging waste, and 25-45% to be recycled.

Animal By-Products Regulation, 2002
The EU Animal By-Products Regulation came into force on 1st May 2003.
In descending order of risk, it defines three categories of by-products

Category 1: high risk which must be incinerated.

Category 2: material unfit for human consumption. Most types of this material must be incinerated or rendered (at a temperature of 133°C and pressure of 3 bar for 20 minutes).

Category 3: material which is fit for but not destined for human consumption.

Category 3 material includes

- Abattoir by-products such as soft offal, blood and feathers,
- Food factory waste,
- Food waste from retail outlets, in particular supermarkets,
- Catering waste, including kitchen waste from domestic households and commercial kitchen waste,
- Category 2 material which has been pressure-cooked.

Category 3 material may be incinerated, rendered or transformed in a composting or biogas plant. Derogation for catering waste and retail outlet waste has been obtained until December 2005.

The Regulations have several requirements for the treatment of Category 3 waste.

- The treatment must be in-vessel.
- A maximum particle size of 12 mm must be achieved in the product.
- The treatment must pasteurise at a minimum temperature of 70°C for one hour.
- Product must not be contaminated with raw waste.
- Product must be free of salmonella.

> "The Landfill Directive is a lever for change in handling biodegradable wastes."

3.3 UK Policy and Legislation

Environmental Protection Act (EPA), 1990
The EPA sets out a licensing system for companies handling controlled wastes, and provisions for integrated pollution control, allocating responsibility for pollution monitoring and enforcement, in many cases to local authorities. The Act also places a duty of care on waste producers to manage waste responsibly from storage to controlled transfer to a suitably authorised party. The EPA equivalent to the "BAT" concept in the IPPC Directive is known as BATNEEC, or "Best Available Technology, Not At Excessive Cost".

Environment Act, 1995
This Act established the Environment Agency as the primary waste regulation enforcement body in England and Wales (the equivalent body in Scotland is the Scottish Environmental Protection Agency, SEPA), and allowed for the provision of producer responsibility legislation as a means of promoting reuse, recovery and recycling.

Special Waste Regulations 1996[23]
These provide for the UK implementation of the Hazardous Waste Directive, including definitions of special wastes, lists of special wastes, and provisions for their treatment, storage and disposal. Food processing wastes such as animal tissue waste, cleaning and peeling sludges, on-site effluent treatment sludges, material unsuitable for human consumption, and wastes from preserving agents are all included on the list of special wastes.

Pollution Prevention and Control Act, 1999
This enacts the EC IPPC Directive in England and Wales, phasing its provisions into UK law over several years. Large food and milk processing operations are thus now under the regulations, shortly to be followed by intensive poultry and pig farming which provide important inputs to food processing. Detailed regulations to back the Act have now been introduced[24]. Generally the PPC framework will replace the earlier IPC and LAPC (Local Air Pollution Control) regulations.

Landfill Regulations
The UK Government has recently introduced new regulations[25,26,27] within the PPC framework to implement the Landfill Directive. Like much of the body of secondary legislation and Statutory Instruments, this material is subject to ongoing amendment, and for specific information it would be advisable to seek specialist advice and refer to the original documentation which is publicly available[28].

Packaging Waste
UK regulations enforcing the Packaging Directive were introduced in 1997[29] and have been subject to further amendment and regional implementation,[30,31,32,33,34] the effect of which has been to raise targets levels for recovery and recycling. Larger food processors (more than 50 tonnes of packaging per annum, and turnover greater than £2 million) must be registered under these regulations. The regulations cover manufacturers, packers and fillers, importers and retailers of food products.

Animal By-Products Order 1999[35] **(Amended 2001**[36] **and 2003)**

The Animal by-products Order regulates the treatment and disposal of the likes of carcasses, products of animal origins, catering waste, waste from the manufacture of ready-to-eat foods, bread and other bakery products, with the aim of minimising disease transmission. The 2001 amendment prohibits the feeding to livestock of catering wastes which have come into contact with animal carcasses or material presenting similar hazards. Further amendments to the ABP Order to enact additional EU restrictions on ABP use are in preparation at the time of writing. DEFRA maintain a web-site dedicated to this area of legislation.[37]

Wastewater

Wastewater legislation is complex, but is based upon two main Acts of Parliament, the Water Resources Act 1991[38] and the Water Industry Act 1991[39], both of which have been amended by the 1995 Environment Act. The former deals with provisions for water management, including pollution and pollution offences. A list of prohibited discharges, including agricultural pesticides appears in the Water Resources Act. The Water Industry Act covers discharge consents and charges.

Since 2001, the Environment Agency has assumed direct control of discharges from certain industries including the meat industry, milk processing, manufacture of fruit and vegetables products, fish processing, soft and alcoholic drinks, and potato processing. The general trend is towards increased effluent costs, shifting the economic equation towards making effluent treatment and reduction measures more cost-effective.[40]





4 Mass Balance

In this chapter mass balances are presented for each of the nine sub-classes of the food and drink processing industry, followed by an overall mass balance for the industry made up from the sum of the sub-class activities. A fuller description of the derivation of data for the mass balances is given in Chapter 1. Case studies are included to provide further background on the issues highlighted by the mass balance data, and to give examples of where companies from the food and drinks industry have taken practical steps to tackle resource flow issues in their business.
The last two sections provide further information on the nature of the wastes arising from the food and drinks industry, the most recent information on how that waste is currently managed, and the regional geography of waste production.

4.1 Sub-Class Mass Balances

All figures are in kilotonnes (kT) unless otherwise stated, outputs are net of packaging materials. Data for biodegradable waste (i.e. that arising from the food ingredients) are used in mass balance calculations. Where available, estimates for other wastes are shown for information, but do not form part of the mass balance since the input and and output streams do not include estimates of the non-organic resources (packaging etc.).

In each case the mass balance is shown in bold for the inputs and outputs directly entering and leaving the sub-class in question. As discussed in Chapter 1, some of these inputs and outputs come from or go to other food and drink processing operations from other sub-classes. These are shown as side streams within a dotted envelope representing the boundaries of the SIC(92) 15.0 Food and Drink Processing sector, see Figure 4.1.

The net mass flows entering and emerging from this envelope are summed in section 4.2 to give an overall mass balance for Food and Drink Processing.

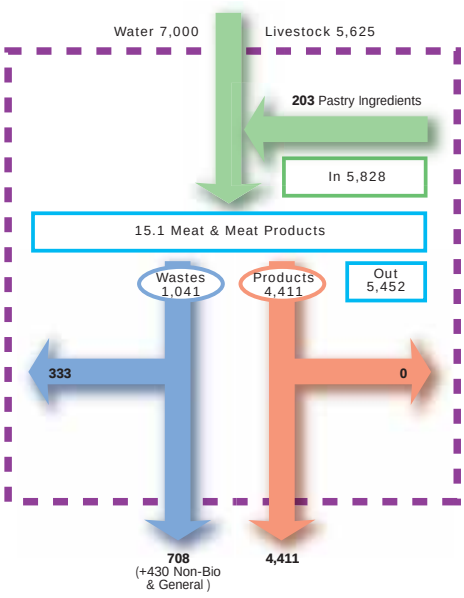
Estimates of water consumption have been shown for information where available, but are not included in the mass balance calculations, as limited data was available for output water (effluent production). If the average moisture content of products emerging is the same as the raw materials entering then masses should balance within the error of estimates. Of course, many food processing operations significantly alter the water content - baking drives water off, beverages are mostly added water. The latter case is the most extreme example of altered moisture content, and the mass balance for beverages has been carried out taking the water content of the outputs into account.

4.1.1 Meat & Meat Products

The National Waste Survey relates to the period of late 1998 - early 1999 and

Figure 4.1
Structure of Sub-Sector Mass Balances

Figure 4.2
Mass Balance for Meat & Meat Products



therefore just precedes the amendment to the Animal By-Products Order of April 1999, although other BSE related restrictions on mammalian tissue were already in force by that time. The main impact of these changes on meat sector wastes is that formerly recycled streams like pig offal and treated (rendered) meat and bone meal are now sent to landfill rather than recycled into the food chain.

Current amendments to the ABP regulations remove the exemptions previously afforded to the likes of blood, feathers, hide and skins, which in future will have to be treated in accordance with the requirements of the legislation. At the beginning of 2003, DEFRA estimated that about a third of slaughterhouses do not have the necessary facilities in order to achieve compliance.

Table 4.1 shows the breakdown of wastes arising from the processing of meat and meat products. This is dominated by animal and mixed biodegradable material. In the post-BSE legislative climate, it is expected that much of the material formerly re-used and recycled will currently be going to landfill after rendering. The large proportion of biodegradable material going to landfill is not sustainable in the light of future targets for landfill reduction. This is clearly an area where more up to date data would be highly desirable.

> " The large proportion of biodegradable material going to landfill is not sustainable. "

Table 4.1

Waste Types and Management Routes for Meat Processing Wastes

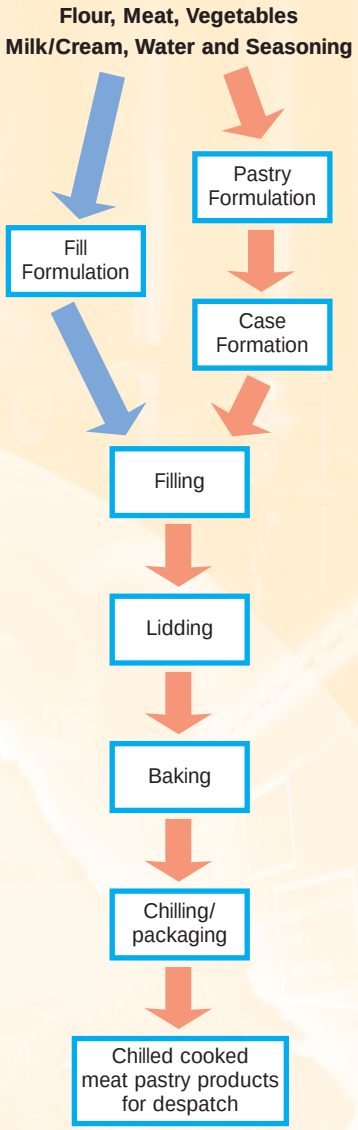
Type of Waste	% of Total	of which sent to		
		Landfill/Land Recovery	Re-used /Recycled	Thermal/Transfer Treatment
Animal & Mixed Waste	66%	36%	34%	30%
Other biodegradable	5%	91%	6%	4%
Other waste	29%	62%	20%	18%

The challenges presented by the Animal By-products Regulation are common to large and small producers alike, but the scale and nature of production operations can make the impact of new requirements and possible solutions more or less feasible for different companies.

Company 1

A long established manufacturer of pre-cooked sausage rolls, pies and pasties, operates three bakery lines with a combined output of 17,000 tonnes per annum, employing 750 staff on a continuous year round basis. Bakery 1 produces pork pies, Bakery 2 puff pastry based sausage rolls, slices and pasties, and Bakery 3 shortcrust pies.

Of the three bakeries, Bakery 2 is the most modern, with predominantly continuous processing and substantially lower manpower requirements than the other bakeries. Bakery 3 has a somewhat smaller overall production volume than the other two. Each bakery supports simultaneous parallel processing of multiple product types, with many variants including hot and cold fills, foil cased pies, and lidded and folded products, but the essential process steps are as shown on the right.



Raw materials are accepted on a range of criteria including physical tests, temperature, and chemical and microbiological safety. A separate formulations department feeds individual process lines as required by production planning. All products are produced for fresh chilled use, with much of production dedicated to a major supermarket retail outlet.

Wastes handled separately are

- Food waste - predominantly mixed pastry and meat although some material would be identified prior to the point of filling. Typical amounts per week are about 18 tonnes for Bakery 1, 4.5 tonnes for Bakery 2 and 1.5 - 2 tonnes for Bakery 3. Sources of food wastes include rejection of raw materials, losses on line down, wash down wastes, and material recovered from water pipework.
- Cardboard - recovery for recycling is cost neutral
- Metals - obsolete racking etc.
- Oils - lubricants, canteen fat and lab wastes collected and disposed of separately.

Major reasons for arisings of waste include losses associated with start-up and changeovers, the impact of new product launches, and write-offs associated with mismatched forecasting and customer demand. Both raw materials and fresh, chilled products have constrained lifetimes, and this, combined with the dominating effect of a very large primary customer, leaves little potential for re-assigning product. Thus any approach which improves the success of the forecasting, planning and demand cycle could potentially represent a positive advance in waste minimisation for this company.

...continued from page 20

Company 2

A specialist producer of branded savoury pastry products including pies, pasties, slices, pastry lattices and sausage rolls, this company supplies frozen products, both baked and unbaked from one bakery handling multiple lines simultaneously. The main processes operated are rather similar to those of Company 1, with the essential difference that dealing with frozen goods, shelf life is less of an overriding issue for Company 2.

Food wastes including end of life pastry, rejected formed product and floor food waste are collected in a single food waste skip, currently disposed of to landfill at about £35 per tonne. Food waste is produced at around a tonne a day in total. The producer believes that it would not be feasible to separate non-meat content wastes due to the relatively small proportion of waste it occupies. General waste including packaging waste from raw materials - ply-sacks, cardboard outers, liners - and product packaging waste fills a skip a day and goes to landfill. The company has explored recycling options for this waste, but it has not proved attractive to recyclers, and further segregation has not been a practical option. Effluent handling costed on COD level and water usage is generally not a high cost issue, however grease interceptors in the trade effluent system require periodic cleaning. This requires off-site treatment with removal costs per tanker of around £500 every six weeks.

In times past both companies had used the animal feeds market as a disposal route for food wastes, however BSE and the Animal By-Products Regulations, have removed that option. Although well aware of the 2005 Landfill prohibition for raw animal products, both companies expressed concerns at the readiness of new technologies to provide a practical solution to their waste management issues. These concerns were not necessarily technically based, but were legal constraints on handling animal by-products with digestion techniques, and legal definitions of the treated wastes.

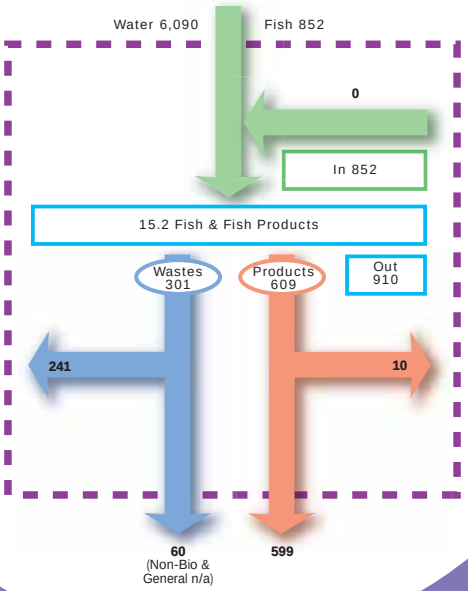
Company 2 felt that in order to cater for similar companies to themselves, the proximity of new facilities and possibly cluster initiatives for specialist waste collection would have to be developed in order to achieve feasible cost levels. The overall picture was that in the short term at least, companies would be driven down disposal routes of either high cost or debatable environmental impact, such as rendering (£60 - £80 per tonne) and incineration.

4.1.2 Fish & Fish Products

At first glance the mass balance for the fish processing industry appears reasonably satisfactory with most onshore wastes reincorporated into the food chain, predominantly through the production of fishmeal and oil. Like the meat sector however, there are currently significant question marks surrounding conventional practices upon which these figures are based.

The fishing industry finds itself caught in the crossfire of the Animal By-Products legislation as amended following BSE.

Figure 4.3 Mass Balance for Fish and Fish Products



Fish and crustacean by-products are generally classified as low risk, and thus should be disposed of by approved routes (see section 3.2), however a 2001 EU-driven temporary ban on feeding processed animal protein to livestock intended for food use has recently been made permanent[41]. This legislation bans the feeding of fishmeal to ruminants - previously a market for around 40% of UK derived fishmeal. Fishmeal can still be fed to non-ruminants, and currently 75% of UK produced fishmeal and 95% of fish oil is used in aquaculture. Other potential threats to the fishmeal and oil industry are the potential accumulation of environmental contaminants such as dioxins.

Even in the absence of these threats a further driving force for waste minimisation in fish processing is the desire to reduce loss of value. A tonne of cod may cost a processor around £2,000, of which around 50% will not be destined for the table. At best this may generate around £40 of income as a by-product feedstock, at worst it may incur disposal costs of around £60. This outcome is determined largely by geography. The UK has three specialist meal and oil plants in Shetland, Aberdeen and Grimsby, but processors who are based in other regions (in particular the South-West) have no cost-effective option other than landfill disposal.

The nature of fish waste presents particular challenges for bio-digestion techniques which are one potential route to exploit them as an energy resource. Fish protein breaks down to produce high concentrations of ammonia, volatile fatty acids, amino acids and hydrogen sulphide. In addition to generating characteristic fishy odours, ammonia is highly toxic to many bacteria active in conventional anaerobic digestion. Advances in anaerobic digestion technology are feasible, for example an innovative project based in Aberdeen has received funding to develop approaches more tolerant of fish breakdown products[42].

While outside food processing as defined in this study, it is instructive to recall that in addition to the 301kT of onshore processing wastes identified, the fisheries industry also discards 145kT of fish and 46kT of gutting wastes at sea (see Figure 2.1). The Sea Fish Industry Authority is a recommended source of further information on the nature of waste issues facing the fish processing industry, and has published a number of reports on various aspects of the topic.



Carafiltration Ltd., a spin-out company of the University of York, has developed a low-cost, biodegradable bioadsorbent (Carasol) from shellfish waste which currently incurs a cost for disposal in landfill or at sea. After cleaning, milling, activation by pre-treatment, and careful grading for size the naturally microporous structure of the shellfish-derived material provides a powerful physi- and chemi-sorptive medium for the immobilisation of a range of organic and inorganic contaminant molecules from industrial and agricultural effluent (both aqueous and in the gas phase).

