The European Commission JRC-IPTS and Enterprise DG

The impact of EU regulation
on innovation of European Industry

Regulation and innovation in the recycling industry

An ESTO Project Report

By

Sponsor

F. Leone
DG JRC-IPTS

Editor

C. Greaves
CEST (UK)

Authors

Eva Buchinger, Heinz Fegerl, Erwin Fugger,
Christian Rammer (Austrian Research Centre)
Hugo Verheul, Arnold Tukker (TNO-NL)
Uwe Kuntze (ISI – Fraunhofer-D)

EUR 19623 EN

Contact details:

European Commission DG JRC
Institute for Prospective Technological Studies (IPTS)
Technologies for a Sustainable Development Unit (TSD)
Per Sørup, Head of Unit
Luis Delgado, Head of Sector
W.T.C. Isla de la Cartuja
E-41092 Sevilla

Tel. +34-95 44 88 405
Fax. +34-95 44 88 339

ECSC-EEC-EAEC, Brussels • Luxembourg, 2000

The views expressed in this study do not necessarily reflect those of the European Commission (EC).

Printed in Spain

TABLE OF CONTENTS

EXECUTIVE SUMMARY

ES.1 Project background, objectives and scope

This report have explored the current state of the recycling industry and unresolved questions concerning links between regulation and innovation. Overall objectives can be summarised as follows:

- to define the drivers for recycling across a pre-defined set of industrial sectors;
- to identify and compare the regulatory contexts of recycling activities across different European countries;
- to determining the regulatory barriers to the optimisation of recycling ;
- to evaluate the impact of regulation on technological and organisational innovation under these different conditions (countries and sectors); and
- to develop recommendations on how regulation can promote innovation in recycling.

In essence, the goal was to determine the interplay between regulations and product, organisation and process innovation. The report focuses especially on the latter three objectives listed above. Consultation and industry examples were used to identify and learn from good practice across Europe.

The research covered three distinct sectors:

- electric and electronic equipment
- construction and demolition
- plastics

The lessons learned through consultation and investigation across each sector were consolidated to define generic findings and serve as a basis for recommendations aimed at improving policymaking.

Sections ES.2-ES-4 below summarise the major findings within each of the three sectors listed above. Overall conclusions are presented in ES.5.

ES.2 Electric and electronic equipment

WEEE (waste electric and electronic equipment) recycling activities and innovation has grown significantly over the last decade. Nevertheless the European situation is still characterised by significant regional disparities.

There are many driving forces for innovation in WEEE recycling, with regulation, market forces (consumer demand for “green” products, “green” marketing strategies) and cost cutting opportunities perhaps the most significant. Consumer attitudes, and the desire of companies to have a "green" image, have a more significant role than in other sectors.

Forms of regulation of particular relevance to innovation in WEEE are amongst others:

- The minimisation/ban of hazardous substances product innovation
- Stimulation of collection and sorting of waste (e.g. refrigerators) organisational innovation.

Although innovation directly targeted towards EEE-recycling is rare, examples do exist. These include technological innovations (e.g. advancements in shredding, sorting, identification) and organisational innovations (e.g. establishment of recycling and collection centres). Beyond these, product innovations, such as eco-design, are having a beneficial effect on recycling.

Proposed regulation can lead to innovation. There are several examples of industry stakeholders joining forces in anticipation of new legislation. As well as gathering information and developing solutions, these groupings may form effective negotiating bodies with policymakers. A relatively common outcome of this activity is the development of voluntary / negotiated agreements between industry and government.

ES.3 Construction and Demolition

Relative to the other sectors under consideration, the construction industry is highly fragmented with very heterogeneous waste streams. As a result, the collection and sorting of waste represent particular challenges to recycling.

Several types of regulation affect innovation in construction and demolition waste recycling. Landfill taxation schemes appears to be an effective instrument to support innovation. Landfill bans, on the other hand, are primarily directed to late adopters and laggards, and therefore have a limited effect on innovation. The very large volumes of waste involved mean that the influence of these forms of regulation is greater than in other sectors.

The influence of technical standards is ambivalent. Their recipe-based character may inhibit the use of recycled materials. This could be overcome by the use of standards which are performance-based rather than recipe-based. Also, proper exemption schemes need to be in place to support demonstration projects.

Building and demolition permissions also affect innovation, specifically in the field of selective demolition. Permission procedures increase the demand for speed, which is a barrier to selective demolition.

Governments could utilise their role as dedicated market parties to stimulate construction and demolition waste recycling; similarly, where local and regional governments are given a high degree of discretion in the execution of regulations this would also be of benefit.

Organisational innovation has an important role to play in stimulating progress in recycling in this sector. However, this is hampered by the structure of the industry (as outlined above). Another barrier is the often local character of the construction industry, which renders the diffusion of organisational innovation difficult.

ES.4 Plastics

This phase of the study explored the recycling of plastics in three discrete sectors, each characterised by particular combinations of driving forces. Principle findings are summarised below:

End-of-life vehicles - Important driving forces comprise the increased use of plastic based materials in vehicles, mounting pressure on traditional disposal routes for this material and social support for greater re-use. In response, leading players have joined forces to defend their position.

Electric and electronic equipment - Anticipation of legislation has lead major manufacturers to develop strategies to reduce reliance on third party recycling companies. In at least one instance, delays in the implementation of anticipated regulations has had the effect of counteracting the earlier incentive to innovate. Adaptation of products to better meet the requirements of recycling has increased.

Construction and demolition - Of particular relevance here is the response of the PVC industry to public concern, which involved the establishment of national take-back schemes. Another industry example reveals how little consideration is given to recycling potential in the development of new materials, and highlights to scope for stimulating action in this area as part of a wider innovation process.

More broadly, the research showed how both planned and implemented legislation can be considered as an integral part of innovation in the plastics industry. However, this is by no means a simple relationship, with demand being a critical driver for innovation, and this in turn being affected by a range of other factors, including regulation.

To date, innovation activities have concentrated on improving the potential of mechanical recycling. Other important areas include increasing compatibility between plastics, design for recycling, material reduction, organisational elements and recyclate applications.

A major challenge for the recycling of plastics is to improve the cost/benefit ratio; this requires a change in attitudes towards recycled products. Standards for secondary raw materials could play a useful role here.

ES.5 Overarching findings and recommendations

Recycling is ‘one option among others’ to reduce the negative impacts of different waste streams on the environment. Regulation should therefore not only concentrate on recycling issues but also aiming at designing alternative instruments and options in order to achieve the overall environmental objectives. Such objectives are e.g. waste prevention, reduction of toxic material, ecological efficiency of production and distribution processes, and introduction of environmentally friendly products (e.g. less energy consumption)

The diverse range of findings showed that there is no single paradigm which will stimulate innovation, encourage cost effective and efficient recycling, and be applicable in every case. More specifically, it is not possible to distil simple relationships between individual regulations and specific innovation outcomes.

Notwithstanding this complexity, it was possible to identify specific linkages. These included:

- the anticipation of regulation as a stimulus for recycling;
- the importance of timing (i.e. the negative impact of delays); and
- the value of demonstration projects in reducing risk.

The aspirations and positioning of the various stakeholders around recycling was highlighted, with each being driven by different priorities and this, in turn, having a significant affect on innovation. There were many examples of beneficial collaboration.

Financial considerations are a critical factor influencing innovation in business. Thus, policy mechanisms which adjust the economic framework or market conditions could play an important positive role. This could work in various ways – for example, making the reference technology more expensive or creating a demand for recyclate.

Perceptions of quality have limited demand for recycled materials. Standards for secondary raw materials and quality certification schemes can stimulate confidence and, thus, market demand.

Recommendations to improve policy making covered, amongst others, the following needs in regulation:

- a holistic approach which recognises the variety of drivers for and barriers to innovation, and the complex relationship between them;
- careful and transparent planning of legislation, which is followed through to implementation;
- providing industry with options for flexible response, rather than traditional prescriptive approaches (there are several examples of voluntary agreements working well);
- regulatory certainty;
- early dialogue with stakeholders;
- ensuring the sector specific characteristics (e.g. industry structures, stakeholder relationships, competitive pressures) are recognised and built upon;
- adjusting market conditions, either directly or indirectly, to stimulate innovation in recycling – typically by improving the cost/benefit ratio in favour of recycling;
- applying pressure for innovation where progress can deliver greatest benefit in the most cost effective and efficient manner (an example could be a focus on waste collection and sorting techniques); and
- performance based standards rather than recipe-based standards.

PART 1

INTRODUCTION

1.1 BACKGROUND AND RATIONAL

Over the past few years, there has been a shift in emphasis in European legislation. During the early years, development efforts were dominated by concerns relating to the establishment of a single market, with only secondary consideration given to proper functioning. More recently, links between certain types and aspects of legislation and unemployment and competitiveness problems have been highlighted, and there is a growing emphasis on improving the design of regulation to take account of the full range of costs and benefits. In particular, the Moliter Report, the UNICE and the European Round Table of Industrialists (1996) have claimed that systematic analysis of proposed regulation is needed to ensure greater efficiency.

Against the background of general concern about the impacts of regulation, recent years have also witnessed an interesting debate on the impact of environmental related regulation on the innovative behaviour of companies. On the one hand, it is argued that regulation can have a negative impact on innovation and, consequently, on international industrial competitiveness; on the other, it is suggested that an active regulation policy can offer incentives to foster innovation.

In seeking to resolve this debate, it has been recognised that relatively little research has been done in Europe to identify optimal forms of regulation, or to understand the effects of regulation on the capacity of European industry to innovate. There seems to be a shortage of good existing literature on the analysis of the impact of regulation on innovation.

Environmentally sound waste management and recycling can play a major role in reducing adverse impacts and conserving natural resources. There is, however, one problem with recycling: without other incentives people tend to recycle only when it is economically viable. Thus, recycling will take place if the recycled product can compete with primary raw materials (i.e. there is demand for recycled raw materials). Without markets for secondary raw materials, a major break-through in the area of recycling can be achieved only with the support of a regulatory framework. Against this background, there is considerable support for legislation and other policy levers which encourage recycling.

As part of the European environmental agenda, material recycling is an integral part of waste management in Europe, and likely to be of increasing importance. It also has an important role to play in promoting sustainable development. However, research suggests there are a number of inefficiencies across the range of players involved. In particular, companies involved in recycling often exhibit low levels of technological, organisational and logistic development. There is considerable scope for innovation across these areas to improve performance and increase competitiveness.

1.2 OBJECTIVES

The research forms part of a major European programme examining the links between regulation and innovation across a number of sectors[1]. The project bring together the two strands of concern encompassed by the current state of the recycling industry and the unresolved questions concerning links between regulation and innovation. The overall objectives can be summarised as follows:

- to define the drivers for recycling across a pre-defined set of industrial sectors;
- to identify and compare the regulatory contexts of recycling activities across different European countries;
- to determining the regulatory barriers to the optimisation of recycling ;
- to evaluate the impact of regulation on technological and organisational innovation under these different conditions (countries and sectors); and
- to develop recommendations on how regulation can promote innovation in recycling.

In essence, the goal was to determine the interplay between regulations and product, organisation and process innovation. An underlying aim was to identify and learn from good practice across Europe. This report focuses particularly on the latter three of the five objectives summarised above.

[1] Hemmelskamp, J/Leone, F (ed.) (1998): The Impact of EU-Regulation on Innovation of European Industry", IPTS technical report series, EUR 18111 EN

1.3 SCOPE

1.3.1 Client

Regulation lies at the heart of most of the activities of the EC and DG ENTERPRISE in particular. The main areas of responsibility for DG ENTERPRISE include the administration of Directives (management of some 415 Community measures on products) and other internal Market instruments, as well as the development of new instruments as appropriate. DG ENTERPRISE is particularly interested in developing a greater insight into the links between regulation and innovation, and in identifying ways in which regulation could be improved in this regard.