Adsorption capacities are of the order of 250 to 350g/kg for (e.g. for copper and zinc). Once immobilised and bound to the Carasol, downstream options include benign disposal of waste securely locked within the bioadsorbant matrix in landfill, incineration of (for example) pesticide residues, or desorption and recovery of (for example) precious metals such as silver or platinum.

4.1.3 Fruit & Vegetables

Wastes in the fruit and vegetable processing sector consist largely of inedible food material, packaging wastes and relatively high volumes of effluent. Effluent typically has high organic loading and contains residual cleaning and blanching materials, salt, and suspended solids such as fibres and soil.

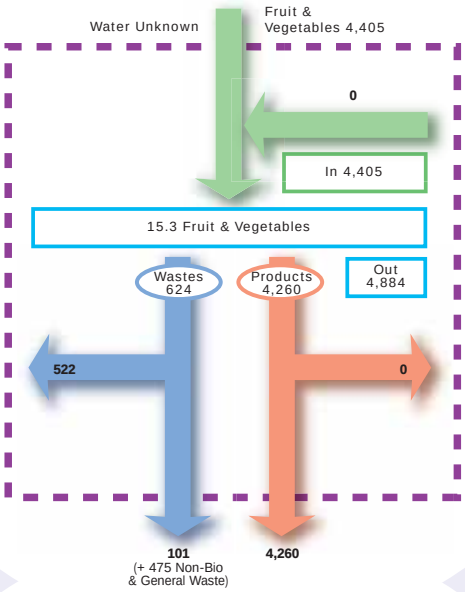
Many larger processors are obliged to carry out on site water treatment and this results in the production of treatment sludge or cake composed of organic matter. Effluent disposal (or treatment) can be a significant cost drain for fruit and vegetable processors, and water use minimisation should be practised wherever possible.

Expected yields from raw fruit and vegetables on the basis of edible content are fairly well known in the industry. Additional waste above these levels can arise from inefficient processing such as excessive peeling, physical damage to the produce or premature spoiling.

Preserving processes such as jam making can suffer from losses associated with product changeovers, where ineffective line cleaning can lead to cross-contamination of products. More effective and efficient line cleaning technology can eliminate these sorts of wastes at source.

The great majority of solid waste produced by the sector is biodegradable and, since it is non-animal in origin, is not subject to the same treatment strictures as wastes from meat or fish processing. Some edible wastes are recovered for the animal feeds market. Fruit and vegetable waste has the potential to be a ready energy source for bio-recovery, although fibrous material may require pretreatment to make it more amenable to digestion techniques.

Figure 4.4 Mass Balance for Fruit and Vegetable Processing



4.1.4 Vegetable and Animal Oil and Fats

The sector is a very small waste producer relative to the volume of products produced. Wastes consist mainly of discarded intermediate packaging and modest amounts of oily sludges, associated with process washdown wastes. The principal by-product of oil production is the spent seed cake and meal remaining after oil has been extracted from the seed. This is effectively consumed by the animal feeds industry.

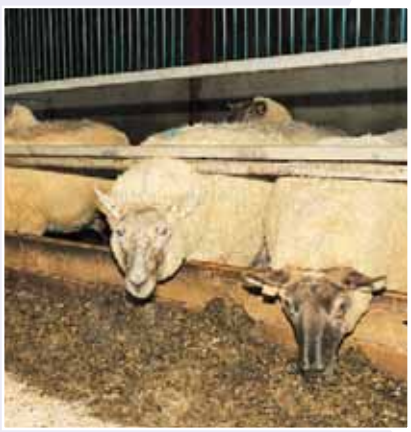
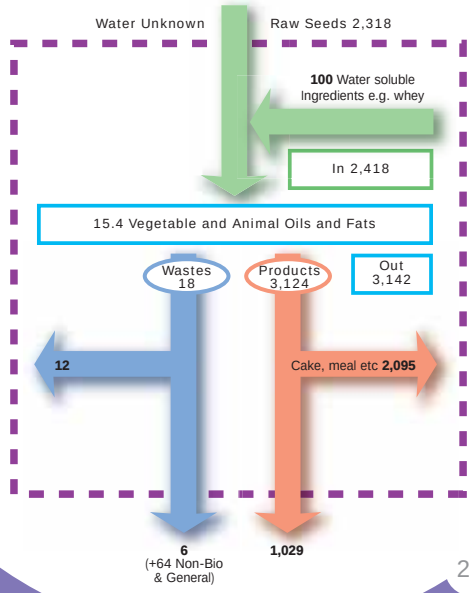


Figure 4.5 Mass Balance for the production of Vegetable and Animal Oils and Fats



4.1.5 Dairy Products

At 4% of the volume of products, the dairy industry produces a fairly modest amount of external solid waste, however it is a large consumer of water, which is used for equipment and workplace cleaning and hygiene maintenance. Envirowise has estimated that cleaning water can account for 50 - 90% of site water consumption in the dairy industry. The industry utilises cleaning in place (CIP) systems which clean thoroughly to very high standards, but control of water use is not always optimised with the quality of cleaning achieved.

Non-organic waste consists mainly of intermediate packing materials, often contaminated by milkfat residues and the like. Organic wastes tend to be fat-containing residues, which are often washed off into process effluent, the end result being effluent of high organic loading, which incurs high treatment or disposal costs.

Very often effluent sludges have the potential for reuse of their organic content if they can be recovered in a suitable form - usually if they can be sufficiently dewatered.

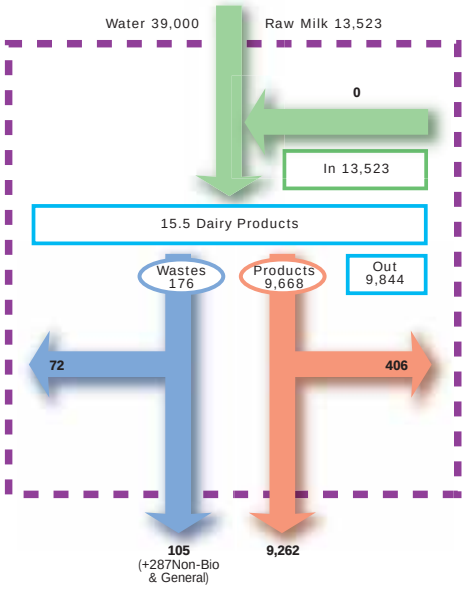
One stream which is both a perennial problem and an opportunity for the sector is whey, a dilute acidic solution of lactose and protein produced in creameries as a by-product of cheese manufacture.
The constituents of whey have several attractive uses, for example in ice-cream manufacture and in the production of protein dietary supplements for health and fitness markets, but the active ingredient content must first be increased by concentration or conversion to a powder form.

The production of 1kg of cheese results in approximately 9 litres of whey, containing around 5% lactose and 1% protein.
In 2001, UK produced sales of cheese products amounted to nearly 750 kT, implying a whey stream of 6,750 kT, containing approximately 340 kT lactose and 70 kT protein.

While sales of whey liquid and concentrated products were at a comparable level of around 440 kT, the amount of liquid in the products is not stated and so it is difficult to assess the overall utilisation of whey.

Although producers can achieve modest incomes from selling whey to third party whey concentration and drying companies, and to farmers for landspreading, these routes achieve less than a tenth of the value realisable from added value final markets like dietary supplements, and demand can often not be matched with whey production, leading to disposal of excess whey as waste. Readily available technologies exist which can allow creameries to produce concentrated whey by-products in-situ, and if the water from the whey is also recovered for reuse, further savings can accrue (see capsule).

Figure 4.6 Mass Balance for the Milk and Dairy Products Industry



Joseph Heler's 9,000 tpa cheese creamery in Atherton, Cheshire has successfully utilised membrane technology to extract whey protein and lactose concentrates from their whey by-product, and recover the balance of the whey water as demineralised water or low grade yard wash water. Techniques applicable include reverse osmosis, ultra- and nano-filtration.

For an initial capital outlay of £1M, and operating costs of £223K per annum, Heler's claim an annual saving in running costs of £909K, equivalent to a one and a half year pay-back period. According to Heler's Managing Director "Membrane technology has enabled us to generate a significant revenue stream from a previously low or no value material. We have removed an environmental headache and increased product recovery from 10% to 95%."

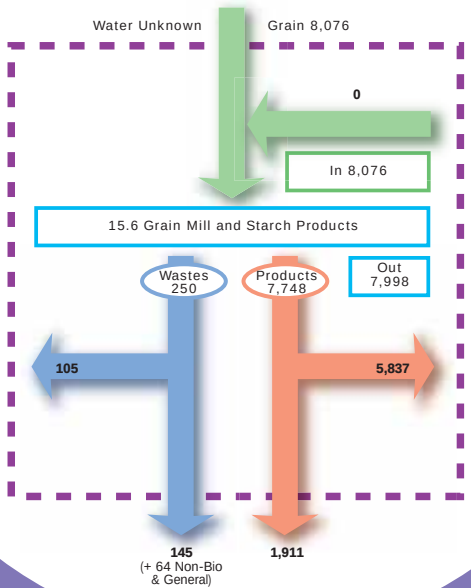
Source: Envirowise Best Practice Programme Case Study GC150 "Turning Waste into Profit"

4.1.6 Grain Mill Products and Starch

The grain milling industry represents an important source of intermediate products utilised elsewhere in food manufacture.
The industry is not a large producer of waste relative to the volume of products, which is unsurprising given the inherently high edible content (either by humans or animals) of most grains, and by the fairly straightforward nature of the processing operations involved.
The main sources of waste are weed seeds, stones and other incoming foreign matter, along with discarded packaging materials.
If grain is held at too high a moisture content, inadvertent germination can occur, leading to spoilage.

Dry milling operations tend to use only modest volumes of water for cleaning, although this is less true of wet milling processes for the likes of starch production. Other important considerations for the industry are good hygiene practice, avoidance of infestation, and dust and noise abatement.
Dust containment is important both to minimise impact on the local environment, and within mills to avoid the risk of dust explosion.

Figure 4.7 Mass Balance for the production of Grain Mill and Starch Products



4.1.7 Prepared Animal Feeds

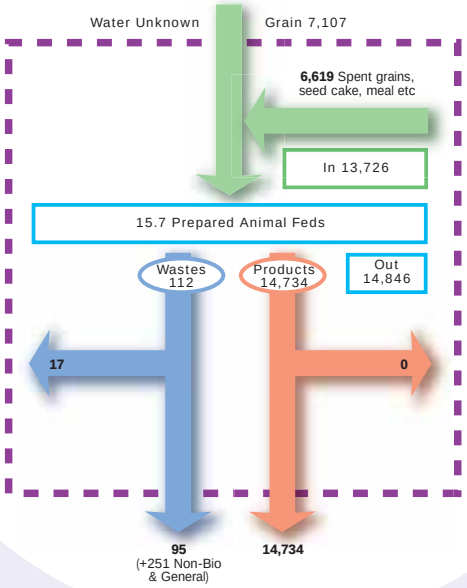
The animal feeds industry is an important part of the overall mass balance for the food and drink sector. Not only does it account for the largest product output tonnage of any of the food and drink subsectors, but it acts a major “sink” for co-products from other areas of food processing, which might otherwise be wastes.

Although the great majority of inputs to feedstuffs - primary grains and oilseeds, meat for petfoods, and vegetable, cereal, sugar and brewery co-products - will not be affected, any stream falling under the animal by-products regulations and similar instruments is currently subject to at best severe restriction, and typically outright prohibition from reincorporation into the food chain. From the point of view of the compounding industry this mainly presents a problem of how to retain the nutritional balance of feedstuffs in the absence of protein derived from animal sources.

A further concern for the industry, and for those activities whose co-products provide its raw materials, (such as spent brewing and distilling grains, sugar beet pulp and molasses, and grain meal) is the apparent legal re-definition of these materials as wastes under the IPPC framework.

The previous position in the UK as stated in the mid-nineties by Department of the Environment guidance around the 1994 waste management licensing provisions was that food and drinks industry co-products were by-products and not wastes.
By contrast, current Environment Agency draft guidance on IPPC states that food materials leaving a site other than intended materials will be viewed as waste. This raises the prospect of, companies that take such material having to become a licenced waste handler, additional compliance requirements for transporting by-products once classified as waste, and - not least - negative public perception around animals being fed compound made from “waste”. How the general principle of unintended materials as waste will be applied in practice is dependent on the consideration of a complex body of legal rulings in various cases put before the European Court of Justice.
The Environment Agency and DEFRA are currently closely reviewing this area, in order to achieve a legally correct and practically achievable position for industry. Further information in this area can be obtained from the Brewing, Food and Beverage Industry Suppliers Association, or from the Environment Agency.

Figure 4.8 Mass Balance for the Manufacture of Prepared Animal Feeds



4.1.8 Other Food Manufacture

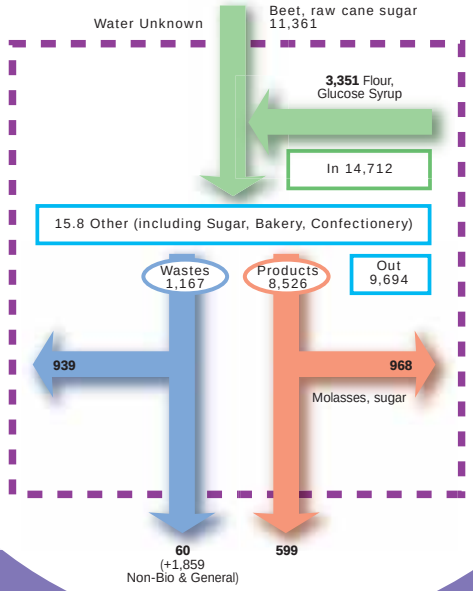
The major outputs in this sector include bread and bakery products (2,800kT approx.) and biscuits and confectionery (1300 kT). Cane and beet sugar are produced in large amounts (1100 kT and 1400kT respectively), with much being utilised in the production of other foodstuffs and beverages. Co-product and food waste volumes are relatively high at nearly 14% of products, however the majority are reutilised elsewhere. The external waste stream is still high however as the sector has a very large component of non-biodegradable and general waste.

As discussed in Chapter 2, the beet sugar industry has evolved markets for all its major co-products, however in recent years the bakery industry has faced the challenge of legal redefinition of pastry wastes. Until 2001, bakery waste which was not derived from meat products fell under the definition of catering waste (along with restaurant wastes and bakery returns). This material attracted nominal amounts when sold for use in livestock feeds, most notably in pig swill.

However reaction to the 2000 Foot and Mouth Disease outbreak (through the 2001 amendment to the Animal By-Products Order) prohibited the production of swill from catering waste from meat products or which had been in contact with meat. Controversially the amendment also banned the use of any catering waste from premises where meat had been handled, even if this waste itself had not had direct meat contact, and furthermore took the widest possible interpretation of what constituted “the premises” and “handling” meat. Examples of this interpretation with which the industry took issue include separate enclosed buildings within the same site being defined as the same premises, and an on-site canteen being regarded as meat handling activity.

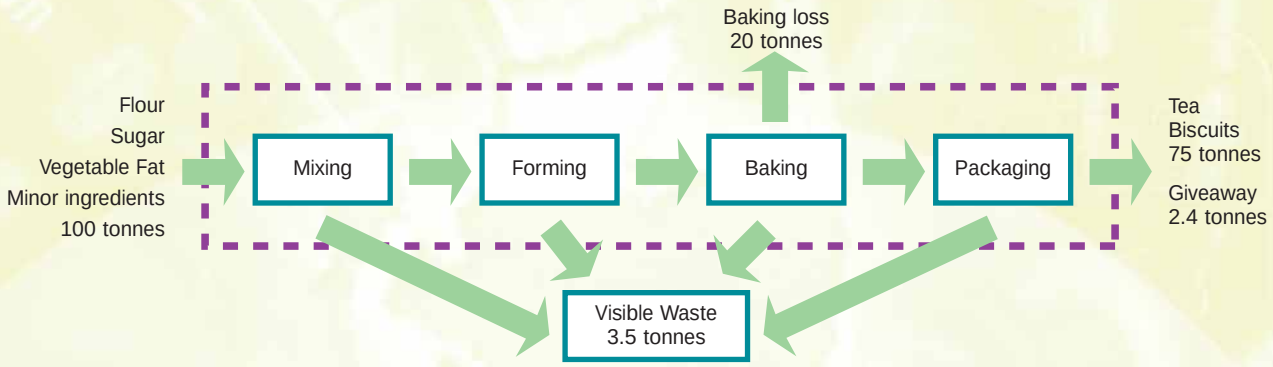
Following the 2003 amendments to the ABP, meat containing or meat-contacted bakery wastes fall into the same risk category 3 as meat wastes. Non-meat contaminated food wastes from bakeries are still permitted to go to landfill, but as a biodegradable stream this cannot be regarded as a satisfactory long-term sustainable position.

Figure 4.9 Mass Balance for the Manufacture of Other Food Products



United Biscuits manufacture a range of products under the well-known McVities brand. In the last 4 - 5 years the organisation has implemented a mass balance based approach to assessing its operations, to enable educated decision making and standard setting for quality and cost-effective running. Line performance is measured against standards for yield (simple output versus input), efficiency (accounting for production rate as well as basic yield), and product quality (measured against carefully defined standards, customer assessments etc.).

A key component of this approach has been to audit input, output and waste flows on individual lines. A typical example of a McVities process is the production of tea biscuits, a high volume product of low unit value (see diagram below). McVities produce more than 11,000 tonnes of tea biscuits annually.



Production is carried out on lines dedicated to tea biscuits and generically similar products, minimising product changeover losses. Raw materials, held in bulk storage, are dispensed for mixing, formed into biscuits and baked before packaging. Resource flows are balanced over the envelope indicated by the dotted box in the diagram.

Bulk delivery and handling of raw materials, and the use of reusable IBC containers ensure that incoming packaging wastes are limited to very small amounts of discarded containers from minor ingredients. Each subsequent stage of biscuit production may produce “visible” wastes associated with unsatisfactory operation, e.g. discarded dough, badly formed product etc. Some wastes can be handled internally - wrongly packed biscuits may be returned to process although the packaging would not be recoverable - others simply result in waste production. In most cases operator time would be wastefully diverted from other tasks to deal with waste issues.

Physical wastes are handled in three segregated streams through the use of colour coded containers. Food waste (sold for use in agricultural feeds) and internally recyclable wastes, are kept apart from general waste which is disposed of to landfill.

The nature of the baking process inevitably results in another waste which the company must carefully manage - the so-called “baking loss” of moisture driven off in the oven. Although not an environmental concern, McVities monitor baking losses carefully, as they have in effect paid a premium for much of the water going up the stack through the moisture content of purchased raw materials.

A further “invisible” source of waste is product give-away - the extra weight over nominal in every pack of biscuits to ensure compliance with legal requirements. Although give-away is more or less inevitable for any producer seeking to comply with weights and measures, the better the level of process control and the less variable the process, the less give-away should occur.

A key cultural requirement for operations in McVities is good factory floor appreciation of the true cost of any event occurring in the process. This is allied to a disciplined approach to running processes which avoids (usually counterproductive) ad hoc changes in running conditions. A general philosophy when dealing with any incidence of waste is to avoid adding further value to bad product - for example by avoiding spending money baking and packing badly formed biscuits.

An audit carried out on tea biscuit production over a three day period produced the mass flow figures shown on the process diagram.

As befits a well-run operation, directly visible waste only represents a small proportion of the total wastes of concern to the company. When assessing cost-effectiveness, the financial impact of discarding modest amounts of waste (or selling it to lower value markets) would usually be outweighed by the ability to produce more of the (added value) product. Thus within current cost structures, high volume biscuit production is an example of a business which would benefit more from innovation related to improved process capability (to avoid any unnecessary baking and give-away losses) than from new ways of handling physical wastes.

4.1.9 Beverages

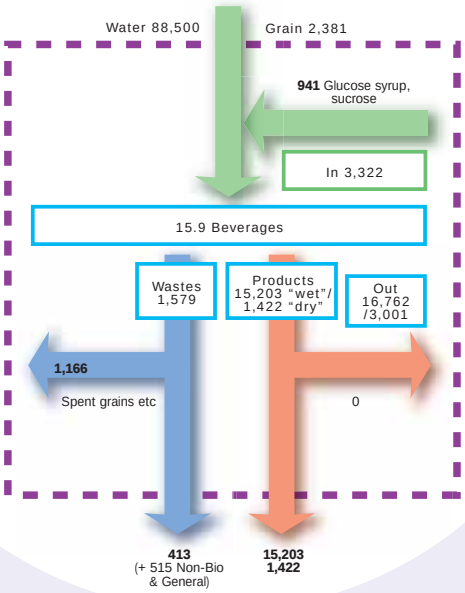
Of all areas of Food and Drinks processing, beverage manufacture involves the largest difference in water content between incoming ingredients and outgoing products. To attempt to balance the dry inputs with the liquid outputs would not be comparing like with like. A “dry” basis estimate of the product output from the beverages industry has therefore been obtained from the alcohol / sugar / flavour content of the range of beverages included in the output total. The total product output, including water is however of use in estimating overall water disposal from Food Processing as part of the overall mass balance.

The level of waste production is high - the nature of the brewing process is to generate a substantial biomass through fermentation, and other streams like spent malt and grain, excess wort (the unfermented extract from the grain prior to fermentation) and ullage (cask washings containing yeast, finings, beer and hops) also arise from the preparation of alcoholic beverages. Fortunately these materials are a rich source of nutritional value which can be utilised by farmers or through the animal feeds industry, and this is reflected in the relatively high amount of waste that is utilised elsewhere.

This does require good practice on the part of producers to ensure that by-product streams do not become contaminated - for example mixing surplus wort and yeast results in fermentation, and the loss of two streams of potential value.

Water use is high in the sector, with equipment and storage washing accounting for most of that use. The UK brewery industry uses an estimated 34 million cubic metres of water, and over 70% is discharged as trade effluent. Brewery effluent tends to be high in COD and suspended solids due to the presence of soluble sugars, starches, alcohol and protein from waste wort, beer and yeast. The soft drinks industry has been estimated (Envirowise) to use around 25 billion litres of water in the production of around 10 billion litres of products, with the major non-ingredient use being in equipment preparation.

Figure 4.10
Mass Balance for the Production of Alcoholic Beverages and Soft Drinks



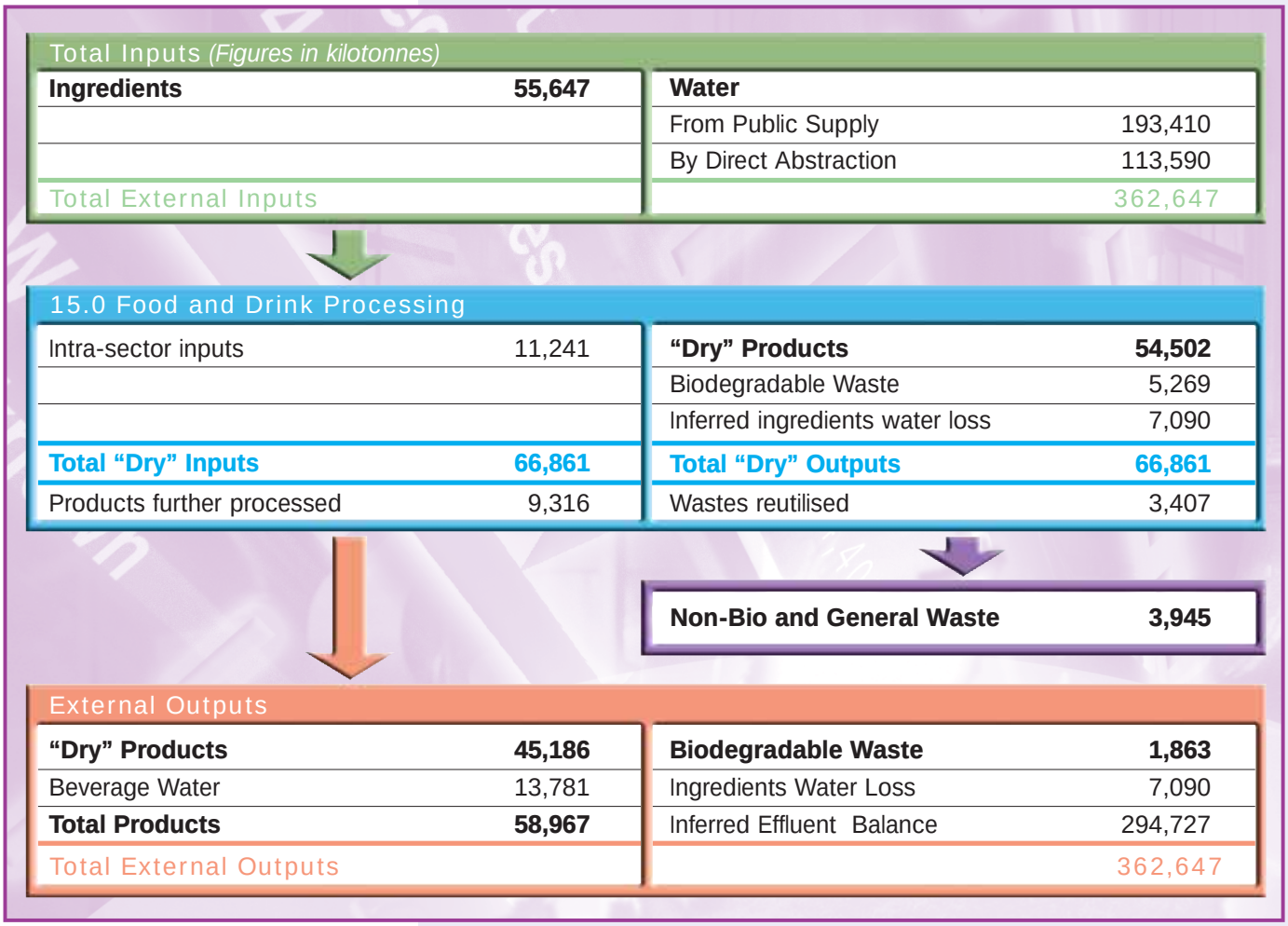
During the malting of grains for use in whisky production, steam is drawn through the process to provide heat using high-speed impeller fans. The fumes drawn off in the process deposited clinker type resins on the impeller causing the fan to be shut down every 3 weeks for cleaning, with each shutdown lasting approximately 36 hours. Impellor manufacturer Howden provided a solution to this problem by using an advanced resin composite material developed by J.M. Composite Technology to protect the fan. The composite has a high resistance to sticking and inhibits clinker build-up, increasing the running life of the impellor between shutdowns. As a result of the improved process technology the fan operated for a total of 13 months without stoppage, removing downtime costs and eliminating shutdown and start-up wastes. Downtime savings alone were estimated to be in excess of £500,000 over the period.



4.2 Overall Mass Balance for the Food and Drink Processing Industry

The sum of the inputs, outputs and wastes for each sub-class of food processing gives the overall mass balance shown in Figure 4.11.

Figure 4.11 Overall Food & Drink Processing Mass Balance



The Food and Drink processing industry consumes nearly 56MT of ingredients per annum, producing almost 59MT of products including the total mass of beverages. Total external wastes for the sector are estimated to be 5.8MT, or around 10% of the weight of useful products. About 1.9MT of this is biodegradable waste, however it should be recalled that currently this figure is probably higher than at the time of the survey due to the limitations on reincorporating animal by-products in the food chain. By summing the wastes re-utilised within food processing in the sub-sector mass balances, **it can be estimated that the industry avoided the external disposal of a further 3.4MT of biodegradable wastes in 1999.**

Including intra-food processing streams, the sum total of products expressed on a dry basis (excluding the water content of beverages) and biodegradable wastes is just over 7MT less than the ingredients input. This could simply be attributed to errors or uncertainty in the many estimates and assumptions used in obtaining the data, however it is believed that if anything the input values will be underestimated as we have only attempted to quantify the most significant inputs. A variety of smaller inputs may cumulatively serve to add to the overall input total.

The mass imbalance may reasonably be interpreted as an estimate of the net balance of the amount of water added to or taken away from food resources during processing. Thus the data suggests that each year over 7MT of water naturally present in the raw materials of food is removed from the products - for example through baking, frying or drying for preservation. This water is "purchased" by food processors at a premium rate - the price of their raw materials - and is therefore of concern to any processor who dehydrates their products. It is of course not possible to avoid most of this loss - cakes must be baked and crisps must be crisp!

Water

Although it has not been possible to obtain satisfactory data relating to effluent discharge from the food processing industry, we have used an estimate of total water consumption by the industry along with the mass balance data to imply a water discharge level of just under 295MT per annum. This is however very dependent on the estimates of water consumption from public supply and abstraction. Estimates of water consumption from sub-sectors of food processing have been quoted where available above, however the sum of these figures leaves a large gap to the overall estimate quoted by the Environment Agency. For comparison, a survey of Food and Drink Federation members in the year 2000 estimated water consumption in the sector to be 9.24 m^3 per tonne of output, implying an even higher water consumption of over 500 MT.

Water UK, the trade body of the UK water supply industry quotes an overall environmental performance indicator for

industry expressed as litres of water consumed per pound of GDP produced. For the entire industrial sector this figure was 1.7 litres per £ of GDP in 2001-02. For food and drink processing, with a total contribution to GDP of around £19 billion, this indicator is around 16 litres per £ of GDP generated, on the basis of the more conservative estimate of water consumption.

Packaging

The 3.9 MT of non-biodegradable and general waste is primarily accounted for by materials associated with packaging - either wastes arising from losses of product packaging or more often intermediate packaging and palletting from raw materials and internal transfer operations.

According to Envirowise, the UK consumes about 9 million tonnes of packaging materials annually, and over half of this is accounted for by the food and drinks industry, with an associated raw materials cost of around £4 billion per year. Another estimate for 1998 placed the food and drink packaging market at £6.3 billion or 55% of a total market of £11.5 billion. Figures for packaging materials consumption derived from various sources are shown in Table 4.2.

Wherever possible food producers should attempt to reutilise packaging where hygiene and food standards requirements allow. Limitations on reuse or recycling of ex-packaging wastes often result from the presence of residual foodstuffs on the packaging material. In some cases cost-effective thorough cleaning would make packaging recycling more viable. Although outside the main focus of this report, similar challenges face the recovery of retail and catering food packaging wastes. In this area, the industry also faces negative public perception over the use of excessive packaging for non-functional purposes.[43]

Energy

Although a detailed consideration of energy consumption is outside the scope of this mass flow report, some overall statistics[44] for the sector are of interest. In 2001 the food, drink and tobacco industry consumed around 12% or 4,200 thousand tonnes of oil equivalent. A fifth of this energy went into sugar production, 13% on beverages, and another 10% on meat and meat products. The total consumed by the sector fell by 2% from 1996 to 2001. Typical energy consuming unit operations in the sector include baking and separation activities, and are categorised as low temperature end uses (by contrast with high temperature operations such as coke ovens and blast furnaces). Energy intensity (energy consumption per unit of output) for the sector fell by 6% between 1990 and 2001. According to the Energy Efficiency Best Practice Programme, energy intensity improved by 4% between 1997 and 1999. 1.5% of this was attributed to improved energy management, 1.5% to fitting new boilers, and 1% to improved steam, motor and drive systems.

Table 4.2 Packaging Materials Consumption by the Food & Drink Industry

Material Type	1996 Total UK Packaging Supply[i] (Mtonnes)	1998 Estimated Total Packaging to Waste[i] (Mtonnes)	2001 UK Recycling Rates[ii]	1998 Percentage (by value) of Food Packaging Materials[iii]	Comments
Paper and Board	3.6	4.0	52%	39.7%	45% of total paper and board output value to food and drink[iii]
Plastics	1.6	1.7	16%	30.2%	25% of total plastic output value to food and drink[iii]
Metal	1.0	0.8	37% (Steel) 24% (Aluminium)	22.2%	60% of all cans by value to food and drink[iii]
Glass	2.2	2.2	33%	7.9%	Food and drink estimated at 10-15%[iii] or 40%[iv] of total value
Wood	2.4	1.3		0.3%	

Source: i. DEFRA Consultation Paper, Review of Producer Responsibility Obligations (Packaging Waste) Regulations 1997
ii. DEFRA iii. Packaging, Food and Drink Market Report,1999 iv. Packaging (Glass) Market Report 2003, research&markets.com

4.3 What Happens to Food Processing Waste

Note: All figures in this section are based on the 1997 Environment Agency Waste Survey and are for England and Wales only.

The National Waste Survey asked respondents to identify the fate of their wastes. Seven different waste management options were used for reporting:

Land Disposal: includes all landfill activities plus lagoon disposal and deep injection to borehole when these are used as disposal methods

Land Recovery: includes spreading waste on land and surface injection (of organic waste for beneficial treatment of agricultural land), and disposal of inert waste to land under the provisions of waste licensing exemptions 9 and 19.

Re-use: covers only wastes that go off-site for re-use; excludes materials which are re-used on-site (i.e. fed back into the manufacturing process).

Recycling: like re-use includes only wastes that go off-site including materials such as oils and solvents which may be regenerated or re-refined.

Thermal: covers incineration with and without energy recovery and the production of waste derived fuel; also includes more specialised forms of recovery such as pyrolysis and gasification.

Treatment: covers all physico-chemical and biological treatment including anaerobic digestion and composting.

Transfer: used for wastes which do not go directly to final disposal, treatment or recovery; these wastes go through a transfer process and may be bulked-up prior to recycling, treatment or disposal.

Table 4.3 shows estimated tonnages sent to each management route for each of the main sub-classes of food processing (except Fish Products - see section 1.7 Deriving Data).

Table 4.3 Waste Management Options for Food Processing Waste

	Amount to Waste Management Route (ktonnes)							
Food Processing Class	**Land Disposal**	**Land Recovery**	**Re-used**	**Recycled**	**Thermal**	**Transfer**	**Treatment**	**Total**
15.1 Meat & Meat Products	283	285	205	146	17	65	234	**1,235**
15.3 Fruit & Vegetables	184	70	152	494	0	1	22	**922**
15.4 Oils & Fats	44	-	0	19	-	4	2	**70**
15.5 Dairy Products	90	78	38	179	0	3	1	**389**
15.6 Grain Mill Products	46	106	77	34	0	0	0	**263**
15.7 Animal Feeds	144	127	1	29	0	0	4	**305**
15.8 Other foods	747	68	893	627	42	28	137	**2,542**
15.9 Beverages	260	86	907	95	0	3	11	**1,463**
Total	**1,799**	**819**	**2,274**	**1,722**	**59**	**104**	**412**	**7,189**

The wastes recorded by the survey were also categorised using a detailed hierarchy of waste descriptors. For the purposes of this report these categories have been collated into a number of generic material types to give an overview of the types of wastes produced by food processing operations, Table 4.4.