The project is also relevant to DG ENVIRONMENT, particularly in the context of promoting environmentally sustainable industry and society.

1.3.2 Definitions

In considering recycling, it is worth highlighting a set of principles and definitions which have been developed.

The definition of innovation adopted for this research corresponds to the definition of R, Kemp[2]:

> *"Innovation is novelty: it can be defined as the introduction and use of new techniques, organisational forms, and methods. However, there can be many degrees of novelty, ranging from relatively incremental improvements to existing products and methods, to radically new techniques which imply very substantial changes in activities and outputs."*

Other terms are defined as follows:

- *reuse* means any operation by which a product is used for the same purpose for which it was conceived
- *recovery* is used as a generic term to cover reuse, recycling, incineration with energy recovery, organic recycling
- *recycling* means the reprocessing in a production process of the waste materials for the original purpose or for other purposes including organic recycling but excluding energy recovery; while with *mechanical recycling* the chemical structure of the material remains unchanged, only the shape is changed (examples: plastics, bitumen; synonym for "back-to-polymer recycling"), *feedstock recycling* refers to a process using chemical techniques to recycle materials to raw materials, e.g. crude oil substitute, naphtha substitute etc.
- *energy recovery* means the use of combustible waste as a means to generate energy through direct incineration with or without other waste but with recovery of the heat

[2] Kemp, R./Smith, K./Belcher, G.: "How should we study the relationship between environmental regulations and innovation?" in Hemmelskamp, J. (ed.) (2000): "Environmental Regulation, Innovation and European Industry – Methodological Foundations"

- *organic recycling* means the aerobic (composting) or anaerobic (biomethanization) treatment of the bio-degradable parts of waste (landfill is not considered as a form of organic recycling).

A further distinction can be made between two specific situations where waste arises. On the one hand, it can be derived as part of the production process of materials or goods, where the producing company looses material during the production process. Here the waste is referred to as pre-consumer waste, which reflects the fact that the material has not yet been turned into products for the consumer. By comparison, post-consumer waste consists of products which have been used by a consumer (of whatever form).

Following the Oslo-Manual[3], *innovation* is defined in this report as new or improved products and processes as well as techno-organisational solutions, as far as they are practically applied or have been introduced into the market. *Diffusion* in contrast, signifies the process of the spreading innovations into applications or onto the market. The adoption of new techniques for internal usage within a company (e.g. through the acquisition of machines and equipment) is not denoted as innovation in our context, even though specific situations elsewhere in literature use the term "process innovation".

The definition of innovation adopted for this research corresponds to the originally (Schumpeter) ample application of the term which comprised technical as well as organisational, institutional, social and societal changes. Today, there is renewed acknowledgement that for innovations to be successful there is a need not only for internal technical abilities but also for a multitude of non-technical and external factors.

1.3.3 Coverage

The scope of the two projects can be defined in terms of three key parameters:

- types of regulation;
- types of recycling; and
- forms of innovation.

The regulatory instruments of particular interest are those relating to environmental protection. These can impact on recycling activities in a variety of positive and negative ways. In addition to new instruments which are aimed specifically at improving recycling rates, there are also a variety of other forms of legislation which have indirect effects, particularly those relating to waste management. Both projects cover all types of environmental legislation (including voluntary approaches, such as take-back schemes) which have an impact on recycling.

A particular challenge in the research will be to ensure that the links between regulation and innovation are fully explored. These links are highly complex and can be manifest in a variety of ways, including, for example:

- maintaining levels of openness and competitiveness, which provide the necessary conditions for research and innovation;

---

[3] OECD: Oslo-Manual, Guidelines for Collecting and Interpreting Technological Innovation Data, Paris 2nd edition 1997

- placing technical demands on industries and, thus, acting as focusing mechanisms for research effort;
- ensuring a “level playing field” background against which innovation takes place;
- erecting barriers to the development of new products / processes or improvements of exiting ones; and
- working towards a broad objective of sustainability.

There are a variety of factors which can influence the relationship between regulation and innovation, including institutional contexts (as defined by national and sectoral conditions, and the type of organisation under consideration). Distinctions between European and national legislation are also relevant, particularly in the context of implementation. The projects seek to provide insights into the complex relationships across regulation, innovation and related externalities.

It is possible to distinguish several forms of innovation. For the purposes of this research, and in the context of recycling activities, the boundaries for these are defined as follows:

- products - including new products derived from recycled material
- processes - encompassing collection, sorting, preparation / processing and transformation into new products; and
- organisations - including aspects such as logistics, and taking account of the various types of organisation involved in recycling.

Collection and sorting processes are recognised as weaker elements in the recycling chain and are, therefore, of particular concern.

The recycling sectors of interest for this series of projects are those which are already covered, or likely to be covered, by national or European legislation. To target resources as efficiently as possible, three sectors have been chosen to form the focus of the project. In line with the priorities of the Commission and to provide insights into areas considered to be of particular interest, these are electric and electronic equipment, plastics and construction and demolition waste.

1.4 APPROACH

The project involved four key steps:

- Consultation - Discussions were held with organisations involved in recycling to determine the impact of regulation on innovation in their activities. The emphasis was on providing relevant insights into practical experience, by way of real examples, and in clearly differentiating the role of regulation from other factors which could influence innovation. The full range of relevant organisations were consulted, drawing from experience across Europe. A copy of the consultation proforma developed to guide the process is presented in Appendix 1.
- Industry examples - A number of experts were consulted for more detailed follow-up to elaborate on the material obtained through consultation. The aim of the resultant industry examples was to explore the complex linkages between regulation and innovation, and to highlight areas of good practice.
- Comparative analysis - This brought together the results of the sectoral studies to draw out key findings and generic lessons to be learned.
- development of recommendations - The results of the comparative analysis were analysed and recommendations for improving regulatory provision so as to optimise the potential for innovation were developed.

A list of consultees is presented in Appendix 2

The research built on current and recent relevant activities, such as the study "the evaluation of initiatives to promote and improve the recycling of waste". Consideration was given to the differences between institutional contexts and implementation practices. The coverage was pan-European.

Steps 1 and 2 described above was applied discretely to each of the three sectors covered by the research. The work was undertaken by the following organisations:

- the Austrian Research Centre, Seibersdorf (ARC): electric and electronic equipment
- Fraunhofer-Institut für Systemtechnik und Innovationsforschung (ISI): plastics
- TNO: construction and demolition waste.

Resources available for each of these components of the work comprised 22 days.

Definitions and research guidelines were derived from the overall conventions for the DG ENTERPRISE-IPTS research programme "Impact of EU-Regulation on Innovation in European Industry".[4]

[4] Leone, F.; Hemmelskamp, J. (eds.): The Impact of EU-Regulation on Innovation in European Industry, Sevilla (Institute for Prospective Technological Studies, IPTS) 1998; Kemp, R.; Becher, G.; Smith, K.: Environmental Regulation and Innovation: A Framework for Analysis and Research Guide, January 1999

Following this introduction, the remaining parts of the report are structured as follows:

- Part 2: Recycling of electric and electronic equipment
- Part 3: Recycling of plastics
- Part 4: Recycling of construction and demolition waste
- Part 5: Overview of links and lessons

It is recommended that this report be read in conjunction with the Baseline Report.

1.5 AN OVERVIEW OF DRIVERS FOR INNOVATION

Environmental policy instruments (regulations) often cause changes in the path of technological development - either explicitly when, for example, specific substances are prohibited (e.g. CFC) or implicitly when *new conditions for technical innovations and/or their diffusion* are created. (The latter may arise as a result of new goals (e.g building insulation requirements) or changes in relative costs (through taxes and surcharges.) There will, however, always be a wide range of factors influencing the creation and diffusion of innovations, and this makes it difficult to predict the innovative effect of environmental legislation. This is why a detailed analysis is warranted.

Analyses of innovation processes enable us to identify the critical determinants of innovative activities. These are:

- profitability calculations of the companies,
- politics and regulations,
- autonomous technical development, and
- the environmental awareness of society.

Whereas "politics and regulation" and "environmental awareness of society" are factors determining the demand for environmental technology, "autonomous technical development" points towards the push-component of the competition with innovations. As is being widely acknowledged in the literature about innovation, most innovations are generated and become successful using a combination of push- and pull- components[5].

Beyond these determinants, the ability to innovate and anticipated demand are not, in themselves, sufficient conditions for innovation to occur. Even in situations where there is an anticipated demand because of environmental awareness or regulation, environmental innovations must serve the profitability considerations of the innovating company, and equally importantly, must be able to compete with alternative innovation projects. These profitability calculations are the basic determining factor for all innovation activities of companies.

Meanwhile, environmental innovations are increasingly being used by companies as a business strategy for differentiation and in response to profileration in competition. Especially on largely saturated markets this helps to gain market shares if - and this reservation has been reinforced through recent empirical surveys[6] - price differentials are limited. Among suppliers, in contrast, ecological competition has hardly any role at present. Among them, criteria such as quality, reliability and just-in-time delivery play the key roles.

[5] e.g. Freeman, C.; Soete, L. : The Economics of Industrial Innovation, third edition, London/ Washington (Pinter) 1997; Rogers, E. M.: Diffusion of Innovations, fourth edition, New York, London, et al. (The Free Press) 1995

[6] Umwelt: Eine Information des Bundesumweltministeriums, Heft 9,1996 Bonn

1.6 ACKNOWLEDGEMENTS

The authors wish to thank all consultees (see Appendix 2) for their time and contribution.

PART 2

RECYCLING OF ELECTRIC AND ELECTRONIC EQUIPMENT (EEE)

EVA BUCHINGER, HEINZ FEGERL, ERWIN FUGGER, CHRISTIAN RAMMER (AUSTRIAN RESEARCH CENTRE)

2.1 INTRODUCTION

2.1 Background

The number and diversity of electric and electronic products increased strongly during recent decades, raising the question of how to treat end-of-life EEE in order to minimise negative environmental impacts. Major regulation approaches refer to the elimination of hazardous substances incorporated in EEE-products, and to the reduction of the amount of WEEE through increasing life times of products and promoting recycling and re-use. Some peculiarities in the field of electric and electronic equipment affect, however, the operation of regulation measures and demand specifically designed approaches:

- First, electric and electronic equipment covers a very wide range of different products which have only little common material characteristics and very different life time spans. EEE-products are produced by different groups of industries (with partially little economic and technological interactions), are sold via very different distribution channels and are used by different types of users. *A single regulation addressed to all types of EEE-products has to take into consideration this variety in products, materials used, producers involved and types of users.*
- Second, the EEE-industry is characterised by a high pace of technological change, partly short life cycle times of products, a rapid change in product spectrum and product designs (including the types of materials used), and a high intensity of product innovations (including radical innovations, i.e. the introduction of entirely new appliances). *Thus, regulation oriented on a particular set and design of EEE-products may partially be outdated after a short period of time as a result of product innovations.*
- Third, the production of EEE is highly internationalised. The main producers of EEE are global actors, i.e. they do not produce for a certain national market but for the world market. A high share of EEE-products consumed in a particular country is produced in other countries. *Regulation should take into consideration this international organisation of production, including the differences in production conditions.*
- Fourth, the global production of EEE-products, the local distribution of these products to consumers, the collection of end-of-life EEE and the recycling of WEEE forms a complex system. Effective recycling of WEEE demands the co-ordination of activities in these subsystems, including the co-ordination of material, knowledge and financial flows within the system. Changes to this system in order to improve recycling of WEEE requires simultaneous organisational innovations by several actors (i.e. a systemic innovation). *Regulation should therefore avoid to focus on only one or two subsystems (and their interactions) but design regulatory measures in such a way that systemic innovation will be stimulated.*