Table 4.4 Waste Types arising from Food Processing Waste

	Type / Amount (ktonnes)									
Food Processing Class	**Animal & Mixed Biodegradable**	**Non-Animal Biodegradable**	**Plastics, Rubber**	**Paper, Card**	**Wood, composites**	**Metal**	**Glass**	**Soil**	**Other, Unidentified**	**Total**
15.1 Meat & Meat Products	816	57	33	42	3	2	1	-	281	**1,235**
15.3 Fruit & Vegetables	35	488	31	57	74	77	0	12	148	**922**
15.4 Oils & Fats	10	5	2	8	2	1	1	-	42	**70**
15.5 Dairy Products	148	0	40	57	102	3	11	0	28	**389**
15.6 Grain Mill Products	144	65	9	24	1	1	0	-	18	**263**
15.7 Animal Feeds	90	4	14	22	7	9	0	-	159	**305**
15.8 Other foods	329	651	120	284	83	43	2	77	954	**2,542**
15.9 Beverages	8	1,023	70	62	9	13	19	-	260	**1,463**
Total	**1,581**	**2,293**	**320**	**555**	**280**	**149**	**34**	**88**	**1,890**	**7,189**

Lastly, Table 4.5 shows the fate of the total wastes from all classes of food processing (except fish) broken down by the type of waste produced.

Table 4.5 Waste Types and Management Options for Food Processing Waste

	Amount to Waste Management Route (ktonnes)							
Waste Type	**Land Disposal**	**Land Recovery**	**Re-used**	**Recycled**	**Thermal**	**Transfer**	**Treatment**	**Total**
Animal & Mixed Biodegradable	344	343	333	293	29	65	174	**1,581**
Non-Animal Biodegradable	100	119	1,574	454	-	0	46	**2,293**
Plastics, Rubber	219	-	3	82	7	8	0	**320**
Paper, Card	274	-	5	242	22	12	0	**555**
Wood, composites	23	-	30	224	0	2	0	**280**
Metal	32	-	4	113	0	0	0	**149**
Glass	3	-	-	32	-	-	-	**34**
Soil	12	-	76	-	-	-	-	**88**
Other, Unidentified	792	357	249	283	2	16	192	**1,890**
Total	**1,799**	**819**	**2,274**	**1,722**	**59**	**104**	**412**	**7,189**

4.4 Regional Waste Production

The Food and Drink processing industry accounted for about 7.2 MT, or 15% of total industrial waste in England and Wales in 1997, Figure 4.12. Commercial food and drink waste contributed another 21% to the total waste figure.

Figure 4.13 shows the relative contributions of the regions to the total industrial and commercial waste in England and Wales. Although the sum of industrial and commercial food waste is a roughly similar proportion of the total waste in any region, there is substantial variation in the relative amounts of each for different parts of the country, Figure 4.14. Waste production reflects both the relative importance of the food processing industry in areas outside London and the South-East, and conversely the important role of this area as a consumer of food products.

Figure 4.12
Contribution of Food and Drink to Waste in England and Wales

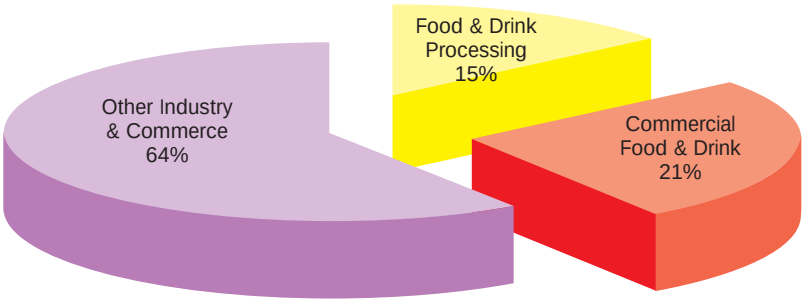


Figure 4.13
Industrial and Commercial Waste by Region

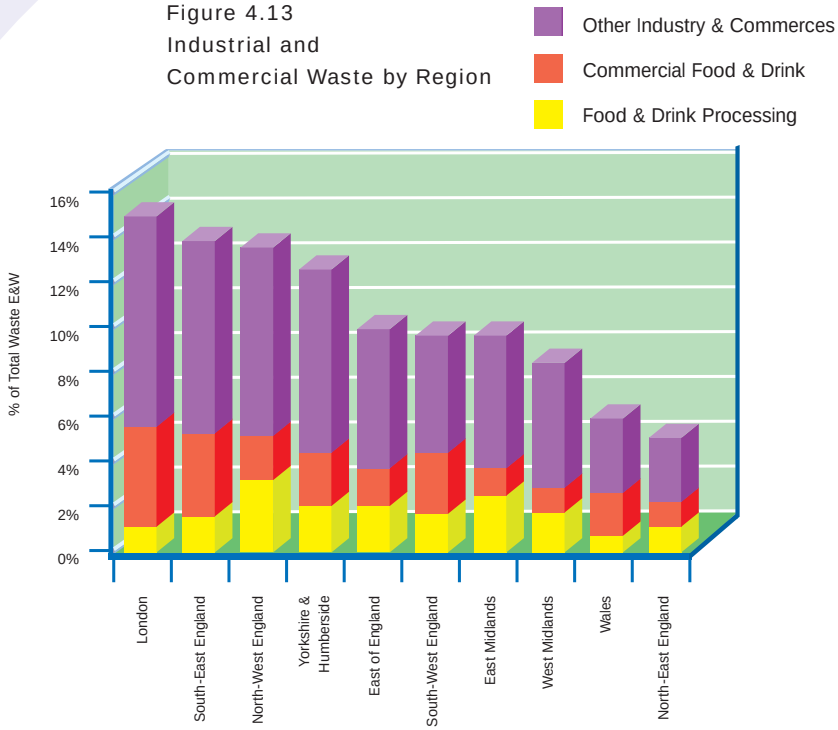
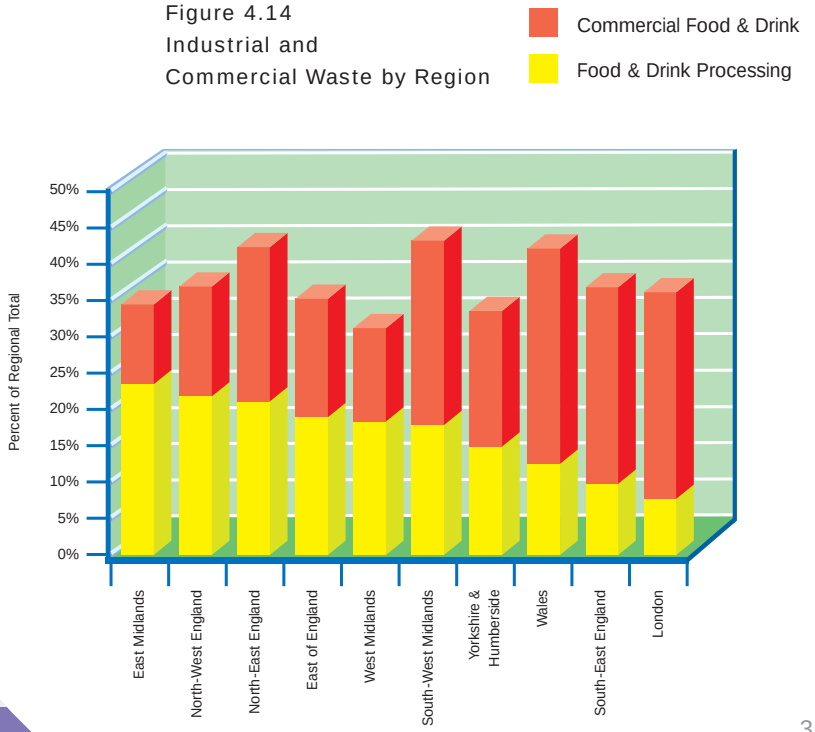




Figure 4.14
Industrial and Commercial Waste by Region





5 Options for Food Processing Waste

This chapter reviews the current and emerging options for dealing with food processing waste in relation to the waste management hierarchy. Advantages, disadvantages, applicability and limitations of a variety of technologies are considered, and references are provided to sources of further information.

5.1 Major Wastes

The food processing industry is large and diverse. Each sub-sector of the industry produces wastes and has issues which are characteristic of the nature of its processes and throughputs. Before considering the options for handling food processing waste, it would first be useful to define some broad categories which encompass most of the wastes arising.

- **Wastes from Foodstuffs**
  The main foodstuff streams produce waste, either through inherently wasteful material - stones, bones, offal etc. - or through actual wastage of viable product - for example a batch of frozen carcasses written off through a freezer being operated out of specification. When assessing utilisation options, the former have the merit of occurring in reasonably predictable amounts, whereas the latter tend to occur spasmodically.

  A recent survey of members of the Chilled Foods Association asked respondents to rank in order the main causes of their biodegradable waste, with 1 representing the most significant. Results highlighted in-process waste as the most important source, followed by raw material waste and off-specification product, Table 5.1. Routes to improved processing are considered in sections 5.3 below and Chapter 6.

Table 5.1

Sources of Waste ranked for significance by chilled foods producers

Source of Waste	Average Rank
In-process waste	1.4
Raw material waste	2.4
Off-specification	2.7
Customer returns	4.0
Change to orders	4.6
Out of date products	4.9

Source: Chilled Foods Association

- **Waste from Packaging and Ancillary Material**
  Packaging and other ancillary materials required during processing accounts for most other non-foodstuff related solid wastes arising from food and drink processing.

  Packaging wastes include the packaging received with incoming raw materials - for example plastic wrapping, pallets etc. - and any wasted materials arising from the packaging of outward bound goods. The Food and Drink industry accounts for over half of total packaging output in the UK, about 4 to 5 million tonnes or £4 billion of raw materials alone. Just under a third of all packaging materials in the UK are recycled and the remainder, about 6.7 million tonnes goes to landfill. [45]

- **Wastewater**
  Wastewater is ubiquitous in food processing operations, arising from the necessary cleaning, separation and hygiene operations required to operate. Wastewater costs are incurred either through the operating costs of on-site treatment facilities for large operations, or in most cases through the charges imposed by the effluent handling authorities. Effluent charges are calculated on the basis of volume discharged and on the strength of the waste, expressed as the COD (chemical oxygen demand) or BOD (biological oxygen demand). Typical waste water handling charges of 50 - 80 pence per cubic metre [46] have been quoted.

- **General Waste**
  Like all industrial and commercial operations, food processing units will inevitably produce a certain amount of general waste from bathrooms, general cleaning, office stationery etc. In most cases the size of these streams will be low compared to process related wastes, however allowing cross-contamination of process and general wastes can unnecessarily add to waste management cost and complexity.

Obvious examples include segregating domestic and process water streams to minimise effluent charges, and avoiding contamination of potentially recoverable food process wastes with general garbage.

- **Invisible Waste**
  As mentioned in the introductory chapter to this report, the physical wastes arising from a business are only part of the story. Every bin that is emptied, every floor that is swept, every instance of downtime caused by waste, and every machine that runs only to produce waste represents a further drain on the human and monetary resources of the organisation.
  Although managers acknowledge these sorts of problems, they are rarely exhaustively measured and tend to be so much part of the scenery of how business is done that they are effectively invisible. While the main focus of this report lies in the physical wastes arising from food processing, it should never be forgotten that a business which manages to avoid physical waste also frees up the resources previously committed to coping with it.

The data of section 4.3 clearly shows the importance of foodstuff-related wastes to the total waste stream from food processing. Biodegradable material constitutes nearly 54% of the total of 7.2MT per annum. Of this around 1.4MT is currently disposed of via routes which will not be sustainable in the medium term. Other wastes, such as paper and plastics associated with packaging materials are a smaller contributor to the grand total, but go predominantly to landfill. The relatively high proportion of unidentified and general waste (792kT to landfill) probably represents an opportunity for waste minimisation, as it is likely to contain at least some material from which value could be recovered if better waste handling practices such as segregation, were more generally adopted.

5.2 The Waste Management Hierarchy

The hierarchy of waste management[47] provides a useful framework to consider the management options for any sort of waste. In order of preference, the options are

- **Waste Minimisation** - produce the minimum amount of waste at source
- **Reuse** - material is directly reused for its original purpose
- **Recycling** - material is reprocessed into another useful form or forms.
- **Energy Recovery** - energy may often be usefully recovered from waste. If waste is reprocessed to a useful form in the act of recovering energy, then this can be a doubly attractive option.
- **Disposal** - if no other practical options exist for a waste stream, controlled responsible disposal is required.

In the following sections, options for waste handling in the food processing industry will be considered with reference to the hierarchy of waste management and major wastes described above.

5.3 Waste Minimisation

The best way of handling waste is to avoid making it in the first place.
Waste minimisation - limiting the waste produced at source - should always be practised wherever practicable before considering other options. Of course many operations are inherently wasteful - it is not possible to peel a potato without producing peelings - however waste minimisation approaches can usefully be applied to reduce the impact of a broad range of wastes.

Generally, waste minimisation activities can be split into three categories,

- **Better operational practices**
- **Improved control of existing processing operations**
- **Innovative process technology**

5.3.1 Better Operational Practices

Many organisations have experienced practical benefits from assessing their basic working practices from the point of view of minimising waste. The UK government Envirowise programme[48] provides extensive information and advice on how to successfully initiate waste minimisation efforts in the workplace, including several examples successfully applied to the food processing industry.

Waste minimisation initiatives will typically focus on

- **Raising awareness of waste -**
  making waste visible through identifying and quantifying waste streams, giving local responsibility for waste producing unit operations to individuals on the shop floor,
- **Involving staff**
  in identifying waste problems and solutions, and putting them in place,
- **Setting targets**
  for waste and reviewing against them.

Local waste minimisation clubs[49] are a good way of sharing best practice and access to other help, and can bring organisations with complementary needs together. Larger organisations may consider utilising the potential for co-operation between their various operations by setting up a company-wide waste club[50].

Food industry specific material may be available. For example, the Food Chain Centre, in partnership with the Red Meat Industry Forum has recently produced a free information pack providing extensive practical advice and information on how the successful manufacturing improvement concepts of Lean Manufacturing can be applied in the red meat chain[51].

Food producers can usefully adopt approaches imported from other areas of industry. The Samworth Brothers group has successfully applied engineering continuous improvement methodologies to their range of ready meal and convenience food processes.

Ginsters, the well-known producer of Cornish pasties and other ready to eat products, are applying SMED techniques to reduce downtime and increase efficiency at product changeovers. SMED - Single Minute Exchange of Die, referring to the method's original application in engineering, where fabrication dies had to be changed as swiftly as possible - focuses on operational practice, planning and execution of changeovers, and areas of waste. Ginsters are already seeing a return on the training investment made as part of the initiative through step change improvement in line utilisation.

Another Japanese technique, known as the Five S's is being applied by Samworth's to improve housekeeping and workflows in the workplace. Continual focus on the "S's" - Sort, Store, Sweep & Shine, Standardise and Self-Discipline - provides staff with a framework to contribute to the improvement of their own operations. Early success has been achieved in the Despatch area, but the methods can be applied to all areas of operations.

5.3.2 Improved Process Control

It can be argued that maintaining effective process control is simply part of good operational practice, and there is certainly a large degree of overlap between this and the previous area. Most companies carrying out a process waste minimisation study identify lack of process control in one form or another as a contributor to their overall issues. However, true process control goes beyond basic good workplace practice in running equipment.

A company in control of its process knows what needs to be controlled in order to produce a quality product with minimal waste. It will utilise the best monitoring technology for those critical measures, and has the necessary integrated management tools to ensure the operation responds appropriately and swiftly to process events. It is claimed that improving process control by focussing on waste minimisation can reduce production costs by up to 5% through reduced raw materials use, product loss, water use and effluent generation[52].

"Measuring to manage" is often quoted as a pre-requisite for process control and it is indeed true that without critical in-process measures it is impossible to measure progress and make operational and management decisions soundly.
However making the most of the monitoring carried out is also vital - bad decisions can be made on technically sound data.
Well-established techniques for data analysis and statistical process control can be incorporated into workplace practices as easily followed procedures. They may be considered to be decision making tools for when to intervene in a process and when to leave well alone, both on the basis of measured data.

Technologically there are few barriers to effective process control in food processing. Critical parameters are typically temperature, pressure, level monitoring, flow rate, and analytical measures including pH, turbidity, and conductivity. Sensing and control systems are available for all of these applications, and most involve minimal outlay on equipment. The Envirowise programme can provide guidance on how to assess the options for particular applications.

Examples of how better process control can be applied to waste minimisation include:

- Making less off-specification product through better control of raw material additions
- Avoiding spoilage by improved temperature control
- Avoiding unnecessary discharge to drain with automatic level control of valves
- Minimising use of wash water through control of flow rate and duration in cleaning cycles
- Reducing product give-away through better control of filling

Process control is often wrongly assumed to focus on either monitoring final product quality or critical in-process conditions. While these are important things to get right, the emphasis must be to assure quality as early as possible in the manufacturing process - the first point of focus being ingredients. However, a second misconception is that having ultra-high specifications for ingredients will lead to better quality. This is not necessarily so, and can lead in practice to additional cost, supply problems and poor utilisation of material resources.

Kettleby Foods, a rapidly growing producer of ready meal dishes including Shepherd's Pie and other potato topped pies receive pre-peeled potatoes, which they cook and mash to produce pie tops. The potatoes are supplied to a high quality specification, and provided stock and production scheduling is managed adequately potato wastes arising during production are minimal. However, in achieving a high quality surface finish and regularity of shape in the peeled potatoes, the supplier of the potatoes is estimated to be overpeeling by 5 - 10% of usable potato flesh, resulting in unnecessary waste and cost.
Since surface appearance and regularity have almost no bearing on the quality of the resultant pie top, Kettleby is working with their supplier to improve their understanding of what is really required to assure quality. This will result in a modified ingredient specification and achieve an upstream waste reduction with mutual benefit for both parties.

5.3.3 Innovative Process Technology

If the existing process technology is being operated in the best way by a suitably skilled and empowered workforce, then the limit for further progress in waste minimisation becomes the technology employed.
New technology may address better ways of carrying out existing unit operations or enable material previously written off as waste to be utilised for existing or alternative purposes.

Barriers to the adoption of new technology include

- Inherent conservatism when attempting to produce products to rigorous quality and hygiene specifications in a market of narrow margins
- Lack of investment capital for new equipment
- Sunk costs in existing technology.

Recent developments in the field of food processing are discussed in more detail in Chapter 6.

> "An important pre-requisite for reuse is waste segregation."

5.4 Reuse

Opportunities for direct reuse of materials in the food processing industry are often limited by hygiene requirements - any reuse of direct contact packaging would require scrupulous cleaning before reuse. However materials such as transportation boxes and pallets may be readily reused either within the processing operation, or often through identifying other local operations who can use excess stock. Where possible food processors frequently employ reuse of materials within their processes - for example the pastry "net" left behind after circular pie lids have been cut from a continuous rectangular sheet will be recycled for as long as the pastry retains its texture.

An important pre-requisite for effective reuse (or indeed recycling) of waste is segregation, enabling wastes to be handled as relatively pure streams. This will usually involve a modest cost in terms of organisational effort - providing segregated storage facilities and investing time in changing old habits - but can produce significant cost and workplace benefits for the company.

It is also important to consider reuse opportunities outside the site where the waste originated. In this regard, waste exchange schemes can be a useful way of bringing together the waste output from one source with a potential application in another area.

Supported by a combination of national government bodies, regional development agencies and Landfill Tax Credit funding, the National Industrial Symbiosis Programme[53] provides a mechanism to identify how resources that are unwanted can be changed into useful and competitively priced inputs for others. Although a nationally co-ordinated scheme, NISP operates regionally, with the intent of providing local solutions to waste issues and resource requirements.

Industrial Symbiosis is the process of identifying previously unwanted or low value output resources, which cannot be avoided in an economically feasible manner, and matching them with needs elsewhere to produce useful and competitively priced inputs for other processes. For a case study involving industrial symbiosis successfully applied to food waste, see Section 5.6.3 on Biofuels.

5.5 Reprocessing and Recycling

The complex interdependencies of the sub-sectors of the food processing industry illustrate that the modern food industry has developed on the basis of large amounts of re-processing of materials from one application to another. For example, utilisation of raw carcasses is extremely high - in addition to the main meat cuts and recovered meats, outlets exist for a range of by-products for both food (edible fats, bone meal, etc.) and non-food use (pelts, pulled wool, feathers, etc.). However future restrictions on landfill and landspreading of biodegradable material, and the response to specific events such as the BSE crisis (severely restricting the onward processing of animal by-products into the food chain) mean that new recycling approaches and markets are required if the industry is to comply with the demands set upon it.

5.5.1 Land Spreading

Traditionally used for on-site recovery of agricultural waste, landspreading is potentially the simplest, lowest technology route available for a wide variety of wastes. Done correctly, landspreading is a sustainable option for diverting from landfill waste with beneficial properties for the soil, and can reduce the reliance of agriculture on synthetic fertilisers.

Although landspreading operations for non-agricultural wastes are required to be licensed under the Environmental Protection Act 1990 and the Waste Management Licensing Regulations 1994, historically exemptions have been available for spreading operations of less than 250 tonnes per hectare per annum. Exempt categories included waste food, drink or materials used or resulting from the preparation of food or drink, and blood and gut contents from abattoirs.

In general, waste recovery by landspreading must not endanger human health or employ methods which could harm the environment, and in particular must not cause

- Risk to water, air, soil, plants or animals
- Nuisance through noise or odours
- Adverse effects on the countryside or places of special interest.

Concerns about how well or otherwise these objectives were being met through the system of exemptions, and the impact of recent well publicised animal food chain scares, have led through the enactment of the EU Animal By-Products Regulation to a ban on spreading untreated blood and gut contents to land. Thus in future landspreading will have to be combined with other pre-stabilisation and risk reduction treatments if it is to be used for recovery of animal by-products.

5.5.2 Composting

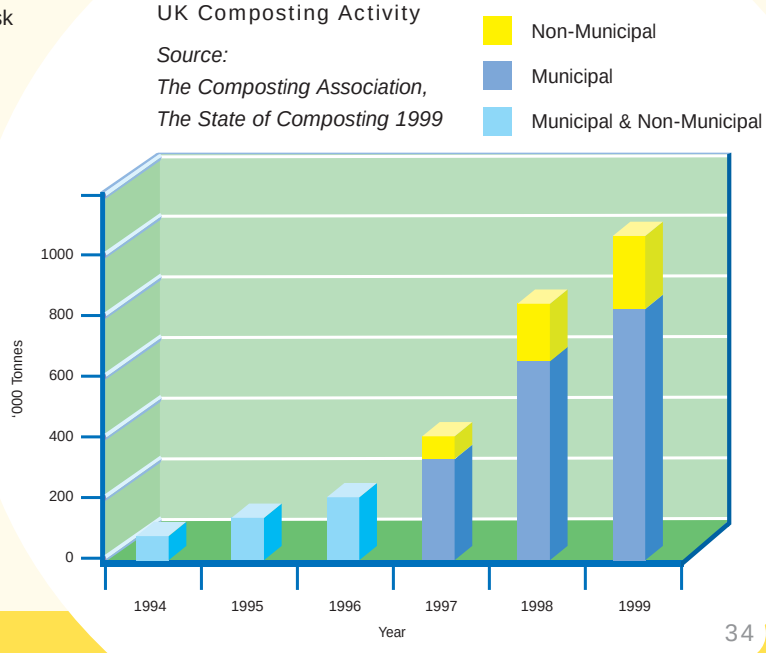
Composting is the aerobic breakdown of bio-degradable waste by naturally occurring bacteria and fungi. Aerobic composting is exothermic (the breakdown organisms are said to be thermophilic) and results in the production of a soil enhancing product and simple chemicals as a result of the complex chemical breakdown processes taking place. Well composted material will typically be much more stable than the incoming organic matter, and of greatly reduced pathogenic risk, through exposure to temperatures of 60 - 65ºC for several days.

Large scale composting activity has grown rapidly in the last few years in the UK[54], however the great majority of material processed is derived from municipal sources, Figure 5.1.



Figure 5.1
UK Composting Activity

Source:
The Composting Association,
The State of Composting 1999



Materials Composted

The make-up of composted waste in the UK is shown in Table 5.2. Nearly three-quarters of all material composted comes from municipal sources. Industrial wastes, including food processing wastes accounts for only 16.4% of composted waste.

Table 5.2 **Make-up of Material Composted in the UK**

Type of Waste	Tonnes composted	Percentage of total UK composting
Garden waste from civic amenity sites	447,044	53.7
Green waste from local authority parks and gardens	107,762	12.9
Garden / kitchen waste from kerbside	46,132	5.5
Other	17,579	2.1
Total Municipal	**618,517**	**74.2**
Industrial	136,303	16.4
Agricultural	32,060	3.8
Green Waste from Landscaping	21,438	2.6
Other	23,939	2.9
Total Non-Municipal	**213,740**	**25.7**
Total	**833,044**	**100.0**

Source: The Composting Association, The State of Composting 1999

Number of Composting Facilities

Table 5.3 shows the mix of different categories of composting sites in the UK in 1999. The bulk of material composted is handled through centralised large-scale sites. Of the totals, 92% of sites were located, and 92% of tonnage was processed in England.

Table 5.3 **UK Composting Operations**

Site Type	Number of Operators	Number of Sites	Amount Composted (Tonnes)
Centralised	62	80	765,155
On-Farm	18	65	66,401
Community	10	52	1,488
Total	90	197	833,044

Centralised composting sites bring materials onto a central site, and either distribute product or utilise it on-site.

On-farm sites are small-scale waste management licence exempt sites processing a mixture of on-site farm waste and materials brought onto site.

Community sites are licence exempt sites processing locally collected materials, and run by community groups or related not for profit organisations.

Source: The Composting Association, The State of Composting 1999

Factors affecting Composting

The efficiency and effectiveness of composting is affected by a large number of interacting factors, which must be manipulated to maximise the activity of the bacterial agents responsible for primary breakdown of the material. These include:

- Oxygen availability, (optimally between 10 - 18%)
- Aeration
- Carbon : Nitrogen ratio, (25:1 to 30:1)
- Moisture Content (50 - 60%)
- Particle size
- Nutrient availability
- Temperature (55 - 65^{0}C)
- PH (5.5 - 8.0)

The single most important aspect is to ensure oxygen availability (aerobic conditions) and composting methods tend to reflect this, concentrating on how best to transfer oxygen freely to all parts of the composting material. An additional precursor frequently necessary for successful and consistent composting is to blend waste into an appropriate feedstock meeting the optimum criteria listed above.

Composting Methods

The everyday view of composting is a heap of material simply piled up and left to decompose with whatever natural ventilation is available. Under these conditions decomposition will be slow and uneven (the warm interior tending to decompose more quickly than the cool exterior) and nutrient loss can occur, however there is virtually no supervision required, and heap composting is still employed widely in farms. Only 2% of sites covered by the Composting Association's 1999 survey employed static piles with no aeration.

The great majority of large composting facilities in the UK use "windrows", where the material to be processed is formed into elongated triangular prisms, several metres long and wide. Windrows are periodically turned during composting to introduce air into the heaps, release trapped heat and even out the composition of the mass. There is greater operator involvement, and hence running costs are higher than for simple composting, however the system is essentially simple, with little capital requirement, and the consistency of compost produced is greatly improved, an important advantage when trying to market the product.

88% of 1999 UK composters used conventional open-air, mechanically turned windrows, however just under 10% used some form of covered or enclosed mechanically turned windrows or in-vessel technology. Forced aeration can achieve good temperature control and shorter composting times without high labour demand. Since these units are more sophisticated pieces of equipment, inevitably capital costs will be higher than more basic options. For composting to be flexibly and widely applicable to food wastes (such as those falling under the Animal By-Products Regulation) fully enclosed systems will have to be introduced to a far greater degree.

Table 5.4 shows the distribution of different types of composting facilities in the UK in 1999.

Table 5.4

Types of Composting Facilities in the UK		
Process Type	**Number of Sites**	**Tonnes Composted**
Open-air mechanically turned windrow	121	736,529
Covered/ contained mechanically turned windrow	5	35,124
In-vessel	7	32,717
Open-air static pile,no aeration	31	17,348
Other	33	11,326
Total	197	833,044

Source: The Composting Association, The State of Composting 1999

Marketing Compost [55]

Potting "compost" and similar products sold to grow plants in are more correctly called "growing media" (as this covers other materials besides aerobic digestion products). The UK market for growing media has recently been estimated at around 3.6 - 4 million m^3 per annum. Around half of this market is supplied by the island of Ireland, with most of the rest coming from Great Britain and the Baltic states. The majority of this production is dominated by peat based media. Destruction of natural peat resources has drawn criticism from environmentalists, and has resulted in pressure to move to alternative sources of growth media.

The Waste and Resource Action Programme (WRAP) identified 55 producers of green compost (compost derived from green waste), licensed to produce about 1 million tonnes in total, and currently producing about 740 thousand tonnes. Of this about 165 thousand tonnes (300 thousand cubic metres) was suitable for growing media, but only 68 thousand cubic metres was actually sold for that purpose. The Office of the Deputy Prime Minister[56] has produced a somewhat higher estimate of 92 thousand cubic metres, but in either case the figure is only a modest percentage of the total market. This figure is forecast to rise to around 275 cubic metres in the next two to three years or around 8% of total growing medium production.

> " Better geographical integration of green compost supply is needed. "

Competitive pricing and availability of green compost to media manufacturers are critical factors to achieving market penetration. Unfortunately, there is currently a mismatch between the location of composting and media production sites. Most composting sites are located around population centres in the South East of England and the Midlands. Growing media are produced in rural areas, such as Ireland, Cumbria and rural Eastern England. Further market penetration will require better geographical integration of green compost supply.

Green compost is also used as a soil improver (i.e. as an additive to soil rather than a complete growth medium).
This application is attractive since technical requirements are lower, and alternatives to peat are accepted to perform better.

However, the market has already been largely occupied by bark with 70% of market share. While green compost has 15% of this market, this seems unlikely to grow in the near future.

Environmental Aspects of Composting

Composting can provide growth media with a far more acceptable provenance than peat based products, via a simple and natural technology. With suitable support to market development, composting can make a direct contribution to the preservation of primary peat resources and the wildlife supported by them. However, making compost acceptable to growth media markets introduces constraints on what material can be composted.
As discussed above, most of the composting in the UK is carried out as a stabilisation step prior to landfilling.
In addition composting does not recover energy from waste, rather utilising the energy to drive the composting process.

One of the principal breakdown products of composting is carbon dioxide, a recognised contributor to the greenhouse effect. While CO_2 is of considerably less global warming potential than other greenhouse gases, Table 5.5, any large scale process that results in CO_2 emission cannot be considered impact free. Poorly managed (badly aerated) compost heaps may produce the anaerobic decomposition product methane.
Methane has many times the global warming potential of carbon dioxide, although its effects are more transient since it will break down to produce CO_2 in upper atmospheric conditions. Open composting with methane emission can lead to objectionable odours as well as uncontrolled release of a greenhouse gas, and concerns also exist about the risk of airborne bacteria, spores and pathogens.

On balance, it is clear that properly managed composting operations have an important role to play in managing biodegradable wastes arising from food processing and elsewhere.



Table 5.5

Relative Impact of Greenhouse Gases			
Gas	Global Warming Potential (GWP)	Estimated EU emissions from solid waste [57] (Mt)	Global Warming Contribution from solid waste
Carbon dioxide (CO_2)	1	16.1	16
Methane (CH_4)	23	7.3	168
Nitrous oxide (N_2O)	296	0.01	3
Hydrofluorocarbons (HFCs)	12-12,000	-	-
Perfluorocarbons (PFCs)	5,700 - 11,900	-	-
Sulphur hexafluoride (SF_6)	22,200	-	-

Source: Third Assessment IPCC report, 2001

5.5.3 Accelerated Aerobic Digestion

More sophisticated composting methods featuring in vessel aeration and agitation are already used to process a small proportion of the UK compost market (Table 5.4 above). Such methods typically reduce the cycle time for composting to no more than a few weeks.[58] The concept has been extended into a fully enclosed enhanced aerobic digestion method which accelerates the decomposition process to a matter of 48 hours.[59] Initially targeted towards fruit and vegetable wastes, this system is operated as a gate collection service, providing dedicated bins for segregation of waste streams at the producer site. Collected waste is macerated into a liquid feed which is subjected to accelerated aerobic digestion in a three stage process with a high degree of forced aeration and agitation within an enclosed system. The resulting liquid digestate is of high protein content and can be used as a dietary feed for livestock (see capsule).

Meso what? A brief digest of terms

The bacteria responsible for the bio-chemical transformations at the heart of bio-digestion methods are classified by the conditions in which they grow most optimally.

There do not appear to be any strict technical definitions, but the Collins English Dictionary offers the following:

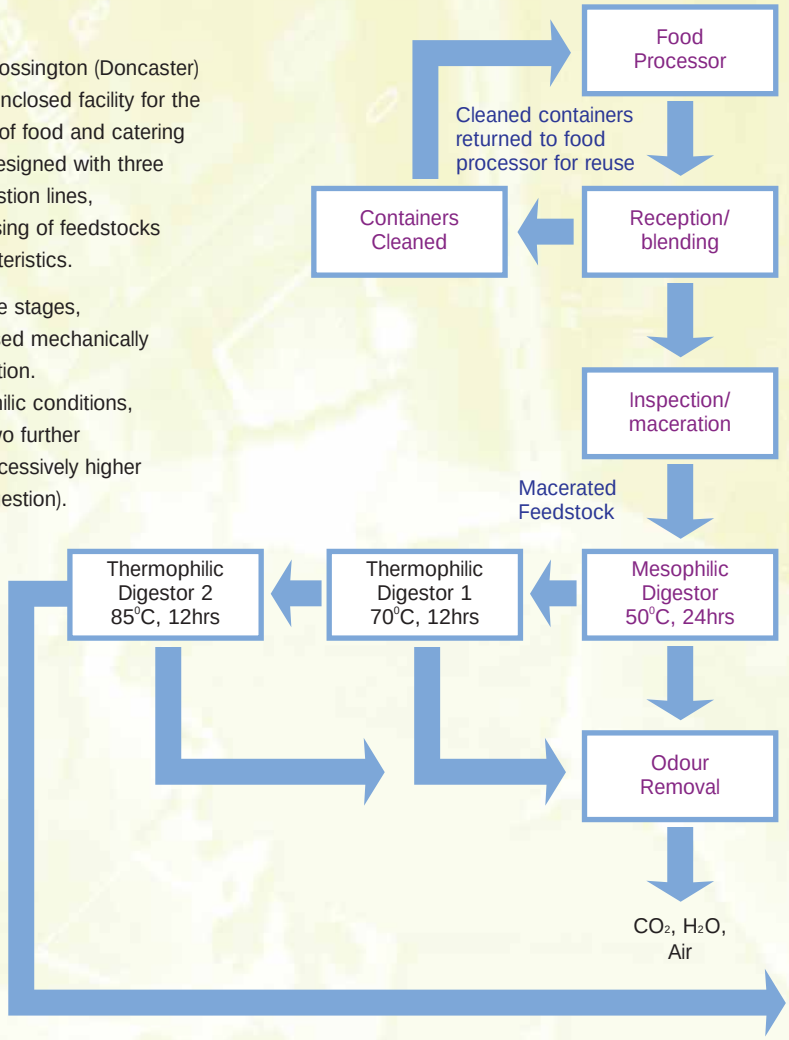
Mesophilic	(Biology) (esp. of bacteria) having an ideal growth temperature of 20-45^{0}C
Thermophilic	Thriving under warm conditions
Aerobic	(of an organism or process) depending on free oxygen or air
Anaerobic	(of an organism or process) requiring the absence of or not dependent on the presence of free oxygen or air.