2.2 Structure of Part 2

This Part of the report has the following structure: Section 2.2. characterises the "system of EEE-recycling" and the main stakeholders within this system. In Section 2.3 the driving forces for (and the barriers to) recycling of end-of-life EEE are summarised. Sections 2.2 and 2.3 mainly use results of the baseline report (part 1 of the study). In

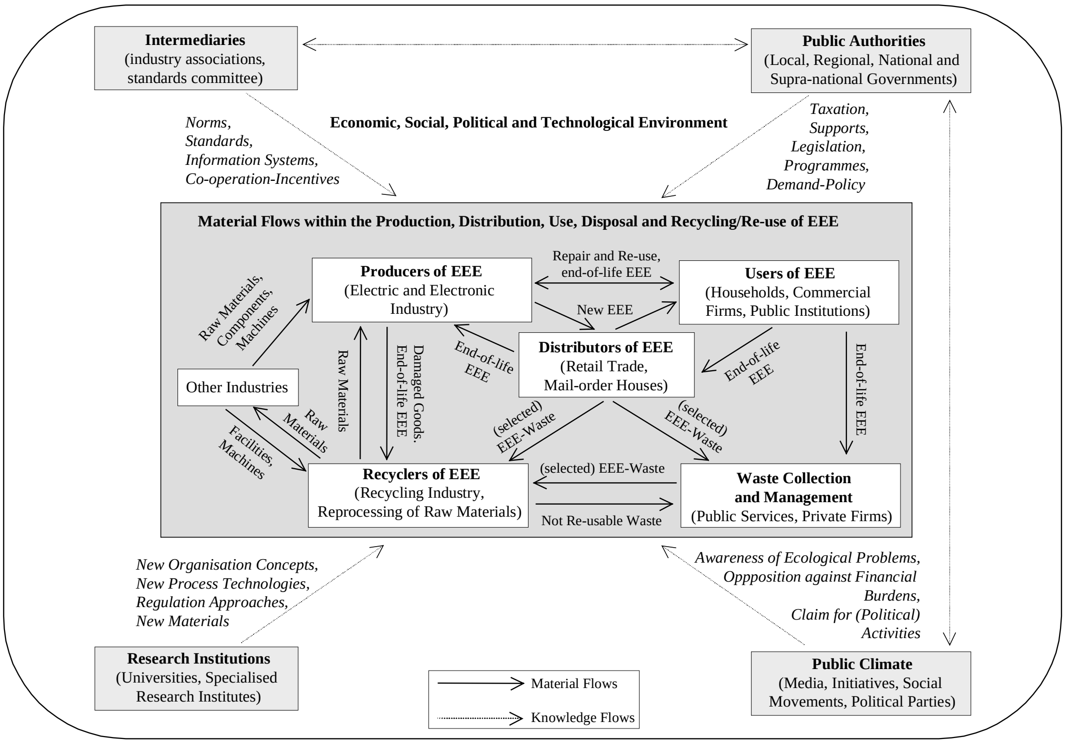
Section 2.4 the research questions mentioned above are answered. This chapter deals with the links between regulation and innovation, the way regulation affects innovation in the recycling of WEEE, and the barriers to innovation stemming from regulation or other factors within the system of EEE-recycling. In Section 2.5 we conclude with a summary of the main links between innovation and regulation and policy recommendations on how policy makers could encourage innovation by regulatory measures.

2.2 MAIN ACTORS IN THE SYSTEM OF WEEE-RECYCLING

In the baseline report (part 1 of the present project, see Buchinger et al. 1999) we presented a discussion of actors who are considered as major drivers for setting up an effective recycling system for end-of-life EEE and who are expected to play a key role in innovation in EEE-recycling. The definition of actors (and their interactions) was based on a systemic perspective on the production, distribution, use, disposal and recycling/re-use of EEE. Figure 2.1 shows the main actors in this system.

Figure 2.1

Major Drivers for the Recycling of Electric and Electronic Equipment (EEE): A Systemic Perspective



The system of WEEE-recycling as presented in Figure 2.1 is an ideal-type model. In most EU countries such a system does not exist in its complete form yet (i.e. there is no recycling industry and/or some of the linkages between actors do not exist). Nevertheless, the system approach seems adequate for a general characterisation of types of actors and organisations, and interactions among them, relevant to the recycling of end-of-life EEE.

In general, two groups of actors may be distinguished. One group comprises those actors interlinked in the process of WEEE-recycling by material flows (as well as financial and knowledge flows); the other represents actors who mainly affect the recycling system via different kinds of "knowledge flows", such as regulation, co-ordination, research results and the articulation of (group specific) interests. In the following, the main actors are characterised with respect to their role in the recycling of WEEE and their position concerning regulation towards promoting recycling activities.

- **Producers of EEE**: Electric and electronic equipment is produced by a large number of firms, many of them being globally oriented corporations. Most firms are specialised in certain EEE-products while there exist only a few corporations which are engaged in the production of (nearly) the whole variety of EEE-products (such as Siemens or Philips). The majority of EEE-products used in the EU are not produced here but imported from other countries, e.g. Japan, South-east Asia, Eastern Europe or the USA. Some exceptions refer to telecommunication equipment, washing machines or refrigerators, some small household appliances and medical equipment systems which are all mainly produced within the EU.

The EEE-industry's position concerning regulation towards the recycling of end-of-life EEE is quite homogenous throughout the EU: The industry has largely accepted that they will have to take over the financing of externalities to the environment stemming from WEEE. Recycling is viewed as only one alternative of WEEE-management and other options should be taken into account as well. Given the variety of EEE-products and the differences in their recyclability (in technical and economic terms), recycling should be restricted to those products where it is economically profitable. Recycling activities should not be carried out by the industry itself but by specialised recycling companies. The collection of end-of-life EEE should to be organised (and financed) by other parties (such as communities). Regulation should strongly take into consideration the dynamics of the production of EEE, i.e. rigid schemes of EEE-definitions, recycling quotas, prohibited substances, product design and information provisions, and long-term oriented financing models shall be avoided.

- **Distributors of EEE**: EEE-products are distributed from producers to users mainly via (specialised) retail traders or mail-order houses. For most EEE-products, distributors are the main information source for users. They give technical and organisational advice and affect the preferences and decisions of users. Some distributors also carry out repairs of EEE. The firm structure of EEE-distributors is quite heterogeneous and range from small single-shop firms to companies acting on a Europe-wide scale.

The position of EEE-distributors vis-à-vis regulation differs by type of distributor. Small, locally oriented distributors are not willing to get responsible for the collection of end-of-life EEE because of bureaucratic and distributive costs. Larger firms possess adequate organisational abilities for taking over collection activities but reject such approaches as well.

- **Users of EEE**: The users of EEE may be subdivided into three main groups: private households, commercial users and public institutions. Each group shows a specific behaviour pattern in terms of product preferences, purchasing and collection of end-of-life EEE. Users of EEE are by definition one of the most important drivers for EEE-recycling as they bring in end-of-life EEE to the recycling process. Effective recycling of end-of-life EEE heavily depends on the incentives for users to collect and deliver end-of-life EEE.

Users of EEE are strongly interested in collection schemes for end-of-life EEE which minimise their efforts and are free of costs. Many users are critical of regulatory measures which oblige them to bring back end-of-life products to collection centres because of the transport difficulties but prefer pick-up services.

- **EEE-Waste Collection and Management Organisations**: Today, most end-of-life EEE is collected in the context of general waste collection schemes (for household waste or for commercial waste) organised by either public services or private firms. Waste management organisations contribute to EEE-recycling by offering logistical services, pre-treatment, and the selection and separation of end-of-life EEE. The logistic infrastructures already set up by waste management organisations may form a backbone for collection systems for end-of-life EEE.

  Waste collection organisations prefer regulation schemes which oblige users of EEE to bring end-of-life appliances to collection centers. Costs for collection, pre-sorting, for the transport of end-of-life EEE to recyclers or for the deposition of WEEE shall be covered either by users, producers or recyclers.

- **Recyclers of EEE**: Recycling of end-of-life EEE may be carried out either by specialised firms ("recycling industry") or by producers of EEE themselves. The former mainly focus on the extraction of raw materials from EEE-waste. These firms try to recycle end-of-life EEE by mechanical processing or dismantling as cheaply as possible in order to offer competitive prices for the raw materials obtained. The level of their activities, and their innovation efforts, are thus strongly influenced by the demand after, and price for, these raw materials. Some recyclers concentrate on picking out the most valuable parts of WEEE while the remaining (large) volume of WEEE is not recycled but brought to land fill areas (see Houwelingen 1998). If producers get engaged in recycling these activities tend to be oriented on re-use, repair and the set up of modular systems. A special case is recycling companies or initiatives which aim at repairing end-of-life EEE (partially by combining parts of several products to a "new" one) and selling them second hand. Such recyclers are often charity organisations.

  The recycling industry is interested in: regulatory measures which ensure a high rate of return of end-of-life EEE to recyclers (in order to exploit economies of scale in the recycling process); the pre-sorting of end-of-life EEE; product designs which ease recycling activities (see 3.); the elimination of any hazardous substances in EEE-products; and the financing of those recycling activities not economically profitable but desired from an environmental perspective.

- **Other Industries**: Within the recycling system, two groups of industries (besides the electric and electronic industry and the recycling industry) are of special relevance: producers and processors of raw materials which are obtained in EEE-recycling and producers of machines and facilities for the recycling of materials. The former affect the demand and the price for the raw materials, while the latter affect the recycling system by the introduction of new recycling technologies which may affect the costs for obtaining raw materials or re-usable parts out of end-of-life EEE.

  Both industries show little specific interests in regulation schemes concerning the recycling of WEEE. Manufacturers of recycling machines and facilities are interested, however, in supporting measures for the development of new recycling processes as well as in the build-up of a strong recycling industry (in order to increase demand for their products).

- **Intermediaries**: Industry associations and standards committees represent major intermediaries who may co-ordinate the activities of the actors within the EEE-recycling chain by defining norms and standards, offering information system and introducing incentives for co-operation.

Intermediaries play a crucial role in the development of regulatory regimes as they participate in the formulation and discussion of new regulatory measures. Major actors in all EU-countries are the national associations of the electric and electronic industries, which represent the interests of the EEE-industry in the process of formulating and implementing regulation measures.

- **Public Authorities**: Regulations promoting the recycling of end-of-life EEE comprise different policy instruments which are implemented by public authorities on different geographical scales. Local, regional, national and supra-national governments and agencies contribute to the formulation, implementation and control of these instruments to different extents. Regulations set by public authorities do not only refer to legislation (command-and-control measures) but also to financial incentives via taxation, charges and financial supports, to support programmes and to their own demand for EEE.

  In the context of EEE-recycling, public authorities are especially keen to design regulatory schemes which, on the one hand, meet environmental objectives (reduction in the amount of waste, elimination of hazardous substances, increasing the amount of materials being recycled and re-used) and, on the other hand, stimulate innovation activities whilst not adversely affecting industrial competitiveness. Regulation tends to be designed in such a way that all relevant actors make a fair contribution to improve recycling.

- **Research Institutions**: Improvements in the recycling of end-of-life EEE demand new organisation concepts, new process technologies, new materials and products, and new regulations approaches. Research institutions such as universities and specialised research institutes may contribute to these innovations by the own research and through co-operation with other actors.

  Such research institutions are especially interested in support for research programmes aiming at innovation in recycling activities.

- **The Public**: The media, political initiatives and political parties, social movements and, in the end, all citizens form a public climate which may support or impede the promotion of new recycling approaches in end-of-life EEE recycling (as well as in other recycling issues and environmental policy in general).

  Successful regulation shall therefore regard the public as a separate, major driver in the overall process. Regulation should be designed and implemented in such a way that the recycling of end-of-life EEE is accepted by all major public groups as an important and valuable measure to improve the environmental situation.

Effective recycling of end-of-life EEE is strongly influenced by the pattern and intensity of linkages between the main actors mentioned above. In general, three types of such linkages (interactions) may be distinguished:

1. **Material flows:** New EEE-products are sold to private households and commercial users mainly via specialised distributors. In the case of large commercial users (including public institutions) direct marketing from producers to users is common. For effective recycling, these material flows should be associated with corresponding information flows on the materials and recyclability of the product sold and on how end-of-life EEE should be brought into the recycling process by

users. In principal, end-of-life EEE can be delivered from users to recyclers via four channels: i) by direct transport to the recycling establishment; ii) by return to distributors (e.g. in the case when new appliances are purchased); iii) by return to the producer; iv) by collection through waste management organisations or specially established pooling companies. Distributors, waste management organisations and producers may sort and/or pre-treat the end-of-life EEE and supply recyclers with pre-selected and sorted EEE-waste. Recyclers deliver raw materials to EEE-producers or to other firms demanding these materials. Remaining waste which cannot be recycled is disposed of.

2. **Knowledge flows:** Within the material circle of EEE, information on the materials and substances used in each individual product and the way the appliance may be disassembled should follow the material flows in order to ease recycling. The most effective approach is to incorporate this information into the product on a computer-readable base (using chips or printed codes). For this purpose, norms and standards, and an industry-wide information system may be useful tools.

3. **Financial flows:** Financing of the collection and recycling of end-of-life EEE is crucial for reaching sufficient recycling rates for EEE-waste. As prices for raw materials to be obtained out of EEE-waste are lower than the costs of collecting and processing the waste, a financial support scheme has to be introduced. Financing may be organised in different ways. In most EU-countries with effective recycling schemes for EEE-products, recycling activities are financed by EEE-producers. Costs of collection and transport of end-of-life EEE is often covered by communities, in some cases by distributors. Normally, these costs are included in product prices or waste collection charges so that at the end users will cover these costs.

In broad terms, the characteristics of main actors in the recycling of end-of-life EEE, and the linkages among them, do not vary much among different EU-countries (producers, users, recyclers exist in all countries). But significant differences may be observed in the level of development of the whole system of WEEE-recycling. In some EU-countries, such as Sweden, Finland, Denmark, Germany, Austria or the Netherlands, a system as described above is in operation at least for some EEE-products (i.e. there are material, knowledge and financial flows among the various actors). In other EU-countries, especially in southern Member States as well as in Ireland and the United Kingdom, no such system has evolved in its full range yet. In these countries, WEEE is treated in the same way as general waste. The position of the groups of actors distinguished vis-à-vis regulation is, however, not affected by the state of development of a recycling system.

2.3 DRIVING FORCES FOR RECYCLING OF WEEE

2.3.1 Definitions

In this Section the different factors which either stimulate or inhibit recycling of end-of-life EEE are summarised. To begin with, a short discussion of how electric and electronic equipment may be defined and which types of EEE-recycling exist is presented.

Definition of Electric and Electronic Equipment (EEE)

There is still no international agreement on the definition of EEE. The challenges in deriving a proper definition of EEE stem from the rapid pace of technological change in the electric and electronic industry. This results in the continuous introduction of new products. Furthermore, electric and electronic components are increasingly incorporated into many products not directly associated with the electric and electronic industry. This is especially true for the use of microelectronics.

The European Commission has recently (05.07.1999) published a new draft version of a ”Proposal for a Directive on Waste from Electrical and Electronic Equipment”. According to this draft, EEE means equipment which is dependent on electric currents or electromagnetic fields in order to work properly and equipment for the generation, transfer and measurement of such currents and fields fall under the eleven categories listed in the draft[7] and are designed for use with a voltage rating not exceeding 1000 Volt for alternative current and 1500 Volt for direct current.

An often-used differentiation of the wide spectrum of EEE-products refers to the use of EEE. Three types of EEE-products are distinguished:

- White ware: household appliances such as washing machines, electric kitchen utensils, vacuum cleaners etc. and their components
- Brown ware: electronic entertainment sets such as radios, TVs, recorders etc. and their components
- Grey Ware: information and communications technology such as computers, telephones, fac-simile machines, copying machines etc. and their components

Types of recycling of end-of-life EEE

Two types of recycling of end-of-life EEE may be distinguished:

- mechanical processing, i.e. the comminution, shredding and sorting of (pre-treated) appliances,
- dismantling, i.e. the disassembling of products into parts which can be re-used or processed into raw materials.

Mechanical processing is used if the costs for dismantling are high compared to the expected returns from sales of recycled materials or components. This is especially true for large household appliances such as washing machines or vacuum cleaners, but also

[7] Large household appliances, small household appliances, IT-equipment, telecommunication, radio/television/electroacoustic/musical instruments, lightening equipment, medical equipment systems, monitoring and control instruments, toys, electrical and electronic tools, automatic dispensers.

for parts or assemblies that result from the restoration or re-use of complex devices. Mechanical processing consists of a sequence of various comminution, shredding and sorting operations. Comminution is necessary to liberate composite materials and to create an assigned particle size distribution which is necessary for the following sorting operations.

Dismantling is mainly used in the case of EEE-products which have a modular structure and where components of end-of-life EEE may still be used in new products. Dismantling, however, is difficult to mechanise and, thus, very labour-intensive and costly. Therefore, dismantling plays only a minor role in the recycling of end-of-life EEE. There are opportunities to improve dismantling through the provision of easily readable information on the material characteristics of parts and components, and the way these parts are mechanically connected with each other. This is particularly valuable where there are regular major changes in the product design.

2.3.2 Main factors inhibiting recycling of WEEE

Compared to other product groups, the recycling of end-of-life EEE is still a relatively small business. Market forces have not yet led to the build-up of a comprehensive recycling industry. Several technical, organisational and economic problems hamper an effective recycling of end-of-life EEE. The main obstacles may be summarised as follows:

<u>There is a large variety of products and parts/components/materials</u>

Electric and electronic equipment embraces a large variety of products each consisting of a large number of different parts and components. Furthermore, EEE contains a high variety of different materials such as various kinds of plastics, metals, and glasses/ceramics. According to that recycling of EEE-products is difficult to standardise. Although the number and variety of parts and components per product has decreased within the last decade (mainly due to cost cutting strategies of EEE-producers), the problem of standardisation is still existing.

<u>The “variety problem” demands integrated collection strategies</u>

The collection of end-of-life EEE is rather difficult to organise compared to other products and materials. EEE comprises a very heterogeneous set of products ranging from small Walkmans or mobile phones to big copy machines or cooling appliances which are distributed via different channels. The structure of users of EEE is also quite diverse (households, firms, public institutions) and the transport of large EEE-products is associated with considerable effort. The necessity to establish “extra” collection centres (public or private) adds a further type of actor (and requires specific communication/negotiation processes). Beside the question of integrating different types of actors it is true for some products with long life spans (e.g. washing machines) that regular collection actions at the household level are confronted with low return rates. According to these factors the most appropriate collection scheme seems to be a decentralised collection (with user responsibility: users bring their end-of-life EEE to those centres) and the transport of larger quantities of end-of-life EEE from collection centres to recycling firms.

The “variety problem” demands expendable treatment of EEE

Presently, a common form of EEE-recycling is mechanical processing by advanced shredding which is applied for larger appliances with a high share of metals. Where this is not appropriate, the (prior) dismantling of products into its individual parts tends to be a labour-intensive (low-skilled) activity of disassembling products by hand. As it was stated above, mechanisation of dismantling is expendable or not possible. To mechanise the separation of different materials (e.g. plastics) advanced technological solutions (e.g. like infrared identification methods) are necessary. The presence of hazardous substances (e.g. acids, toxic metals) in EEE gives rise to particular challenges. In the recycling process these substances are difficult to separate from other materials in a safe way and thus raise the quantity of hazardous waste whose disposal or combustion is rather expendable.

The “variety problem” entails economic disadvantages

Most of the parts/components are of little value per unit. According to that costs of recycling are in general higher than the returns which can be obtained from selling the recycled materials. Consequently, recycling of end-of-life EEE is in general not a profitable business.

The solution-strategy “Eco-design” is somewhat limited

Efforts to re-design EEE-products in order to facilitate recycling are increasingly taking place (see Box 1 and 2) even if with some difficulties. First, producers of EEE face strong price competition in most fields of products (such as consumer electronics, computers, telecommunications equipment) as those markets are in dynamic expansion phases with a large number of firms entering the market. Therefore firms try to minimise production costs per unit of product. Recycling oriented product design may, however, increase production costs. Second, a limitation is given by the fact that recycling oriented Eco-design takes place sometimes seven to ten or more years prior to recycling (life time of products). It is somewhat difficult to generate ideas which recycling technologies/strategies are available/introduced in the future. Third, it can be expected that producers and recyclers of EEE are different actors. An additional communication/negotiation process is necessary between producers and recyclers (This needs to take into consideration the “time lag” between product design and recycling.).

Nevertheless, many larger firms have started to adapt the design of their products to meet recycling requirements. Such initiatives are often embedded in a broader corporate environmental policy, e.g. in the context of introducing an environmental management system (such as EMAS) or focusing on an environmentally oriented marketing.

First conclusion

Due to the large number and different types of actors involved in the production, distribution and use of EEE, recycling has to be organised in a systemic manner. Effective recycling of EEE demands:

- the re-design of products;
- a change in production technologies;
- certain information flows from producers to recyclers (e.g. on the materials and substances used);

- the active involvement of users, distributors and waste-management companies in the collection of EEE-waste (partially by a re-organisation of the distribution and waste-collection system);
- a financing system which stimulates innovation and makes recycling economically attractive; and
- initiatives by public authorities, research institutions, the media and intermediaries.

Such a system can only succeed where all actors are willing to become involved, and this will a considerable amount of time and may be confronted with several uncertainties and setbacks. Furthermore, the huge product variety in EEE may demand differentiated regulation schemes for different types of products.

In order to stimulate the recycling of WEEE, four potential approaches may be distinguished:

- advancements in the recycling technology (process innovation),
- re-design of EEE-products including product information systems (product innovation),
- re-organisation of the collection system of end-of-life EEE (including producers, distributors and users of EEE) in order to increase the quantities of WEEE per type of product entering the recycling process (organisational innovation),
- improvements in the financial basis for recycling activities either by direct financial support or by a raise in the demand for recycled materials.

2.3.3 Main factors promoting recycling of WEEE

Considering the above characterised obstacles/problems, the following activities are generally regarded as being suitable to promote the recycling of end-of-life EEE:

<u>Technological research and development in the recycling industry in order to raise the productivity of recycling processes</u>

Starting points may be the automation of dismantling activities, the improvement of material detection methods, and the improvement of mechanical material separation and sorting methods. Innovation activities by recyclers will be stimulated if there is competition among recyclers for end-of-life EEE to be recycled. Special attention should be paid to co-operation between producers of EEE and recyclers so that information on product design can be used for the design of recycling technologies.

<u>Re-design of EEE-products by producers in order to facilitate recycling</u>

Major approaches are:

- the reduction of the number of parts per unit of product (simplification and parts consolidation),
- the standardisation of material types, parts and modules used by different firms and/or in different products,
- the use of materials which are recyclable to useful raw materials,

- the introduction of modular product structures (to ease the repairability, up-grading and disassembly),
- the reduction or elimination of hazardous substances.

The initial design process, i.e. the design of a new product by a producer, is of crucial importance to the future recyclability of the product. At this stage major product characteristics are set such as the product structure and the materials used (including hazardous substances). These characteristics are difficult to change at later stages through re-design. The initial product design may result in a lock-in situation, as product design demands certain production technologies which represent major investments by producers.