The pragmatic definition of mesophilic is roughly around body temperature, and thermophilic therefore refers to a temperature regime somewhat above body temperature. The main aerobic digestion technology for organic waste is composting where complex organic matter is broken down with energy release to smaller molecules and carbon dioxide. Anaerobic digestion technologies are sometimes referred to as “biogas technology” because the decomposition process in the absence of oxygen results in the production of a mixed gas stream rich in methane, which can be combusted for energy recovery. Both aerobic and anaerobic digestion can be achieved by meso- orthermophilic organisms.

Tanks and Vessels Limited’s Rossington (Doncaster) site is a 150 tonnes per day, enclosed facility for the accelerated aerobic digestion of food and catering wastes. The plant has been designed with three parallel 50 tonne per day digestion lines, allowing simultaneous processing of feedstocks with different digestion characteristics.

Digestion is carried out in three stages, each taking place in an enclosed mechanically stirred vessel with forced aeration. Stage 1 occurs under mesophilic conditions, with subsequent transfer to two further digesters operating under successively higher temperatures (thermophilic digestion).

The digestion process is autolytic, and therefore no additional energy (other than modest amounts for agitation and aeration) is required to drive the process.



5.5.4 Mechanical and Biological Treatment

Mechanical and Biological Treatment (MBT) is a generic term covering hybrid treatment technologies for the splitting and stabilisation of mixed waste prior to disposal. “MBT by splitting” firstly separates the mixed waste and biologically treats a suitable fraction to a stable state. “MBT by stabilisation” subjects the entire waste stream to biological treatment with subsequent splitting of the stabilised material to various fates as appropriate. These can range from recycling (primarily of metals) and energy recovery through refuse derived fuel (RDF), to landfilling.

MBT is already in extensive use in other European countries, notably Germany and Austria, but like many alternative technologies has made little headway in the UK while landfill has remained cheap and available. This situation is set to change, with at least one major waste management company receiving planning permission for a major MBT facility[60]. MBT is currently being promoted for the handling of residual municipal waste (the mixed waste leftover after other waste minimisation and segregation techniques have been applied). It may well prove to be a useful approach for handling the similar challenges presented by mixed food wastes like combined meat, pastry and metal containers.

5.6 Energy Recovery

The French may live to eat, while the English eat to live, but by eating we all extract energy from food. Organic waste from food production is potentially a plentiful and valuable source of energy. Furthermore technologies exist today to achieve energy recovery from food wastes, some with the potential to provide valuable co-products and closed loop resource recovery.

5.6.1 Combined Heat and Power

Combined heat and power (CHP) is a fuel-efficient technology which yields energy as both electricity and heat from a single plant. The electrical component is typically around a quarter to one half of the total output. The heat energy, which would be lost as dissipated heat in conventional power generation, can be usefully utilised, for example to heat nearby buildings, raising energy recovery efficiency to around 80 - 90%.

CHP can be used to enhance the economics of many approaches to energy recovery. These can be divided into direct and indirect recovery types. Direct recovery burns the waste and recovers heat, indirect recovery involves waste processing to produce a derived fuel. When used in indirect energy recovery routes, the heat can be usefully put to work driving the treatment process, for example to maintain thermophilic anaerobic digestion conditions.

CHP installations vary in size from individual mini-CHP units, used (for example) to provide heat and power in sheltered or social housing developments[61], up to large integrated facilities designed for energy provision to a cluster of industrial users within the vicinity of a power station.[60]

5.6.2 Anaerobic Digestion

Anaerobic digestion (AD) converts biodegradable waste into biogas (predominantly methane and carbon dioxide) in the absence of oxygen. Although utilising natural decomposition routes AD is carried out in an enclosed and highly controlled environment. Energy is subsequently recovered from the biogas by a combination of combustion, turbine and combined heat and power technologies. AD is a well-established large volume technology for the treatment of sewage sludge and cattle slurry on farms, and is widely applied in continental Europe. In Germany for example, WEDA has around 1,400 digesters in operation.[63]

AD has been shown to be capable of handling a wide variety of organic feedstocks, see Table 5.6, however optimum performance is obtained from material which contains high levels of volatile organic solids and less structural content (lignin rich material). Like most recovery processes, the output from AD may be expected to be best characterised when the input feedstock is of reasonably consistent composition and form.

Table 5.6

Food wastes with high energy recovery potential via Anaerobic Digestion	
Feedstock	Sources
Volatile fatty acids - fats and oils	oil mills rendering plants
Proteins - animals and animal products	abattoirs rendering plants
Carbohydrates - sugars and starch	potatoes sugar beet maize

Design and construction of an anaerobic digester requires a sound knowledge of the required duty and operating principles as different types of system will be appropriate for different tasks.

There are two main forms of AD:

Mesophilic digestion - where digestate is maintained at about 30 - 35^{0}C. Typical cycle times for digestion are 15 to 30 days. Mesophilic digestion is relatively robust and tolerant to variations in the feedstock but would tend to require larger digestion tanks for equivalent throughput to a thermophilic process. Since the operating temperature is relatively low, any pathogenic material in the residual digestate is not directly destroyed and may require additional treatment.

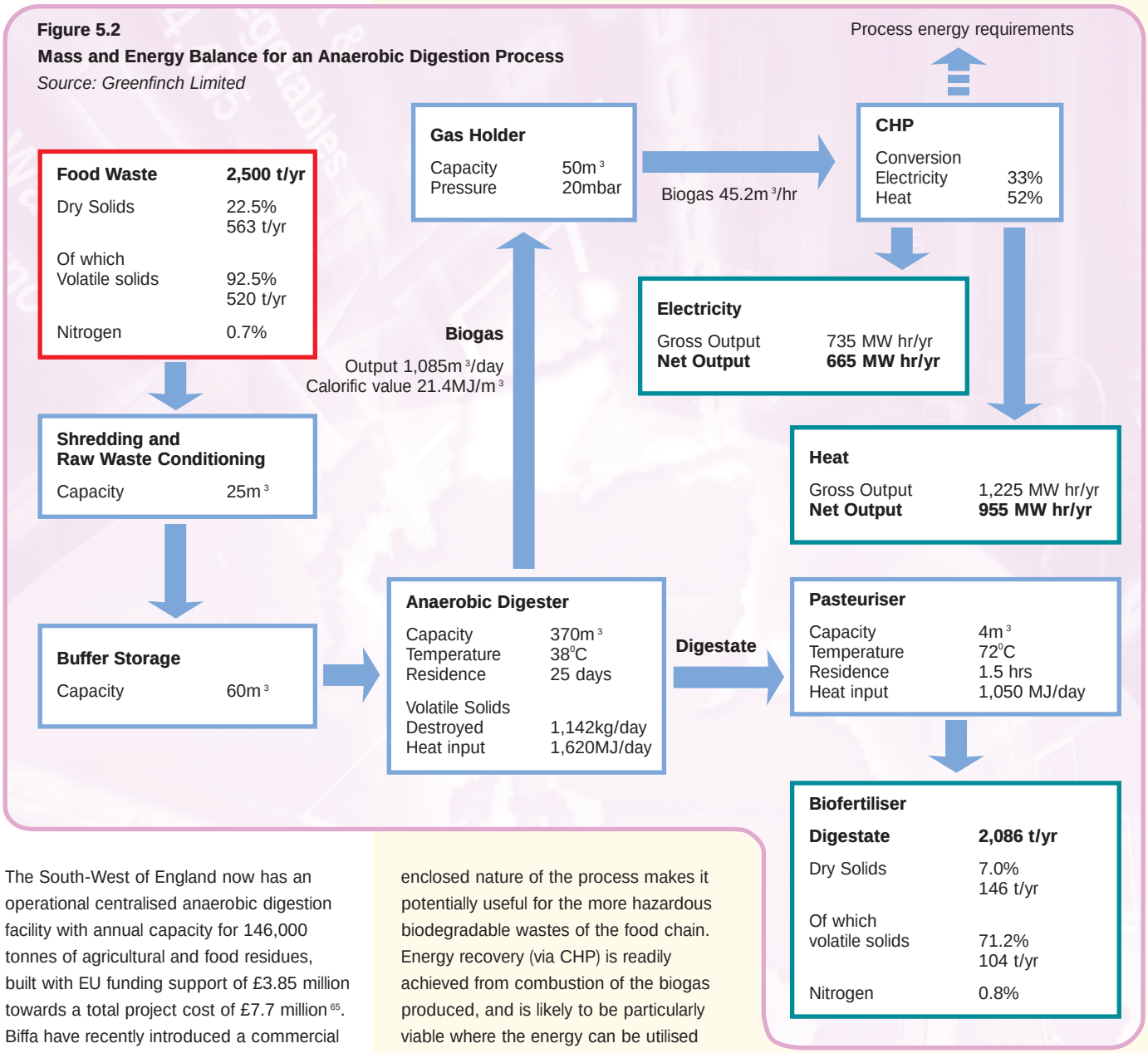
Thermophilic digestion - where digestion is achieved at around 55^{0}C. Residence times are shorter at 12 - 14 days, and therefore vessel dimensions would tend to be smaller than the equivalent mesophilic digester. Elevated temperature operation tends to result in higher methane production and direct pathogen destruction, however the technology is more expensive to install and operate, requiring more intensive monitoring and greater heat input.

Figure 5.2 shows a mass and energy balance for an AD process[64] designed to process 2,500 tonnes per year of household food waste. The energy output per tonne of waste is 648 kW hours.

There is no fundamental size restraint on the scale of anaerobic digestion equipment. Concepts range from domestic in-situ digesters which supplement household utilities supply, to modular units for single factories or farms, and larger facilities positioned at the heart of a regional food or agriculture cluster.

Source:
“Feedstocks for Anaerobic Digestion,” R. Steffen, O. Szolar, and R. Braun. Technical Report, Institute for Agrobiotechnology Tulln, University of Agricultural Sciences, Vienna, 1998.

Figure 5.2
Mass and Energy Balance for an Anaerobic Digestion Process
Source: Greenfinch Limited



The South-West of England now has an operational centralised anaerobic digestion facility with annual capacity for 146,000 tonnes of agricultural and food residues, built with EU funding support of £3.85 million towards a total project cost of £7.7 million[65]. Biffa have recently introduced a commercial scale AD stage as part of a 40,000tpa complete treatment process for municipal waste in Leicester, see Figure 5.3.
Such facilities provides a clear demonstration that the technology needed for energy recovery from food processing wastes is already established if other factors allow it to be applied.

Anaerobic Digestion - Strengths and Weaknesses

Like composting, anaerobic digestion has strengths and weaknesses when considering either its application to a given waste stream, or its overall position in the country's resource management strategy. Its great attraction is as a simultaneous energy recovery and biodegradable waste stabilisation route. These twin goals can be achieved with process plant of low impact on the local environment, and the enclosed nature of the process makes it potentially useful for the more hazardous biodegradable wastes of the food chain. Energy recovery (via CHP) is readily achieved from combustion of the biogas produced, and is likely to be particularly viable where the energy can be utilised back into the process or an adjacent cluster of energy consumers.

However the technology of AD, while not complex in principle, requires greater engineering input in practice than composting, and would be more capital intensive for a given scale of facility.
AD plant typically involves relatively large vessels which can be wholly or partially underground. While this makes for a low profile plant, installation into existing industrial locations would require careful planning and execution.

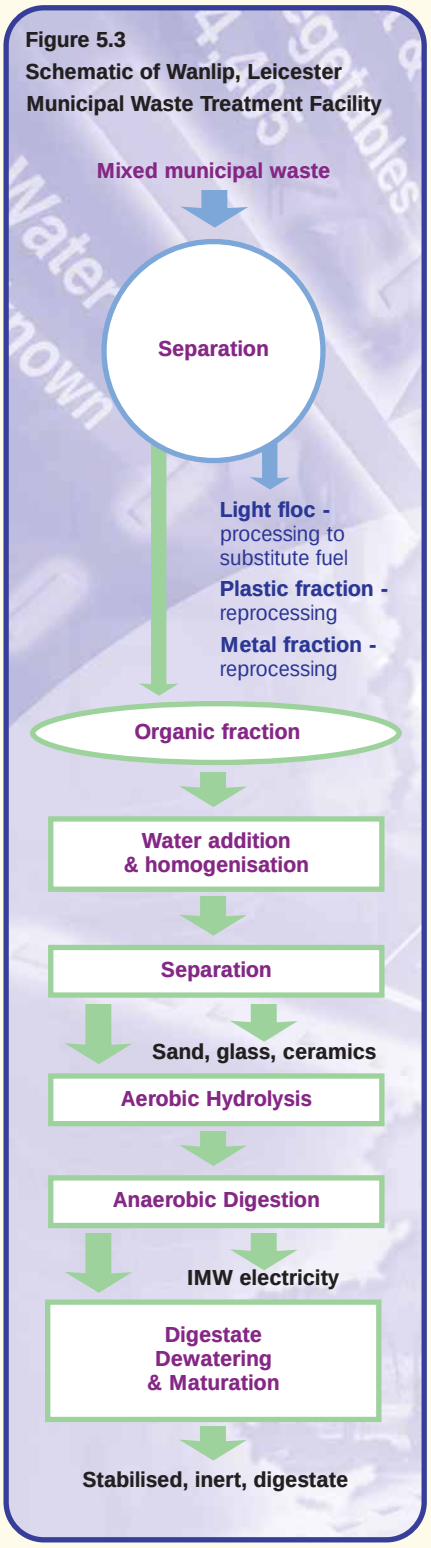
The digestate produced by AD retains a very high proportion of its useful soil nutrients due to the enclosed processing conditions, but it is typically much higher in water content than compost. The marketing of AD digestate needs to be considered in more detail.

Are there high volume markets for liquid products or can dewatering be achieved cost-effectively and sustainably? Ultimately is there sufficient market capacity and value to support an industry of sustainable growth products, be they derived from composting, anaerobic digestion or anything else?

In its typical form, AD results in the production of carbon dioxide after energy recovery from biogas. Smaller amounts of sulphur oxides, etc from the biogas can be readily scrubbed out of the process tail gases. Again the enclosed nature of AD can be advantageous in managing carbon dioxide, as the potential exists to utilise its properties as a horticultural growth accelerator and greatly reduce greenhouse gas emissions (see capsule).

None of the above should be seen as good reasons for not utilising AD for energy recovery. We could and should be doing more of it. However there are considerable barriers to its early adoption by individual businesses, and support from regional and national government in getting the first generation of larger scale demonstrations of the technology successfully running and recognised is crucial to successful wider adoption.

Figure 5.3
Schematic of Wanlip, Leicester Municipal Waste Treatment Facility



AMEC's Waste Research Station [66] has been providing valuable baseline information on the waste reduction, energy and CO_2 recovery characteristics of a variety of feedstocks during mesophilic anaerobic digestion for over two and a half years (see table)

Feedstock	Liquid (% of Feedstock)	Max. Cycle Time[a] (days)	Biogas[b] (m^3 per day per tonne)	Methane[b] (m^3 per day per tonne)	Total Methane[c] (m^3 per tonne)	Residual Solids (%)	Projected Net Value[d] (£/tonne 2010)
Fresh fruit/veg	80	20	7.0	4.2	82	5	95
Food remains	70	20	2.2	1.7	33	5	83
Sewage Sludge	60	28	9.1	5.9	166	10	50
Garden Waste	60	32	4.5	2.7	76	15	47
Animal Fat	33	40	10.0	6.5	260	40	24
Whey	96	18	1.8	1.1	20	1	14
Pig Slurry	90	20	2.0	1.2	24	5	9
Chicken Litter	75	32	4.0	2.6	73	5	7
Cattle Slurry	90	20	1.1	0.6	12	5	7

[a] Cycle time is the maximum duration of the steady state period of a continuous batch digestion most suitable for projecting continuous operating characteristics. This is typically between a quarter and two thirds of the entire batch digestion time.

[b] During steady state period

[c] Obtained from entire digestion

[d] 2010 projections at current values, based on recovered energy value and savings in waste disposal (2010 landfill c.a. £80 per tonne) minus estimated operating costs over a twenty-year lifetime. Whilst no value is currently placed on the inactive nutrient rich digestate, this is likely to change by 2010.

Housed underground within a two storey R&D glasshouse, which enables growth trials to be carried out as part of the complete energy recovery package, the Station has 500m^3 total underground processing capacity in 5 independent experimental cells, each 4m deep. The facility was located with local authority co-operation in a Wirral Green Belt site adjacent to residential areas, and has proved to be not only a low environmental impact waste treatment site, but a well-used educational tool for sustainable approaches, with regular visits from environmental groups, local schools, and universities.

The station combines a simple recirculating digester system with novel aspects such as energy recovery via an efficient turbine system, and intense process monitoring. Backed by the University of Liverpool's Centre for Intelligent Monitoring Systems, its purpose is to establish firm operating data to help clients establish the viability of anaerobic digestion for their waste streams. Typically biodegradable waste can be reduced to

- 72% water at a pH of 8
- 5 - 15% residual mass
- 23% biogas at around 66% methane

Depending on the nature of the input waste, the process yields up to 250m^3 biogas per tonne of waste, resulting in

- 250kWh of electrical energy
- 500kWh of thermal energy
- 500kg of CO_2 (plus about 15% of thermal energy output in clean flue gases).



CO_2 enriched flue gases can be used to promote photosynthesis in horticultural crops, accelerating growth rates and yields by 25%, while minimising CO_2 emissions and returning oxygen to the atmosphere. Thus an anaerobic digestion facility for the food industry could be the springboard for the development of more intensive horticulture, providing valuable inputs back into the food industry.