<u>Information system on the construction of EEE and the materials used in order to facilitate disassembling of EEE and the separation of materials for further processing</u>

Information should be provided by the producers in a standardised way and should be made available for recyclers when end-of-life EEE enters the recycling process. Therefore, product-integrated information systems (such as labels, readable codes or chips) should be preferred. They may also record information relevant for the re-use of parts and components (e.g. number of hours a cathode ray tube has been in operation). Crucial to such an information system is a high degree of standardisation and international comparability in order to reduce information processing activities by recyclers.

<u>Take back systems and other measures to increase the amount of WEEE brought into the recycling process</u>

Such systems shall ensure that as many appliances as possible enter the recycling chain (e.g. that there are as few barriers as possible for users to bring their end-of-life EEE to a collection facility), that the collection and transport of end-of-life EEE does not affect the possibilities of re-use and repair of the appliances and that different types of EEE which have to be treated separately in recycling are collected in such a way that separation by the recycler is easy to carry out. An increase in the quantities of end-of-life EEE being brought to recyclers enables the exploitation of economies of scale and raises the economic competitiveness of recycling activities.

<u>Financial basis for EEE-recycling</u>

In general, EEE-recycling is not a profitable business on its own. This is true both for the recycling process itself and the collection of end-of-life EEE. Financial resources should be gathered in such a way that producers and users of certain EEE contribute in relation to the environmental impact and the waste management costs of these products (in the case when they are not recycled) as well as the costs of recycling per unit of product. Direct financial contributions by households are expected to substantially reduce the willingness to bring of end-of-life EEE to collection facilities. Financing schemes should be designed in such a way that recycling oriented innovation by producers is stimulated. The challenge is to establish a system that spreads the financial burdens on the various actors involved in such a way that the corresponding rise in costs or prices stimulate innovation in recycling and/or changes the behaviour of actors in such a way that products with a comparably low recyclability are not produced or not consumed. Financing scheme should also ensure that all producers participate in the financing and that WEEE from brands which are no longer present are taken care of.

Responsibilities of different actors involved in the system of WEEE-recycling

A key element to effective recycling of end-of-life EEE is to co-ordinate the various actors and to clearly define who is responsible for carrying out different steps in the recycling chain. Activities by producers (e.g. concerning the technical design of products and the materials used), distributors (e.g. concerning marketing and consumer information), users (e.g. concerning the treatment of end-of-life products), waste management establishments (e.g. concerning collection schemes) and recyclers (e.g. concerning recycling technologies applied) as well as public authorities (design of regulatory measures), intermediaries, research institutions and the general public (including media) have to reconciled. Especially in the case of collection and financing, responsibilities must be well defined.

Positive public climate towards the recycling of end-of-life EEE

As regulatory measures will affect and change substantial parts of the existing system of the production, distribution, use, disposal and re-use/recycling of EEE, several actors may refuse to accept behavioural changes necessary for an effective running of a recycling system. Thus, public awareness for the problems associated with the increase of EEE-waste should be raised including the communication of the gains of an effective recycling scheme.

2.4 REGULATION AND INNOVATION IN THE CASE OF EEE-RECYCLING: THE MAIN LINKS

This Section explores the main links between regulatory measures promoting the recycling of WEEE, on the one hand, and the innovation activities by individual actors or within the whole system of recycling of end-of-life EEE, on the other hand. The findings comprise several industry examples from various EU countries and cover producers, collectors and recyclers[8]. The main research question was to analyse - on a qualitative level - the likely impacts of regulation on recycling oriented innovation activities in different parts of the recycling system. On a conceptual level, the analysis was based on the large body of literature on the relationship between environmental regulation and innovation, especially on Kemp et al. (1999). Further background information concerning the main research issues, the methodologies employed, and empirical results derived so far in this study may be found in Kemp (1998), Brousseau (1998), OECD (1997), Hemmelskamp (1996), Jaffe and Palmer (1996), Jaffe et al. (1995), Rothwell (1992).

For successful innovation, co-ordination with other actors and partially simultaneous innovation by these other actors is needed (e.g. a process innovation by recyclers demands product innovations by producers and new collection schemes). Such “systemic” innovations are difficult to realise, however. In the final section of this chapter an initiative aiming at the promotion of such system innovation is presented (SCARE-project within the EUREKA-framework).

An analysis of the impacts of regulation on innovation in the recycling of end-of-life EEE is hampered by the fact that comprehensive regulations do not exist in any EU Member State yet (see Part 1 of this project). Therefore, other types of regulation measures are taken into consideration as well.

2.4.1 Regulation and Product Innovation

Product innovations directly focused on the facilitation of recycling processes are rather rare in the EEE-industry (these rare examples can be found e.g. within multinational firms). Such product innovations concern the re-design of products in a way that dismantling in the recycling process will be facilitated, hazardous substances will be eliminated (although their use would not be prohibited) and materials used will be changed to those which are both easy to separate in the recycling process and easy to be re-used after recycling. However, innovations aimed at other objectives have quite significant (indirect) effects on the recyclability of EEE-products. These innovations cover:

- "eco-designed" products which meet several "ecological" criteria such as a relatively low energy consumption, longer life-spans, avoidance of certain hazardous or potentially dangerous substances, recyclable packaging, and the use of recycled materials;
- re-design of products in order to replace substances prohibited by environmental regulation (whereby environmental regulation is not directly oriented on recycling issues);

---

8 For persons interviewed in the course of this project see Appendix 2.

- organisational innovations associated with the implementation of eco-auditing (environmental management systems such as EMAS);
- market oriented product innovations which lead to new products with new product characteristics (which are sometimes more favourable for recycling than the predecessor products);
- technological innovations in the production processes of EEE affecting some product characteristics as well (such as modular structures, number of parts and components etc.);
- marketing innovations with a view to new kinds of producer-customer-relations, e.g. stronger ties to customers by raising the service intensity and repairability of the products, often associated with a shift in marketing strategies from purchasing to leasing.

Some of these innovations are stimulated or at least affected by regulation, and some are simply results of competitive processes within the industry. There are three types of regulation which affect, in some way, the innovations mentioned above:

- First, the prohibition of certain substances being viewed as dangerous to health or the environment lead to new technical solutions which either result in the use of alternative substances or in a radical change in product designs which may lead to the closure of production of certain products. In order to avoid serious distortions of economic activities, the EEE-industry demands a sufficient time span before such regulation is set in force so that research into alternatives may be carried out. In some cases (such as the proposed prohibition of lead in all EEE-products by the year 2004) the EEE-industry is afraid of far-reaching negative impacts of such regulations if alternative substances are not available.
- Second, and in general more important to recycling-oriented product innovation in the EEE-industry, are fundamental changes in the priorities and orientation of economic policy (and other policy fields as well). In the late 80s and early 90s such a change took place with respect to the role of environmental issues in several societal areas. The "greening" of policy objectives and a general change in the perception of environmental problems in the whole society in many Western European countries also affected firm strategies, especially in the case of firms within the consumer-goods industries.
- Third, the introduction of eco-auditing and environmental management systems at the firm level (based either on EMAS or on ISO 14001) helped many firms to become aware of the systemic character of the environmental impacts of their activities. In some cases, ecological balancing and other instruments associated with eco-auditing offered cost-cutting possibilities through an environmental oriented re-design of products and processes, e.g. through the reduction in the number of different materials which also facilitates the recycling of these products.

However, *the most important factor for product innovations in the EEE-industry which support recycling processes are market forces*. Typical examples are Bosch-Siemens-Hausgeräte, Europe's largest producer of electric household appliances (see Box 1) and Philips, Europe’s second largest producer of EEE (see Box 2). The so-called eco-design of products partially focuses on increasing recyclability. But the main purpose is to introduce new marketing strategies. Firms perceive a growing demand for “greener” products and, therefore, aim at utilising this market potential by offering eco-designed products. The main characteristics of such products are the avoidance of hazardous substances, less resource consumption (in terms of energy, water etc.), less and more environmentally friendly packaging, reduction of negative environmental impacts of the production process, the use of recycled materials, and the recyclability of the materials used.

First steps towards "green" products result from rises in energy prices in the 70s. The development of comprehensive "green" marketing strategies (as a niche strategy within conventional marketing strategies) took place in the early 90s (concerning at least the larger firms within the EEE-industry). This might be seen as a reaction to general changes in values and attitudes within society. Parallel to these adjustment processes on the firm level, governments started to implement environment oriented regulation which partially supported the rise of eco-design (especially with respect to hazardous substances and to reduce resource consumption of appliances).

Today, competition among firms in the EEE-industry is the most important driving force for innovation towards increasing "recyclability". Competition forces firms to implement a continuous reduction in production costs, which is partially achieved by standardisation of product components, a reduction in the number of different materials used and in the elimination of certain hazardous substances (if alternative, non-hazardous substances are available). Simultaneously, however, competition forces firms to increase product differentiation and introduce new products both which increase the product variety and thus might be seen as an negative impact for the promotion of end-of-life EEE-recycling.

Regulation or the announcement of future regulations on the recycling of end-of-life EEE has not contributed yet to an adoption of considering critical factors for successful recycling in product design. Such critical factors are, firstly, a product design which substantially facilitates disassembling processes, and, secondly, the introduction of an information system which allows the identification of material characteristics by the recycler. EEE-industry strategies on recycling are still oriented on recycling by mechanical processes (shredding etc.) in order to recycle the bulk of materials (metal boxes, plastics, glass) and deposit the remaining rest.

Box 1: Eco-design for electric household appliances by Bosch-Siemens-Hausgeräte (BSHG)

BSHG is a joint enterprise of the two leading firms of the German electronic industry, Robert Bosch AG and Siemens AG, in which both firms have combined their activities in the development, production and distribution of household appliances. Today BSHG is the leading household appliances producer in Europe. BSHG is confronted with a growing demand for "green" appliances which should have little impact on the environment (i.e. low energy consumption, low consumption of water, chemicals and other working materials, no hazardous substances, environmentally friendly production processes and distribution networks, etc.). In order to meet these customer demands, and to occupy a market niche perceived to grow in future) BSHG has introduced a procedure in the course of product development which aims at the development of all-integrated optimised products meeting both technical, economic and environmental objectives.

Therefore, *BSHG has introduced environment oriented guidelines from 1993* on. These guidelines refer to the elimination or avoidance of hazardous substances (those hazardous substances which are not subject to regulation yet are set on a special list and should be avoided as far as possible; *the definition of this list is strongly influenced by the anticipation of future regulation*), the active improvement of the recyclability of products (including the recyclability of materials used, information systems for plastics parts and other materials difficult to identify in the recycling process, standardisation and modularisation, the avoidance of compound constructions, and the use of recycled materials) and the introduction of a product-environment-analysis.

The latter may be regarded as the backbone for the development of eco-designed products. It mainly covers an ecological balancing, i.e. the analysis of all relevant energy and material flows during the lifetime of a product (from production via distribution and use to recycling or disposition*). For most household appliances, the most severe impacts on the environment occur during their use, followed by the production phase*. The disposal of end-of-life EEE has comparably little environmental impact. Based on the results of ecological balancing, potentials for reducing these impacts are analysed and objectives are defined. These objectives lead the development process for a re-design.

A first main result of the efforts of BSHG to bring eco-designed appliances onto the market, a dish-washer was developed and produced which requires 10 % less energy, 25 % less water and 20 % less materials, for the same performance as its predecessor. Furthermore, the use of packaging material could be reduced considerably. With respect to recycling, the main effect was the reduction in the number of parts from 444 to 198 different parts.

The role of regulation

Regulation had little direct impact on this kind of innovation. The main field where regulation does play a role is the definition of hazardous substances not allowed to be used. The decision to re-design products is mainly driven by market forces, i.e. the demand by customers for “green” products. As this demand is at least partially influenced by the stage of environmental policy and environmental regulation one may speak of indirect effects of regulation. However, these effects can not be attributed to certain regulations and the way they are designed.

Box 2: Eco-design as part of an overall environmental strategy by Philips

One of the worlds leading EEE-producers, the Dutch-based firm Philips, gives a good example for the indirect effects of a environment-oriented change in corporate strategies on the recyclability of products. As early as 1970, Philips introduced environmentally oriented guidelines. In 1987, a comprehensive environmental policy was formulated and in 1991 this policy was up-dated. From this time on, Philips tried to integrate environmental issues into their global strategy and implement environment oriented guideline at most plants and national branches. In 1998 a new environmental policy was established, called EcoVision. Its main purpose was to extend the marketing strategy towards “green” labels and to establish Philips as a strongly environment oriented corporation.

The main measures for realising EcoVision are, first, to introduce environmental oriented aspects into product development (reduction of weight, hazardous substances, energy consumption, facilitating recycling), second, to urge every business unit to define one “green” product of excellence (“flagships”) and to increase the share of “green” products within the next 3-4 years, and third, to reduce packaging. The increase in the share of “green” products shall contribute to a significant reduction in the amount of waste, the consumption of resources (water, energy) and the elimination of hazardous substances. Increasing recyclability is not a direct aim of this programme.

First results of EcoVision

The results for 1998 of the EcoVision Programme show that 32 Philips products were selected as “green flagships” and had been launched as such at the market. Of the industrial sites that reported on their environmental performance in 1998 compared with 1994, 52 % are managing now their environmental performance in accordance with ISO 14001. The energy saving in manufacturing, compared with 1994, is 23 % and in the case of water it is 34 %. Industrial waste has decreased by 28 % while emissions into air and water were lowered by 68 % for restricted substances, by 39 % for hazardous substances and by 42 % for other “environmentally relevant“ substances.

Examples of “green” products with relevance to recycling

Monitor A 580 BQ: This monitor does not contain any hazardous substances and its energy consumption is among the lowest in the market. Fewer wires and components mean better recyclability and a significant reduction in total weight.

FAX Magic Vox: This fax machine, which includes an answering machine, consumes less energy on stand-by then comparable fax machines. Moreover, it contains no hazardous substances, and plastic parts are marked with official abbreviations for recycling.

Television TV 28PT: This television comprises a large proportion of recycled materials and uses little energy on stand-by. It has a high recyclability because it is fairly easy to disassemble.

Fluorescent tube TL-5: This fluorescent tube is a slim 16 mm diameter, compared with the standard 26 mm tube. Use of glass, phosphor coating and mercury is reduced thanks to the 40 % diameter reduction. The diameter reduction also resulted in greater freedom in the design of lighting fixtures. HF operation and more efficient optical/thermal design up to a 25 % energy saving.

Fluorescent tube TL Super 80: This fluorescent tube is nearly 100 % recyclable. The mercury, glass, metal and even the fluorescent powder can be recovered and re-used, thus closing the material loop.

The role of regulation

Regulation plays a major role for product re-design with respect to environmental parameters in the case of hazardous substances. The EU regulation 93/259 on waste shipments including the green, yellow and red list on types of waste is reference points for the orientation of “green” product innovations and the definition of targets. The ongoing discussions on regulations aimed at recycling of end-of-life EEE have stimulated Philips into taking account of this aspect, but there is no comprehensive adjustment of product innovation processes towards recyclability. Improvements for recyclablility seem to be rather an effect of efforts to improve production technologies (i.e. to lower production costs per unit).

2.4.2 Regulation and Process Innovation

Process innovations in the recycling of end-of-life EEE aims to improve the economic efficiency of the recycling process (i.e. to reduce costs per unit of material recycled). Two issues are at the heart of innovation efforts today:

- automation of dismantling processes,
- automation of material detection, especially concerning plastics.

In principal, two recycling technologies may be distinguished: mechanical processing by shredding and automated material separation (little labour inputs, high degree of automation, considerable volume of materials which cannot be recycled, gaining of raw materials), and dismantling of EEE-products by hand or partial automation (labour intensive, low degree of automation, relatively small quantities of materials which can not be recycled, gaining both raw materials and components for re-use). The application of a certain technology depends on product types and characteristics such as simplicity for dismantling, re-usability of components, content of hazardous substances, share of different types of materials (such as metals, glass, plastics), volume of appliances etc.

In order to increase the automation of dismantling processes, three approaches may be followed: Re-design of products in order to ease disassembling (see above), pre-treatment of end-of-life products by users of collectors (decomposition into main parts and pre-sorting of these parts), and automation of dismantling itself. Incentives for research and development activities on the latter by the recycling industry itself is hampered by too small recycling quantities per type of product and by product variety, respectively. *Consequently, only little progress has been made yet, and dismantling of WEEE is still done mainly by hand.*

In the case of the computer industry, there are several examples for innovations in the recycling of computers. These innovations are less oriented on the recycling process itself (which is mainly dismantling by hand into parts and components) but on systemic innovations with respect to the design of computers in the development phase, the testing of components on their functionality and the build-up of a second-hand selling strategy as well as the use of recycled components for the maintenance of other computers. *All main computer producers have established recycling centres in Europe in the 90s or even earlier.* The first mover was Siemens-Nixdorf (see Box 3) which runs a recycling centre in Paderborn (Germany), IBM Europe (Mainz/Germany), Digital (Nimwegen/the Netherlands) and Hewlett-Packard (Grenoble/France) followed.

A similar situation is in the field of copying machines. Rank Xerox and Canon, the world’s main producers of copying facilities, changed their production and marketing strategy substantially. They now re-design their products towards reparability and introduced leasing (instead of selling) as the main marketing strategy, especially for commercial users. This change was associated with an increase in the overall recyclability of appliances.

Major innovations in recycling technologies can be observed in the case of material detection methods (see Box 4). The main purpose of innovation efforts concerns the identification of different types of plastics by optical means such as infrared. The driving forces for this innovation are, first, market demand for recycled plastics purely separated by type, and second, an increase in the quantities of end-of-life EEE brought to the recycling yards.

The latter resulted in an increase in plastics waste and an increase in deposition costs. Regulation affected this innovation indirectly via a proposed prohibition of the incineration or deposition of WEEE meaning that EEE-products will have to be dismantled to separate different materials for further processing and recycling. In reaction to this regulation which is planned to be put into force by the year 2000, recyclers are preparing for the increasing demand for recycling resulting from this regulation by improvements in recycling technologies.

So far, regulation has not affected innovation in recycling technologies very much. But regulation could play a major role if it stimulates both the re-design of products at the producer side and increases the quantities of end-of-life EEE brought into the recycling chain. Thus, the recycling industry is highly interested in regulation measures with such a systemic perspective. A second major factor is of course financing. The recycling of end-of-life EEE is a profitable business if recyclers concentrate on the extraction of a few high-valued materials bringing the rest of WEEE to deposition. If regulation would be able to stimulate producers of EEE to design products in such a way that the share of materials to be recycled increases in value, this might promote both recycling rates (in terms of weight recycled) and innovation activities by recyclers.

Box 3: Re-use and recycling of computers at Siemens-Nixdorf

Siemens-Nixdorf is Germany’s leading computer producer and was founded in 1990 after a take-over of Nixdorf by Siemens. In the early 80s, Nixdorf started with the taking-back of old appliances of computer hardware of different kinds. Initially, recycling activities resulted from the high service demand of large computer facilities in the 70s and 80s. In general, it was cheaper for users of computers to repair old facilities than to buy new ones. Nixdorf used end-of-life computers to gain replacement parts and components. The collection of old appliances was organised within the own sales organisation. In the first stage take-back and recycling was seen as an additional service for customers and was supposed to increase the market position.

From 1988, take-back was intensified, and in 1993 a recycling centre was established as an integral part of the Paderborn manufacturing plant. It was the first one for IT-products in Germany. The recycling centre was organised as a profit centre within Nixdorf to avoid cross-financing. As the recycling of materials from end-of-life computers is not economically viable on its own, Siemens-Nixdorf put efforts into increasing the second-hand use of old appliances. Today, the recycling centre covers its costs via sales of recycled materials, re-usabel components and second-hand computers. Siemens-Nixdorf takes back all kinds of IT-products produced and sold by the firm, ranging from small personal computers to large facilities and specially designed systems. The volume of end-of-life computers entering the recycling centre exceeds 5000 t per year. The number of employees at the recycling centre is around 80.

Recycling of end-of-life computers follows a three stage process:

At a first stage, the functionality of old appliances is tested at the sales office where the computers are returned by customers. If a computer may be sold second-hand, the computer remains at the sales office. If a re-use through an exchange of components or worn parts seems possible the appliance is brought to the initial production plant. There, the product is overhauled, tested and brought back to sale. Potential customers of these recovered products are for instance users with larger computer systems who are not willing to change the whole system but need additional facilities for purposes of enlargement.

At a second stage, those end-of-life computers which are neither suitable for second-hand-selling and overhauling are handled on to the recycling centre. Computers are dismantled by hand concerning those parts which may be used for replacements. Such parts are tested for their functionality and – if necessary – repaired, as long as repair is not too time consuming. Such recovered parts are used for maintenance and repair of computers still in use but are not installed in new computers.

At a third stage, the remaining parts of computers are finally dismantled manually. Dismantling aims at separating those materials which can be easily recycled to new material and sold at a sufficient price. Automation of dismantling is hampered still by too small quantities of end-of-life computers of the same design. In order to identify those materials of a computer where separating makes sense, types of computers entering the recycling centre for the first time are analysed in detail. Information on the way dismantling may be carried out and which parts and materials have to be selected is gathered by this analysis. The depth of dismantling is oriented on both economic and ecological criteria. All parts containing hazardous substances are separated in any case, the separation of other parts depends on their economic effectiveness.

The further treatment of materials separated from end-of-life computers and the remaining waste follows traditional ways. Metals, packaging material, cables and sorted plastics are returned to raw material producers. Special attention is paid to monitors and semi-conductors. The overall recycling rate in terms of the material volume of an end-of-life computer which is recycled or re-used is 86 % today. In 1988 the corresponding figure was 30 % only. Until the year 2000, Siemens-Nixdorf aims at raising this ratio up to 90 %.

For this purpose, experiences gained in the recycling of end-of-life computers are flowing into the design of new computers. The main results of this feedback from recycling to product development are the following:

Plastics used in new products are pre-evaluated concerning their recyclability. For plastic components type and mixture of plastics used are labelled on the component. Only recyclable plastics are used, and the number of different plastics used is reduced to a small number.

The compounding of parts and components is designed in such a way that dismantling is eased. Various kinds of coating are avoided.

The re-design of products with respect to recycling issues is embedded in a broader process of continuous product and process innovation which also takes into account environmentally friendly product design. A main purpose of this process is to increase efficiency in production (reduction of different materials used, reduction in assembling times, reduction in product weights, reduction in packaging materials, reduction in logistic costs etc.) and to increase use-values of products for customers (reduction in energy consumption, improvement of performance).

The role of regulation

Regulation played a minor role in the build-up of a comprehensive recycling scheme at Siemens-Nixdorf. One impact of regulation on recycling concerns the prohibition of certain hazardous substances which reduces costs for disassembling and treatment of parts including such substances. The main driving force for Siemens-Nixdorf to get involved in recycling activities was the market. Service for defect computers, offering cheap second-hand appliances and offering take-back of end-of-life computers were regarded as major elements for a successful marketing strategy.