5.6.3 Biofuels

Production of ethanol (power alcohol) by yeast fermentation could potentially be fed by sugary wastes from food processing. Whilst the technology, essentially a variant on brewing and distillation, is proven and widely practised, particularly in the USA and Brazil, the technique is currently geared towards utilisation of purpose grown energy crops. The first commercial scale facilities for conversion of municipal solid waste to ethanol are currently appearing in the USA[67] and application to similar industrial wastes such as food processing waste is possible in the future.

Waste cooking oils can be used to produce biodiesel, which can be used directly or blended with fossil diesel in conventional diesel engines. Bio-diesel is produced in significant amounts in other European countries, most notably Germany, France and Italy (predominantly produced from oil-seed energy crops), and has substantially lower emissions of greenhouse gases, local pollutants, particulates and sulphur compounds than fossil diesel. Forthcoming limitations on the use of waste cooking oil in animal feedstuffs (banned under the Animal By-products regulations from October 2004) make this an attractive alternative route for a common food processing waste[68].

> "The Biofuels industry continues to lobby for further tax incentives."

British Industrial Plastics and Rix Bio Diesel Limited have developed a 50,000 tonne per annum market for production of biodiesel from waste vegetable oil through a match up of complementary needs and capabilities (Industrial Symbiosis). BIP, facing a decline in their traditional markets, wanted to increase utilisation of their large volume, licensed chemical facility, and had identified bio-diesel production as an opportunity. However BIP had no ready access to reliable sources of the feedstock vegetable oil or, nor a clear route to market until they matched up with Rix.

Rix by contrast had identified sources of vegetable oil and a ready route to market through their fuel distribution business, but would have faced a major capital investment to produce bio-fuel themselves. A 5 year contract from 2002 granting Rix exclusive rights on BIP bio-diesel has saved or created 27 jobs, and will result in the diversion of 56,000 tpa vegetable oil from the waste stream.

Biodiesel is mostly used at present in blended form with fossil diesel at a level of 5% in the blend. Current tax rebates of 20 pence per litre make recycling waste cooking oils to biodiesel just viable, but the bio-fuels industry continues to lobby for further incentives to promote growth of the market.

5.7 Other Options

The range of commercially viable and available minimisation, reuse and recovery options will hopefully increase with time, but ultimately some fraction of waste which cannot be accommodated by other routes will have to disposed of. Even here however, technology exists which can help improve the environmental profile of these options, for example achieving some level of energy recovery or minimising impact on the local environment through better operation.

5.7.1 Rendering[69]

Renderers process most animal by-products from the meat production chain that do not end up on the consumer's plate, dealing with an estimated 1.75 Mtonnes per annum in 25 principal plants. The rendering process is the crushing and grinding of animal by-products, followed by heat treatment to reduce the moisture content and kill micro-organisms. Separation of the melted fat (tallow) from the solid (protein) is achieved through centrifuging (spinning) and pressing. The solid fraction is then ground into a powder, such as meat meal or meat and bone meal. Approximately 250,000 tonnes of fat and 400,000 tonnes of protein meal are produced by rendering annually.

Many waste streams which could potentially be processed for indirect energy, cannot be sent down these routes today because of the legislative framework. Given the constraints of the Animal By-products regulations, for many food producers handling animal derived wastes, or material that has come into contact with animal products, the traditional treatment route of rendering will continue to be a cost-effective option even into the medium term.

5.7.2 Incineration

The public profile of incineration technology has historically been poor in the United Kingdom. Concerns about dioxins, particulate releases, effects on local air quality, and the high visibility of the required



plant (which usually features a prominent exhaust stack) led to the displacement of incineration in favour of landfill in the UK. In more recent times however pro-incineration arguments, deriving from the more positive European experience of the technology have re-emerged.

Incineration, it is argued, is a well established and highly regulated[70] technology for waste treatment, resulting in ash of greatly reduced volume. This material has been subject to a high thermal cycle, and may be used as a secondary aggregate in the construction industry or disposed of once stabilised and reduced in volume. Energy recovery from the heat of incineration may be an attractive option. Energy recovered through heat transfer can be used to generate high pressure steam and hence electricity. With conventional generation, conversion efficiency is around 22%, however using CHP can increase this figure to around 75%. In summary, the technology of incineration has moved on substantially, is widely practiced in other countries and contributes to their much better performance in the diversion of material from landfill.

This argument has apparently received a sympathetic hearing, with approvals for incinerators increasing, and contracts awarded for new facilities, but the debate remains polarised with many planning applications becoming mired in major objections. Opponents remain unconvinced of the efficacy of gas scrubbing treatments and point out these simply result in the production of hazardous waste. If ashes are to be used as aggregates (or even landfilled) risks of hazardous material escaping to the ground are cited. Friends of the Earth[71] and Greenpeace[72] strongly argue against incineration, favouring a combination of waste minimisation, recycling and where necessary stabilisation by other routes notably mechanical and biological treatment (MBT).

5.7.3 Advanced Thermal Treatment

Two methods fall under this banner currently - gasification (high temperature partial oxidation to a gaseous fuel) and pyrolysis (high temperature heat decomposition in the absence of air to a mixture of gaseous and liquid fuels and a stabilised solid residue). Although built on well-established processes from the petro-chemical industry, such methods are commercially unproven on mixed waste streams, and have generally been utilised to deal with relatively uniform waste streams such as plastics and rubber tyres. Many of the previous comments about incinerators concerning regulatory requirements and public perception could equally well be applied to ATT routes, although equipment is inherently more compact.

For further information on advanced aspects of thermal waste treatments and their relationship with improved incineration technology the reader is directed to specialist expertise such as Sheffield University's Waste Incineration Centre. [73]

5.7.4 Landfill

Landfill is the UK's predominant route for waste management, handling 80% of municipal waste and 50% of industrial waste. This report has shown that the food processing industry is no exception to this general pattern. The UK's position is not typical of the rest of Europe where historically incineration has been more widely practiced and landfill levels are therefore generally lower. Our obligation to comply with the EU Landfill Directive, and the need to comply with IPPC requirements for landfill sites will clearly lead to a fundamental change in the way landfill is carried out in this country, but this does not mean that landfill will cease to exist as an option to be considered.

Well designed and managed landfills handling only stabilised, residual material that cannot be recovered via other routes can be a sound disposal choice. Measures such as sub-dividing sites into cells can facilitate improved levels of control over the integrity of the site, and allow reasonably efficient recovery of resources such as landfill gas. [74] Energy recovery from landfill methane can help to mitigate landfill contributions to greenhouse gases, although in the future it would be anticipated that the biodegradable material from which the gases derive should not be in the landfill site in the first place.

Like incineration however, the debate over landfill is polarised and well-rehearsed. Every positive previously mentioned can be countered with an environmental downside. Providing landfill space does nothing to promote waste minimisation and arguments on the basis of the consequences of site mismanagement are impossible to absolutely refute. However the landfill industry now operates in a more closely monitored and licenced environment than ever before and this is not likely to decrease in the future. What will increase is the expectation that other routes will have been taken before landfill is used in future, and that what does go to landfill has been minimised and rendered compliant with strict acceptance criteria prior to disposal.

There are many options for handling the food industry's waste, and each has its strengths and weaknesses. Established routes are either rendered unsuitable or increasingly unavailable by policy and legislative changes, or face widespread public opposition to further expansion. For many emerging technologies the weaknesses centre on the lack of available, proven, large-scale facilities, and a lack of risk takers with suitable capital funding to establish such facilities. At the time of writing government encouragement to the development of new approaches to sustainable treatment of biodegradable waste as part of the delivery package on the National Waste Strategy 2000 has recently been announced in the form of a £30 million new technologies demonstrator programme from DEFRA. This programme is intended to support at least 10 demonstrator plants by the end of 2006, but its scope is limited to biodegradable municipal waste. While the similarities of BMW to biodegradable food processing waste are evident, it is a matter of current concern to those seeking to develop innovative technologies for the industrial waste sector that no specific support appears to be earmarked in this area. For further reading in this area, the DEFRA strategy unit web-site is suggested as a starting point. [75]





6 Advances in Food Processing Technology

This chapter considers R&D in food and drink topics in two areas. Firstly innovations which provide for enhanced, more efficient and less wasteful processes, and secondly advances in the handling of food waste streams, and in particular routes to realise value from waste streams through conversion to desirable (often non-food) products.
In some of the examples cited, new developments employ groundbreaking advances in science and technology, and thus carry a significant element of development risk before they are employed routinely. In others, the basic technology for new approaches will be well proven, and non-technical drivers will dominate successful adoption.

6.1 Sources of Expertise in Advanced Food Processing

Innovative activity in food processing technology and related topics is dispersed through a plethora of academic and private sector research organisations in the UK and elsewhere, and it is beyond the scope of this report to provide a comprehensive list of contacts and activities. Specialist food research organisations and associations tend to be well known in the industry, but individual departments within large universities may have strong interests in advanced food processing as part of a suite of activities. Identifying and accessing expertise and common interest in specific areas is increasingly being made possible through a variety of virtual organisations, networks and partnership initiatives.

Since 1997, the DTI has fostered better collaborative links between industry and the academic and industrial knowledge base through Faraday Partnerships [76]. The partnerships exist to encourage and facilitate activities which will more effectively transfer technological novelty into industrial application. Faraday Partnerships aim to help potential participants meet, exchange needs and ideas, formulate projects, identify funding routes and deliver successful projects.

There are currently 24 Faraday Partnerships in existence, several of which have aspects of food, waste and environmental technologies within their remit. The Food Processing Faraday Partnership [77] exists to promote research into fundamental aspects of food processing leading to new industrial applications. Areas of particular relevance are the solving of fundamental process problems, the development of key proof-of-principle research projects to provide the basis for investment in new process and plant technologies, and provision of totally new technologies.

The Mini-Waste Faraday Partnership [78] focuses on waste minimisation through the application of novel processes and technology. Mini-Waste is a cross-sector Faraday Partnership, with food processing as one of the core sectors from which its membership is drawn. The University of Birmingham is a core partner of both the Food Processing and Mini-Waste Faraday Partnerships and has strong involvement with the food industry through its Schools of Engineering and Biosciences. Food process related research is conducted as part of the Formulation Engineering Research Centre, relating chemical engineering principles to food processing applications.

> "Identifying expertise is increasingly being made possible through a variety of virtual organisations, networks and partnership initiatives."

The Institute of Food Research in Norwich is a major publicly funded integrated provider of independent basic and strategic research in food safety, nutrition and food materials science. IFR has extensive national and international collaborative links fostered through a wide programme of research activities and participation in knowledge networks. IFR operates a Food and Health Network incorporating four expertise clusters including waste upgrade.

The Central Science Laboratory (CSL) provides underpinning research in food safety and quality [79], covering advances in cellular and molecular biology, consumer protection techniques, environmental contaminants and trace elements, microbiology, food packaging, and additives. Specific topics include methods to identify changes in chemical composition of food materials, the nutritional role of trace elements, identification of environmental contaminants in foodstuffs, mechanisms of formation of food contaminants, and interactions of food and packaging.

Independent membership-based organisations like Leatherhead Food International [80] and The Campden and Chorleywood Food Research Association [81] (CCFRA) provide R&D services and technical and market information to client organisations ranging from Government to individual companies.

Research activities can be gauged through publicly funded and disseminated programmes. In recent years DEFRA has encouraged innovative approaches to food manufacturing through the Advanced Food Manufacturing Link Programme [82], part of the wider activities of FoodLINK [83]. The LINK mechanism exists to accelerate the commercial exploitation of Government sponsored collaborative research with commercial promise. The AFM Link programme particularly aims to improve process design, process capabilities and operational efficiency through better diagnostics and control.



Individual institutions may provide "industry-facing" services, often geared to promote regional links and activity, such as the Food Technology Centre at the University of Teesside. Imperial College, also a core partner in the Mini-Waste Faraday Partnership, now incorporates the former Wye College as its Department of Agricultural Sciences. The Wye campus hosts an interdisciplinary Centre for Food Chain Research, drawing on expertise in animal sciences, consumer behaviour, economics, environmental chemistry, genetics, management, marketing, microbiology and plant sciences.

The School of Food Biosciences at the University of Reading has strong links with the Food Industry operating two industry-focused units. Food Industry Training - Reading, provides up-dating and training courses for food industry professionals, and Food Knowledge and Know-how, which offers a multi-faceted consulting service to smaller food companies.

6.2 A Taste of Things to Come

Just as a comprehensive list of research expertise is beyond the scope of this document, so too is an in-depth evaluation of R&D in food technology. However the following examples will hopefully provide a flavour of the emerging possibilities in food processing which can contribute directly or indirectly to waste minimisation.

6.2.1 Enhanced Food Processing

Maintaining cleanliness and hygiene is a universal challenge in food processing. This is reflected in projects dealing with surface modification to improve cleanability and hygiene status [84], electrostatic fogging for disinfection of vertical and underside surfaces [85], cleaning in place [86], cleaning of heat exchange surfaces [87]. Ice pigging [88], is a line cleaning technology based on a semi-solid pumpable ice with advantages over conventional projectile pigging.

An alternative approach to line cleaning based on a highly concerted and controlled airflow has been developed to commercial availability by Whirlwind by Air [89].

Better food cutting systems for, improved yields, reduced costs, and better reliability are promised by research into fracture technologies [90]. This offers a better understanding of crack production and propagation through foods and applies novel sensing devices to monitor the efficiency of cutting. Flour milling has been subject to similar process modelling [91].
Other researchers seeking to achieve a higher level of mechanistic understanding in operations traditionally relying on know-how are looking to improve fermentation processes using multivariate statistical analysis [92] to better understand critical operating and develop predictive models for optimum process operation.

Better utilisation of raw materials can be realised by better extraction and separation systems, such as a method of separating raw seafood meat attached to crustacean shells [93]. New filtration technology offers the potential for greater efficiency and lower product losses than traditional methods in any application that utilises large volumes of process water [94], for example whisky manufacturing [95]. Separation treatments for effluents such as nanofiltration and reverse osmosis are commercially available and receiving research attention for better understanding of their operating characteristics in food applications [96].



Liquid foodstuffs tend to have awkward handling properties, in particular during heat transfer operations. During heating and cooling, skins, and build-ups can lead to reduced heat transfer efficiency, off-flavours, poor appearance, and line blockages. Improved heat exchangers [97] for high and non-constant viscosity food processing fluids can help eliminate these problems.

Ohmic heating utilises the electrical resistance of fluids to impart heat directly to the fluid by application of an alternating electric field. Since heat is generated directly in the fluid medium, there are no heat transfer gradients or hot spots, and the technique is particularly applicable to viscous liquids and slurries, and shear sensitive fluids. [98]

Awkward powder, solid or mixed phase processing challenges can be addressed by innovative processing techniques such as magnetically stabilised fluidised bed reactors (in enzymatic food processing applications such as brewing).
These provide more effective contact of fluid and enzyme substrates than packed columns, however they can suffer from bed stability problems. Where the fluid bed contains particles with magnetic characteristics, the application of an external magnetic field can help overcome these problems, leading to enhanced process throughput and yield. [99]

Electrostatic effects have the potential to enhance traditional food processing applications [100] such as applying flavouring coatings (for example where powder coatings can be persuaded to stick onto crisps) and separation of granary streams.

Alternative heating technologies for heating and cooking such as radio frequency (RF) [101] and microwave processing [102] - sometimes referred to collectively as dielectric heating - can offer more features such as more uniform, faster cooking cycles than conventional ovens. Microwaves are of course well known domestically and commercially, but in many industrial scale operations RF has advantages, such as better uniformity and depth penetration, [103] although microwaves are capable of higher power densities and are less capital intensive pieces of equipment.
RF heating is a well established technology for certain applications, such as post-baking of biscuits [104] and cereals. It is intrinsically self-levelling as more energy is dissipated in moist areas than dry ones, a property highly desirable in applications where drying is carried out to near completion. [105]

Radiative infrared (IR) and near infrared (NIR) heating, often in combination with convective or other conventional heating mechanisms has long been considered for applications such as industrial drying of low moisture content products, baking [106] and frying [107] (where contaminated fat raises concerns about product quality, nutritional value and effluent issues).





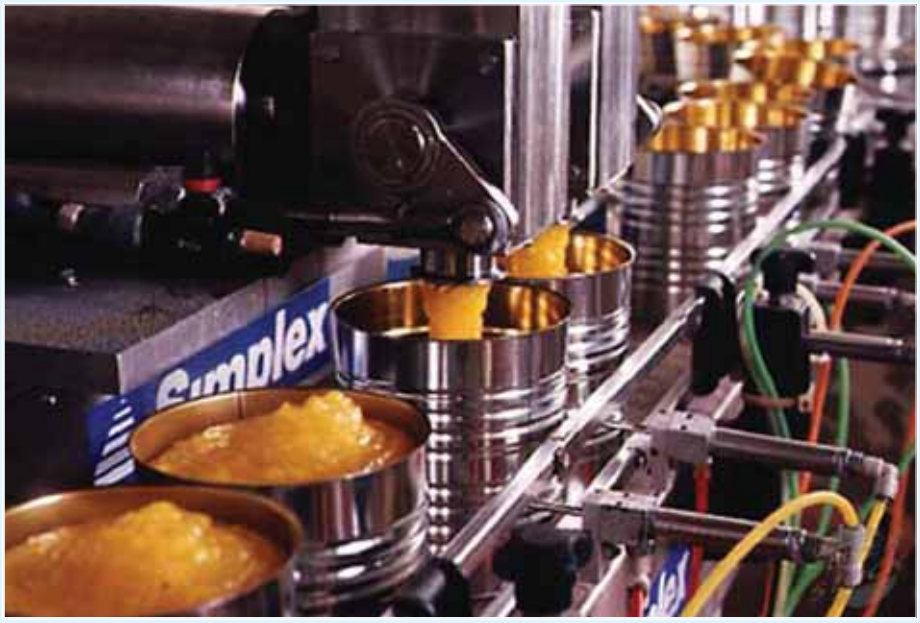


More recently the method has received significant attention in Asia, where it has been applied to production of fish products [108], and rice and potato [109] processing.