Automation of dismantling of end-of-life computers is still restricted by the small amount of appliances per type of computer. Recycling may be promoted if standardisation among different types of computers and a reduction in the number of types can be achieved. It is unlikely, however, that regulation can support such developments effectively as market demand and technologies change rapidly and demand continuous product adaptation, differentiation and innovation.

Box 4: Process innovation in recycling of WEEE – the case of Stena Technoworld AB

Stena Technoworld was established in 1992, with the main location in Bräkne-Hoby (Southern Sweden) and Sollefteå, as a daughter of the Swedish Stena group. In 1994 and 1996 subsidiary companies were established in Denmark and Norway respectively. The business idea of Stena Technoworld is to offer environmentally sound services for the treatment and recycling of consumer electronics. In principal Stena recycles all types of end-of-life EEE. The activities carried out cover the collection and transport of end-of-life EEE, the development and application of disassembly processes, the build-up of a knowledge base for processed materials and the realisation of closed loops for industry. Concerning WEEE, Stena Technoworld is the leading recycling company in Scandinavia. The quantities of WEEE, which are recycled by Stena, are rising steadily, reaching in 1998 a volume of 3,700 tons. There is competition on a low level with less qualified, tax-financed recycling initiatives, mainly in connection with employment programmes. The complaint against this kind of competitor is that they operate at lower costs allowing them to achieve a better market position.

Example of process innovation and improvement strategies

Computer keyboards are a good example for discussing innovation and improvement strategies in recycling at Stena Technoworld. These products are manually disassembled at the recycling works of the company. Since it is not economically efficient to recover all the different materials (up to four sorts of plastics, metal, rubber and a printed circuit board), only certain parts (e.g. housings, metals and printed circuit boards) are collected and recycled separately. Remaining plastic sorts are mixed and can only be reused as downgraded material (after re-granulation).

To cope with expected higher amounts of electronic waste and consequently with the problem of recovering low-quality (downgraded) plastics, the company has started to apply a new method for the separation of different sorts of plastic (e.g. ABS or SB, SAN, PMMA). A mid infrared system (MIR) has been introduced to identify different plastic sorts, allowing to separate and collect certain qualities. To improve the organisation and logistics of scrap collection, as well as the sorting of different product groups, Stena Technoworld has started with special training courses for responsible persons from communities at their recycling works in Sweden, Denmark and Norway.

The value of these innovations

Currently, it is still hard to quantify the value of the actual innovation, since the capacity of the MIR-system is limited, due to relatively long processing and identification times. Thus, the system is mainly used for the identification of probes, to allow a rough selection of plastic by sorts with unknown origin and the identification of "contaminated" parts. As a result, slight cost reductions are already possible, due to the following advantages:

Reduction in storage room, as a consequence of higher sorting rates,

selective purchase of sorted (high value) plastics to producers of virgin plastics at the European market.

Advanced detection systems, like NIR (near infrared systems), which were tested during the research project "DISCO" would allow the identification of all relevant plastic sorts, but the applicability and organisational integration of this advanced solution has still to be proved.

Incentives for innovation

The separation of pure materials is a presupposition to "motivate" producers of virgin plastics to take back and process recycled plastics. Connected with increasing volumes and improved quality of recycled plastics, the economy of dismantling processes can be improved. Not only the differentiation of plastic sorts is a prerequisite for the re-use of parts, but also the avoidance of contamination, e.g. flame retardants. If recovered plastics are to be re-used for the same type of product or function, the recycler has to assure its quality (i.e. purity).

Thus, the introduction of new detection methods for the identification of different sorts of plastic is seen as a main step towards sustainable solutions for the recycling of electronic waste.

The role of regulation

According to the Swedish regulation for WEEE, which is to be enforced at the beginning of 2000 (Renhallningsförordning SFS 1998:902), manufacturers, importers and retailers will be obliged to take back defined product groups, like IT products. The actual regulation does not allow the incineration or deposition of WEEE, and only certified recyclers may be entrusted with the processing of this type of waste.

As a consequence, products will have to be dismantled to recover the different materials for further processing and recycling. Manufacturers, importers and/or retailers are to bear the cost of accepting and dismantling end-of-life EEE. Furthermore industry is made responsible for developing a take-back scheme. It is possible that there will be a fee on new products so as to finance the new scheme.

Realisation of the innovation

The decision to introduce an MIR-system was a consequence of the employment of a young technician from Linköping University, who was engaged in the area of measuring techniques and assembly automation. He was responsible for the function and operation of the system as well as for training of personnel. To improve the efficiency of manually operated identification, the company participated in the R&D project “DISCO” (Disassembly of mass consumer products). Within the framework of this programme a concept for “Disassembly and Quality Sorting” was developed, together with research partners from Germany and Austria. The central goal of this project was to apply new detection methods (NIR and others) for the differentiation of plastic by sorts, connected with robot-guided handling of parts. The application of this method would allow the separation of plastics from the products or components (e.g. keyboards) and recycle (re-granulate) them individually, in order to achieve high quality plastics without contamination.

Impacts of networks and relationships on the innovation process

Stena Technoworld has established a network of recycling stations, which are located in over a hundred of communities in Sweden, Denmark and Norway. These stations are operated by the communities and responsible personnel are regularly trained at the company’s works. The function of training courses is also to get responses from the communities’ personnel for the improvement of recycling-related aspects like logistics of collection, pre-sorting of products etc. Beside this network, Stena has agreed special arrangements with big carriers to collect and transport WEEE in an environmentally sound way (see Box 6).

Impacts of the innovation

The main effects of the innovation are the improvement of the recycling process itself, due to the utilisation of the MIR system, as well as the possibility to increase the sale of high quality plastics which can be reused as “re-granulates” in the production process together with virgin plastics.

Example of hindering regulations for innovation

From the organisational side, problems are expected for the collection of the necessary quantities, since the economic utilisation of the new method (as described under “DISCO”) requires considerably higher amounts of returned plastics compared to actual quantities.

2.4.3 Regulation and Organisational Innovation

In most European countries, no comprehensive collection of end-of-life EEE has been established so far. For some selected appliances, such as batteries and refrigerators, special regulation and, thus, special collection systems exist. The majority of small end-of-life EEE is treated in the same way as general waste, i.e. collected within household waste collection and deposited at land-fill areas. For larger appliances such as washing machines, TVs or dish-washer, a collection within the system of bulk rubbish collection is quite common. Those appliances containing a high volume of easy to recycle materials (i.e. metals), a mechanical recycling by shredding is often applied. In the case of monitors, separate collection and recycling systems do exist in most countries.

The main purpose of organisational innovations in the recycling of end-of-life EEE is to build up an integrated, comprehensive and efficient system for end-of-life EEE collection in order to increase the volume of end-of-life EEE. The main target is to increase recycling quotas, i.e. the share in the volume of end-of-life EEE which is brought into the recycling process. Collection systems have to deal both with the logistics side and with the questions of responsibility and financing. Several approaches are followed to achieve this objective:

- *development of a separate collection scheme* for all kinds of end-of-life EEE at the local level (by special boxes, containers, recycling stations or pick-up services),
- *raising the willingness of users to collect end-of-life EEE* by various kinds of information policy, education and advice, and direct and indirect incentives,
- *involving the distribution side in the collection system* (take-back by retailers, especially in the case when users purchase new appliances),
- *co-operation with EEE-producers* to introduce pawn-systems or information on recycling on the appliances or on packing material,
- *implementation of finance schemes* in order to cover the costs of collecting and recycling activities (e.g. through a special waste charge added to the general waste charge, through a charge which has to be paid in the case of returning an old appliance, or through financial contributions by producers),
- *introduction of collection systems* on the level of commercial users combined with other forms of commercial waste collection.

In most cases two or more of these approaches are combined. Austria was among the first European countries to start with pilot projects for an integrated and comprehensive collection of end-of-life EEE at a local or regional level. Three pilot projects were carried out in order to gain information on how to organise collection systems in an effective way (see Box 5). In Sweden, the collection of end-of-life EEE has been an integral part of the collection of bulk rubbish for several years (see Box 6). From these and several other European experiences, the main driving forces for a successful collection of end-of-life EEE can be derived:

- Active information of users plays a critical role for raising recycling rates (weight of collected end-of-life EEE per capita).
- The more convenient a system is for households, the higher is the participation rate and the collection success. Direct collection from households by pick-up services is associated with high operating costs, but ensures high collection quotas.
- Direct charges for users when returning old appliances (individually take back fees) to collection points reduce the participation in collection. If users are going to contribute to collection costs, a general tax approach seems more appropriate.

Organisational innovation in the collection of end-of-life EEE is affected by regulation in different ways. First, for some specific EEE-products there exist a separate regulation (e.g. batteries, refrigerators). This regulation was strongly motivated by the potentially high negative environmental impacts of inappropriate deposition. Therefore, recycling obligations have been introduced earlier than for other appliances. Second, proposed regulations stimulate local authorities to analyse the possibilities and bottlenecks for a comprehensive collection and recycling system. By doing so, innovation within the existing collection system may emerge and lead to higher collection rates even in the absence of a definitive regulation. Third, regulation for recycling is often a prerequisite to raise collection volumes above a critical level which allows for a cost-efficient operation of the whole system.

On the other side, regulation may hamper collection if it is too rigid and constrains users, distributors, collectors (waste management establishments) and recyclers to fewer degrees of freedom. In such cases, by-passing of collections systems (including illegal deposition) may occur.

Box 5: Local collection systems for end-of-life EEE in Austria: Experiences from pilot projects

In three Austrian regions pilot projects for the collection of end-of-life EEE took place between 1994 to 1997. The first project started in 1994 in the city of Bregenz, in 1995 and 1996 pilot projects in a rural area around Weiz (Styria) and in suburban and rural areas around the city of Salzburg (Flachgau) followed. The main characteristics of these projects will be discussed in some detail. Special attention is paid to innovation aspects of WEEE-collection, especially how collection is organised, how financing is solved, which factors stimulated the success of collection, which kind of barriers emerged, and what was the role of regulation in the collection of WEEE.

Although each of the three projects was designed in a slightly different way, some main characteristics are common to each project: Collection of end-of-life EEE was restricted to household appliances, commercial users were not considered. Private households were guaranteed to return all kinds of EEE, irrespective of the age of the appliances, largely free of charge and on a voluntary basis. The implementation and organisation of the system was the responsibility of the local communities. The collection and recycling system was financed both by public subsidies and by communities (out of general waste charges).

End-of-life EEE is collected and pre-sorted at central collection centres in the communities (and run by the community) and transported to private recycling firms which already existed before the projects were started. They took over the recycling activity mainly on the existing technological base. Net costs for recycling were covered by the project budget.

Collection organisation and results

Four possibilities for returning end-of-life EEE were offered to households: Delivery to the main waste collection centre by households, return to distributors (retail trade), return of small appliances at decentralised collection boxes, and pick-up direct from households in the framework of bulk rubbish collections or the collection of environmental problematic products and substances. Apart from collection by retailers (which normally takes place at the purchase of new appliances) collection was organised by municipal authorities.

About two thirds of all end-of-life EEE which was collected during the pilot projects was returned to community waste collection centres, about a fifth was returned to retailers. Decentralised boxes for small end-of-life EEE were not accepted by households. High acceptance is reported for pick-up services although they were not carried out very often and in the case of Bregenz it was formally not allowed to return end-of-life EEE to a bulk rubbish collection.

Collection rates for end-of-life EEE (weight of collected end-of-life EEE per inhabitant and per year) could be raised considerably compared to the collection rate before the pilot project started. There are significant differences in collection rates between the three project regions. Highest collection rates (4.6 kg per capita and year) can be observed in the project region Bregenz which covers an urban area with about 28.000 inhabitants. Lower rates are reported from the Salzburg suburban and rural region Flachgau (135.000 inhabitants, 3.5 kg) and from the rural region Weiz (83.000 inhabitants, 3.0 kg). Differences in collection rates correlate with population densities.