Freezing and chilling operations can be achieved more rapidly and controllably than with conventional air blast technology using techniques like cryogenic freezing [110], and fluidised bed freezing [111].
Bacterial reduction and stabilisation of foodstuffs for extended lifetime can be achieved by a variety of means, such as RF and microwave heating, application of ozone [112], UV surface decontamination [113], high pressure treatment [114], ohmic heating [115], and pulsed electric fields [116]. Such techniques can avoid wastage occurring in purely thermal pasteurisation or sterilisation.

Process automation can often provide a means of waste avoidance through the avoidance of human error. Examples include automatic tracking and handling of meat cuts [117], robotic cutting of hot and chilled pork [118] automated transport, dispensing and placement of ingredients for sandwich and pizza production [119] and automated sandwich assembly and packaging [120].
A related topic to automation is that of better process monitoring, where innovative approaches can be brought to bear to achieve for example better measurement and control of temperature [121], combined temperature-humidity profile in tunnel ovens [122], and powder purity [123].



Shortcomings in forecasting and scheduling is often cited by food processors as an important root cause of processing wastes, resulting in product being produced and no longer required. The UK Foresight programme [124] has identified the potential of seasonal weather forecasting for the food chain to enhance business decision making when mapping out resource planning on a six month horizon.

Alternative materials for food packaging have received considerable attention. Problematic mixed plastic/foodstuff wastes may in future be avoided by, for example, the use of biodegradable starch based material for food packaging [125]. An EU funded collaborative programme has provided a useful and extensive review of activities in this area [126].

Awkward wastes such as fats, oils, grease, sugar and starch often present problems when they accumulate in drainage and effluent systems. Bioremediation using the injection of vegetative bacteria into pipework can routinely digest blockages to carbon dioxide and water [127].





6.2.2 Added Value Products from Food Wastes

The Institute of Food Research is researching methods of utilising plant based co-product material, a sizeable component of wastes arising from food processing. Research effort is focused on approaches to deconstruct cereal and vegetable cell-wall structures using physical and bio-chemical methods. Achievements to date include exploiting cereal- and vegetable-based wastes to produce compounds with inherent value such as ferulic acid, vanillin, and caffeic acid.

The technology for life support systems for long term manned space missions may seem an unlikely source of ideas for food processors, but the concerns of the European Space Agency's MELISSA project - the recovering of food, water and oxygen from waste - have much in common with those seeking to realise value from food chain wastes. MELISSA [128] (Micro-Ecological Life Support Alternative) seeks to apply a variety of microbial technologies to breakdown and manipulate structures in metabolic wastes, and the findings of the programme have already led to terrestrial applications such as the conversion of cashew apple waste into protein-rich animal feedstock, and degradation of lignin structures into cellulosic fibres. Such technology has the potential for application to a wide variety of vegetative by-products such as fruit stones and peelings.



An enzymatic treatment which hydrolyses cocoa shell waste to produce useful flavour concentrates has been disclosed by Nestle [129]. Starchy potato peel waste, may be converted into food-grade binders such as gums and modified starches [130], products with much greater value than animal feeds.

Mars. Inc. have developed a method of recovering slaughter wastes from the meat industry for use in pet foods which over-comes problems of variable water, fat and protein content [131]. A Japanese group have identified how outer layer onion waste can be a useful source of health food ingredients [132], providing a utilisation route for material normally discarded due to inferior flavour in conventional cooking.

A joint-venture collaboration between a spin-out company from Queen's University Belfast and a US-based partner is seeking to commercialise products derived from egg-shell waste [133]. Potential applications include cosmetics, bio-medical devices, and food industry additives such as texturisers for ice-cream. A variety of European funded projects aimed towards realising value from biological materials through non-food product applications have been carried out in recent years. [134]

Technology developed by the United States Department of Agriculture's Agricultural Research Service [132] is being exploited in a Missouri based facility which converts waste poultry feathers into a fibre suitable for mixing with natural and synthetic co-fibres for use in a range of products including filters, absorbent pads and wipes, nappies, insulation and upholstery padding. The de-feathered quills can be processed into plastic or fibreglass substitutes or can be used as a protein source for added value products such as shampoos, cosmetics and dietary supplements. Other potential applications for added value products derived from feather waste include extraction of insect pest attracting chemicals (for application in horticulture) [136], or as as part of composite materials such as MDF [137] or microprocessor chips [138].

6.2.3 Other Waste Related R&D

Vermiculture - worm farming - has the potential to be a solution to one of the big problems for food processors - mixed food and packaging waste. Lack of cost effective routes for separation of food contaminated packaging materials is a barrier to successful recovery of these materials, and also prevents bio-treatment of the organic food fraction with which it is contaminated. In vermiculture, the action of earthworms on mixed waste as they consume it can be to "clear the plate" so to speak, leading to treated organic waste in the form of worm castings, and a thoroughly clean non-food fraction. A collaborative research effort carried out at the Worm Research Centre [139], involving the Open University and Urban Mines Limited has evaluated large scale outdoor vermicomposting as a treatment route for food waste, using potato slurry as a model feedstock. This work has characterised both technical - including optimised operating conditions and greenhouse gas emissions - and economic aspects of vermiculture as a potential waste treatment. Gates fees in the range £23 - £34 per tonne of waste were estimated. Other considerations include the footprint necessary for a large scale plant, as worm beds cannot be made too deep.

A variety of approaches to wastewater treatment have emerged, and novel technologies based on bio-treatments continue to appear. Dairy and winery wastewater can be treated by a moving bed biofilm for COD removal, [140] [141] and the potential use of water hyacinth for



> "Better managed information related to resource flows is vital."

the same purpose has been demonstrated at laboratory scale [142]. On a larger scale, a variety of high organic loading waste and effluent challenges have been addressed by the application of ecological principles, by re-creating the conditions of pond, wetland, soil and woodland ecology [143]. Projects of relevance to the food and drink industry include fish food water and waste treatment using pond, wetlands and a willow soakway, and treatment of distillery pot ale solids and effluent.

While waste minimisation is an important consideration for food processors, it cannot be achieved at the price of compromised product quality. Dutch researchers have recently studied the impact of water recycling on the quality of potato products [144] where accumulation of salt (chloride ions) is a factor influencing product acceptability.

Researchers at the University of Massachusetts, Amherst have recently published findings which may provide a means of direct electricity generation from sugary wastes via a microbial route [145]. *Rhodoferax ferriducens*, breaks down sugars by stripping them of electrons, a process which may be harnessed to a fuel cell to generate a current. The new work indicated 83% stripping of available electrons in the current work compared with 10% for other bacteria.

In addition to the large body of research and technical development activity which food waste is inspiring, the vital nature of better managed information relating to resource flows should not be overlooked. A project funded under the auspices of Biffaward, and led by researchers at the University of Surrey has addressed this issue from the perspective of identifying what is need to enable industry to meet producer responsibility obligations as exemplified by European legislation for priority waste streams, including packaging.

The PRO project [146] considered aspects such as compliance data provision, how data is to be obtained, and formats for data presentation in order to develop a generic framework for data collection and reporting. Consultation with key stakeholders resulted in a draft framework built around three key parameters - resources, products and processes, and the development of a demonstration version of a proposed resource flow management software tool known as REMAT. This tool is structured to import data from external sources, map and validate data, and provide trend and compliance output in accordance with recognised formats. Stakeholder consultation confirmed that the outline tool and methodology would satisfy current and anticipated compliance reporting requirements, but furthermore identified the potential for conferring internal business benefits - including enhanced business efficiency and waste reduction - through the analysis process.



7 Conclusions

The food and drink processing industry is literally and figuratively part of the lifeblood of the UK. Processors and manufacturers are the primary consumers of UK agricultural output and the industry is an important source of employment, particularly in areas of the country where the impact of recent growth activities, like the service economy, has been least felt.

The physical well-being of our nation is closely linked to the commitment of food and drink manufacturers to provide wholesome products of attractive cost and quality. Important export markets like that for Scotch Whisky make a strong contribution to the UK balance of trade, and increase the global profile of our nation. As the spate of food scares in the past decade have shown, it is vital that the food chain is able to demonstrate its integrity and commitment to the best possible health, safety and environmental practices.

This study has shown that the UK's food and drinks output of 59 million tonnes is produced with an accompanying external waste stream of just over 5.8 million tonnes, or about 10% of output. Given that the industry relies on natural (and therefore variable) inputs, with an inherently inedible fraction, this is in some ways a remarkable achievement. This is in part the result of many years of striving to maximise product yields, and partly due to the highly interdependent nature of the sector, where by-products from one area are frequently reused elsewhere. The mass balance suggests that around a further 3.4 million tonnes of wastes were reutilised within the food and drinks processing sector in 1999.

However waste is a challenge which the food and drink processing industry needs to address with some urgency. The measures introduced to mitigate the effects of BSE have resulted in the closure of some significant reuse routes for animal by-products, and other materials such as uncooked dough and pastry wastes are also no longer allowed to re-enter the food chain. In the interim, these materials are being forced, after undergoing thermal treatment, to the UK's primary waste management destination, landfill. However the long term theme of EU policy, enacted through UK legislation is to minimise landfill wherever possible.

> " The industry needs to address waste with some urgency. "

Waste Minimisation

In common with most industries, food and drink processors strive constantly to operate as productively as possible. Within the overall mix of yield, volume, costs and effective utilisation of assets, the minimisation of waste at source must be more visible and explicit. This requires a better understanding of the full impact of waste on an organisation, taking into account the time and focus which handling waste steals from more important tasks, as well as the headline costs of waste disposal. In preparing this report it has been apparent that even this basic level of information is not always readily available, and waste is simply not a top priority for many food processors. As landfill disposal prices become increasingly punitive this will surely have to change. The organisations featured in case studies in this report are already trying to face the future. Best practice initiatives have successfully impacted on waste in local operations and across larger firms, but managers find it difficult to justify the risks of new technological approaches to senior decision makers.

> " Processors strive to operate productively, but for many waste is simply not a top priority. "

A further difficulty encountered is a fairly high degree of uncertainty over how specific wastes streams will be affected by legislative changes, and how legislative instruments will be enforced. Attitudes vary from a lack of awareness (typically in smaller organisations), through uncertainty over specific cases, up to co-ordinated lobbying for particular interests. Common interest groups, industry bodies and regional and national government agencies must strive wherever possible to communicate these important issues to enable sound decisions to be made.

Reuse and Recycling
A wide range of alternative treatment routes exist for or could be applied to food processing wastes. Biodegradable food processing waste has much in common with sewage, agricultural organic waste, and commercial food waste. Technology transferred from other industries can be adapted to handle food processing wastes.

The composting industry has developed greatly in recent years, both in technological improvements to traditional methods, and in the understanding of the market for growth media. Composting remains in essence a simple, low capital route to convert organic waste streams into a potentially commercial product, and advances in the technology allow for enclosed systems and accelerated decomposition rates, which can help composters comply with waste handling legislation and reduce local environmental impact. It should however be recognised that composting does not provide energy recovery from waste and results in the emission of carbon dioxide.

Land spreading has been an important element of waste management for food processors and clearly will remain so for straightforward non-animal organic material which can benefit the soil. However the BSE related restrictions on animal by-products re-entering the food chain has blocked this option for possibly more than 300,000 tonnes of animal and mixed waste per annum. There is a need for sustainable approaches which can stabilise and make safe such material and ideally recover value from it - most probably in the form of energy. In the meantime treatment routes like rendering present the most readily available holding solution for producers.

Energy Recovery
Energy is the most obvious form of recoverable value from food processing waste, however food wastes are typically too moist to recover energy easily by thermal means. Anaerobic Digestion (AD) has great potential as a recovery route for energy from food wastes. The technology has an established track record in the treatment of sewage sludge, and the UK possesses several centres of expertise in the technology required to adapt AD methods for the requirements of the food processing industry.

> " Energy is the most obvious form of recovery from food waste. "

AD equipment is necessarily enclosed, making it suitable for handling Category 3 animal by-products. The nature of the technology ensures demonstrable consistency of treatment cycle for wastes, with no short-circuiting of the treatment possible. Thermophilic AD can provide faster treatment rates and a degree of thermal treatment for microbiological safety. Other thermal treatment techniques such as ohmic heating can easily be combined with AD to provide consistent and thorough pre- or post treatment pathogen kill.

The profile of AD as a recovery option does not appear to be as high as composting. The distinction between AD - a bio-stabilisation and energy recovery route - and composting - which does not recover energy - is not one that is universally appreciated by stakeholders. On more than one occasion during research for this report, interested parties referred to composting and digestion as if synonymous. This is an example of the kind of understanding gap which knowledge transfer activities must address if sound resource management strategies are to be made at local and national level.

On-Site and Centralised Processing
The decision whether to process wastes on-site or in centralised facilities is, rather like the question of what is the best waste management option, not one with a single definitive answer. The nature, amount, frequency, and regularity of production of a particular waste stream will play a part, as will site location, proximity to compatible inputs and markets for outputs. Factors such as the road miles incurred by a particular strategy need to be given serious consideration when weighing up the options.

> " On-site solutions will be favoured in isolated locations, centralised processing where large scale is more cost-effective. "



On-site solutions will be favoured in geographically isolated locations, or when no particular economies of scale exist and recovered products and energy can be readily utilised, for example using energy to directly drive the process. On-site solutions need to be, if not necessarily simple, certainly robust to operation by non-specialists within the environment of a food processing site. Individual processors are unlikely to be able to make large capital investments in on-site waste recovery facilities without a clear pay-back schedule compatible with the expectations of the industry.

Centralised processing will be preferred where waste can only be cost effectively handled on a larger scale than that of a single factory or where a central location with easy access to the markets for recovered products (or energy) is particularly desirable.

Centralised processing would also make more sense where regional clusters of similar food processing activity (and hence waste streams) can be identified. The nature of large scale centralised operations will require a significant element of collaboration between processors, waste management companies, support agencies and policymakers to bring solutions into place.

In some cases integrated food chain solutions can be envisaged where the stabilised by-products of energy recovery from food processing waste can be reutilised to the benefit of the agricultural or horticultural sector which provides its input. An example of this is the possibility to use carbon dioxide from the combustion of biogas as an aid to horticultural growth.

Whichever route is taken, the use of combined heat and power (CHP) technology can help maximise the efficiency of energy recovery, and tip the feasibility balance in the right direction.

Mixed Waste and Segregation

One feature strongly emerging from the analysis of waste types and from company visits was the challenge presented by mixed general waste. Over a quarter of the total waste (1.89MT) from food and drink processing enumerated by the Environment Agency survey of England and Wales fell into the category of general waste or unidentified mixed waste. Examples encountered include animal and non-animal food wastes being collected in a single skip for disposal, mixed food and packaging waste from quality rejections late in the production process, and food waste becoming mixed with general factory waste.

These and similar practices are carried out because, in the short term, they are expedient. Operators do not have to handle multiple waste storage vessels or make decisions about where to consign various materials, and managers do not have to deal with the complexities of different collections for different wastes. While the costs of simply disposing of all wastes together remains more tolerable than investing in technical and organisational change companies will continue to do what they have always done.

> " While disposal costs are low, companies will do what they have always done. The end result is more mixed waste. "





However producing mixed wastes creates complexities and additional costs when attempting to introduce new recovery methods. The technology of, for example, mechanical and biological treatment can be usefully applied to mixed waste streams, but it would be better to move industry practice to a situation where wastes are more effectively and more universally segregated at source.

Packaging and Other Wastes

Much of this report has focussed on the biodegradable component of food processing waste as this is the largest single category of waste arising from the industry and currently requires new management practices in several aspects. However the mass balance has estimated that the non-food waste streams amounted to 3.9MT. Of the other wastes identified, paper, metals and plastics arising from packaging waste feature strongly. In discussion with food producers, although hard data was not readily available, most packaging wastes arose from rejected packaged product rather than from packaging line failures. Some companies also identified wastes arising from non-reusable packaging arriving with raw materials.

Finally, although outside the scope for detailed study in this report, it should be recognised that many fresh food producers have to deal with product returns from the retail sector. The end result is more mixed waste, in which the energy value of the food and the materials value of the packaging are both made more difficult to realise.

There are undoubtedly prospects for technology which can thoroughly and efficiently separate and clean mixed metal and plastic from organic matter.

What we don't know

Given the importance of the decisions that have to be made in the area of waste minimisation and management, it is important that information about the nature and amounts of waste from food and drink processing - and elsewhere - is kept up to date and communicated effectively. The 1999 Food Wastes survey was a valuable undertaking, and the first of its kind in the UK. However since 1999, as we have outlined in this report, the landscape of viable management options has changed significantly, and also some business practices, and more up to date information is highly desirable. The Environment Agency has recently carried out a new wastes survey in England and Wales, and the results of this major new effort will be a valuable addition to the knowledge base available to decision makers.

> " Information about the nature and amounts of waste must be kept up to date and communicated effectively. "

To the best of our knowledge, no similarly exhaustive data collection has been carried out, nor is planned in other parts of the United Kingdom. It is to be hoped that this gap in our knowledge may be recognised and addressed in Scotland and Northern Ireland.

In Conclusion

In common with much of industry, the food and drink processing industry is having to balance business performance with its impact on the environment through the resources it consumes and the wastes it produces. Our hope is that this report is one highlighting opportunities as well as challenges, and that businesses will be left with the message that good environmental practice can make good business sense.

The very real challenges faced require concerted effort; from legislators and enforcement agencies to create a framework where good resource management practices are promoted without undue burden on companies; from support bodies to help make food and drink processors and waste management companies aware of the options available to them; from support to innovative organisations developing technology solutions for value recovery and waste minimisation; and from food processors themselves being prepared to adopt change and adapt for the future.





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