The three pilot projects produced total collection costs per household and year of appr. 3 Euro. If a total collection of end-of-life EEE within the collection systems developed is aimed at, total costs are estimated to be approximately 5 Euro per household and per year.

Critical Success Factors

There are three factors which seem to be of particular importance for the success of end-of-life EEE collection:

First, information campaigns both before the start of the project and during the collection phase increase the participation by households. Measures to motivated households to participate in WEEE-collection may include both special information media (information folder, direct mailing, direct advice by waste management employees, stickers at retail traders) as well as general media (newspapers, radio, local television etc.).

Second, households should be enabled to bring back their old appliances free of charge. Collection centres should have convenient opening hours and at the collection sites information by qualified personnel should be offered.

Third, the channels by which households can return their old appliances are of crucial importance. In the case of the Bregenz and Flachgau projects, pick-up services showed a high collection rate although they were not intended to be used as a main collection channel of end-of-life EEE. Systems demanding users to bring their appliances to collection centres on their own represent a barrier and reduce the willingness to participate in collection. This is especially true for small appliances.

The role of regulation

The main reason for starting the three pilot projects was gathering empirical information on organisational and financial issues of WEEE-collection as a preparation for future regulations on the recycling of end-of-life EEE. Information from these pilot projects was used for the design of a guideline by the Austrian ministry for the environment on the recycling and collection of EEE. The projects themselves were not affected by regulation in force in the context of collection. Some regulation activities affected the recycling of end-of-life EEE, however (concerning the treatment of hazardous substances and a draft on the treatment of end-of-life EEE – ÖNORM “ 2106 and 2107 – which came into force in 1998).

General assessment of Austrian pilot projects

The main lessons which can be learned from the three Austrian pilot projects on the collection of end-of-life EEE are the following:

Information plays a critical role and should be circulated both before the start of a special collection project as well as during the collection phase.

Collection rates for end-of-life EEE are higher in urban than in rural areas; this may, in part, reflect different per capita allocation of EEE in urban and rural areas.

Direct collection from households by a pick-up service guarantees highest collection rates. This form of collection is associated with high operating costs, however. A regular but not too frequent pick-up service for different kinds of waste (with pre-information on pick-up dates) would allow costs to be reduce.

Charges for returning old appliances to collection centres will diminish the willingness to participate and should therefore be avoided.

Some pre-sorting by users (e.g. separating cables from appliances) would facilitate transportation and pre-sorting at the collection centre.

Collection costs are fairly low and could be financed by a slight increase in general municipal waste charges.

Box 6: WEEE-collection in Sweden: a state-of-the-art example

In 1993, a network of recycling stations for end-of-life EEE was established in Sweden. The purpose of the recycling stations is to collect and sort end-of-life EEE from private customers (households) and carry these appliances to the recycling plant of Stena Technoworld (see Box 4). The network was founded by Stena Technoworld, the leading recycling company of WEEE in Sweden in co-operation with local communities. Today more than 100 recycling stations exist, some of them located in Denmark and Norway.

Organisation of recycling

In Sweden, the majority of communities has organised in co-operation with Stena Technoworld recycling systems, where end-of-life EEE from private households is being collected. The recycling stations are operated by local communities of firms commissioned by the communities. The costs for running these yards and for further treatment are covered by communities who finance these costs by a special tax from every household. The payment of the tax entitles each household to bring a certain amount of end-of-life EEE free of charge to a recycling centre. Transport of end-of-life EEE from households to the recycling stations has to be organised by each household individually. There is no pick-up service. Companies may deliver their end-of-life EEE directly to qualified recyclers, like Stena Technoworld (and are, thus, directly liable for costs).

As an average for the last three years, about 1.5 kg of WEEE has been collected per household and year. The range of costs for recycling varied between 5 and 10 SKr (0,5 to 1,1 Euro) per household and year. Costs for collection and recycling vary considerably among communities, depending on the dimension and the location of the community.

Transport from recycling stations to recyclers: GreenCollect

At the recycling stations, WEEE is collected, pre-sorted and stored. Transport from stations to the Stena recycling works is organised in a special way, called GreenCollect. This initiative of Stena Technoworld. intents to minimise the transport frequency by using only high volume carriers for the transport of WEEE, to utilise empty storage room of motor carriers, and provide special containers for the conveyance of WEEE.

GreenCollect is open to all Swedish carrying agents. On the one hand the system allows to minimise empty or only partly loaded drives of trucks, on the other hand it is an additional and calculable return for involved agents. Another advantage is that individual bargaining with every single community is not necessary, since all transport matters are agreed with Stena Technoworld according to a specific scheme.

Problems at the implementation and running of the system

The implementation in 1993 was supported by preceding information and training of responsible personnel by Stena Technoworld and also the first year of running the system was accompanied by this enterprise. Thus the implementation of the recycling system could be realised without problems.

But there is one major problem in running the system. This is the growing number of thefts of electronic parts during the night. As a consequence, electronic scrap has to be stored in lockable containers or indoors, resulting in higher costs. One indirect reason for this is supposed to be the decreasing time of product use and substitution of older products by more powerful ones. As a result, still functioning electronic appliances are returned to recycling yards, contributing to the illegal “reuse” of these products

The GreenCollect initiative has been running for five years now and there were some problems in the beginning. Stena Technoworld insisted on rather short transportation times between recycling yards and the recycling works in Bräkne Hoby, in Southern Sweden (about five days). For the carrying agents, which originally needed several weeks for the collection and delivery of recycling goods, it was a logistics problem to re-organise the routes and it took about one year to integrate “recycling routes” into regular transport routes in order to realise delivery times of less than one week. Today the GreenCollect system is fully accepted by the Swedish carrying agents.

The role of regulation

The collection system was built up before regulation on the recycling of end-of-life EEE came into force in Sweden. The proposed law on producers responsibility (Renhallningsförordning, SFS 1998) is expected to result in a significant rise in recycling rates and thus it is seen very positively by recyclers, waste management agencies and the carriers of end-of-life EEE.

The network of recycling stations has been established in 1993. From the consumers / households side it is seen as an economic and well functioning system and is fully accepted. The recycling system is financed by the communities, via specific fees from households.

The storage room at the recycling yard in Helsingborg has to be enlarged steadily, due to the growing amount of scrap, especially TV sets and monitors. The scrap is collected once a week via the GreenCollect initiative and usually there are no major problems concerning the arrangement of collection times or pre-selection of products.

2.4.4 Systemic Innovation to meet Regulation

In the following box an initiative is presented which took up the systemic innovation approach in order to significantly improve the whole system of electric and electronic equipment management from production via distribution and use to recycling and re-use.

Box 7: SCARE – Strategic Comprehensive Approach for EEE recycling and re-use

In July 1999 a project within the EUREKA umbrella action CARE "Vision 2000" was established. The projects aims to improve the production, use and recycling of EEE by a comprehensive, systems approach connecting and co-ordinating various actors. The project focuses on the whole life-cycle of EEE. The motivation for this project is the proposed Directive by the European Commission WEEE.

SCARE aims at achieving this goal by

co-ordinating existing projects and networks by providing an "one stop shop" for information on research and development projects in order to avoid duplication;

initiating research projects among the various partners as well as initiating real pilot applications;

eco-efficient technology transfer between countries, companies and research organisations.

Project participants stem from 14 European countries and cover various types of organisations (including most of the large EEE-producers such as Alcatel, IBM, ICL, Matsushita, Motorola, Nokia, Nortel, Philips, Siemens, Sony, 3M).

In order to stimulate system innovation in the fields of eco-design and end-of-life management, the following working areas had been defined and will be interconnected:

innovative product and/or system design

new production technologies

consumer behaviour

end-of-life management

and horizontal core competencies fulfilling support functions: information management, education and training, financial economical aspects

The role of regulation

The strategic background of the SCARE-project is the proposed EU-Directive on WEEE on the one hand and various general trends affecting the production, use and recycling of EEE on the other. Amongst others, these trends cover the reduction targets for various kinds of emissions defined in the Kyoto protocol; the need to break-through the long lasting discussion on how to build-up an effective EEE-recycling scheme; the need of SME and supply-companies to get prepared for new demands resulting from recycling issues; the possibility to use Europe's competitive strength in eco-design in the EEE-sector to raise competitiveness vis-à-vis the USA and Japan; and the general requirements for a sustainable development.

The concept of eco-efficiency and end-of-life management is aided by objective analysis and the setting of meaningful goals towards which the various actors may move jointly. Actors to which this initiative is addressed especially are public authorities, EEE-producers, refurbishers, recyclers, consumers as well as the general public.

2.5 CONCLUSIONS AND RECOMMENDATIONS

The recycling of end-of-life EEE is only 'one option among others' to reduce the negative impacts of WEEE on the environment. EEE-regulation should therefore not only concentrate on recycling issues but also aim to design other instruments as well in order to achieve the overall environmental objectives. Such objectives are e.g. general waste prevention, reduction of hazardous substances, increased ecological efficiency of production and distribution processes, and introduction of environmentally friendlier products (e.g. less energy consumption).

Generally it can be stated that WEEE recycling activities together with technological and/or organisational innovations have grown significantly over the last decade. Whereas at the end of the eighties and at the beginning of the nineties recycling opportunities were underdeveloped and the rise of WEEE was seen as a substantial problem, nowadays the public sphere (policy makers, municipalities, universities) and the private sphere (producers, recyclers, R&D institutions) are clearly better prepared to tackle this problem. Nevertheless the European situation is still characterised by significant regional disparities in the advancement of WEEE recycling.

Notable (but of course not sufficient) progress in innovative activities has been achieved in some European countries through a set of different driving forces, one of which is regulation. The different effects of regulation on innovation and other important driving forces are:

- Regulation I: The minimisation/ban of hazardous substances on national as well as European level through regulation entailed product innovation.
- Regulation II: As far as collection and sorting of waste in Europe is affected by regulation, organisational innovations were stimulated (e.g. refrigerators).
- Market forces accompanied by public schemes: Industry has reacted on the growing interest of consumers to buy environmentally friendlier products (environmentally friendlier product features as an added value) and introduced product innovations. "Green product" marketing strategies by firms are supported and accompanied by (public) eco-label schemes (e.g. the German "Blue Angel" or the EU "Eco-label").
- Cost cutting opportunities: Where industry can realise cost reduction, process innovations like energy efficiency improvement programmes or product innovations through the reduction of components/material variety have been carried through. These cost cutting strategies have been supported and accompanied by (public) environmental management schemes (e.g. the environmental management system EMAS or ISO 14001).
- Regulation III: Proposed regulation may serve as a driver for technological as well as organisational innovation. The announcement of regulatory activities is well perceived by the relevant industrial community and major industrial players may take action to develop their "own" solution. For example, establishing a company-owned recycling centre enables the company to gather information on opportunities and barriers as well as to be an informed and experienced negotiation partner vis-a-vis public (regulating) bodies. Voluntary agreements - unilateral agreements between companies (e.g. SCARE) as well as public voluntary schemes (e.g. eco-labels, EMAS) and negotiated agreements (e.g. waste management agreements)

between public authorities and industry – are also often initiated by anticipated regulation. Of course, announced regulation can also have the effect that concerned parties "freeze" their activities in order to avoid misled investments.

- Subsidies: National and/or European R&D programmes (e.g. European RTD Framework Programme) are an important driver for the development of highly advanced technological solutions when these developments are costly and risky (e.g. the research project DISCO).
- The general public climate: Nowadays, the concept of sustainability works – irrespective of its fuzziness – as a widely accepted societal orientation standard. Slowly but constantly a production-consumption-legislation system emerged which partly responds to the message of sustainable development.

Based on the relevant literature, the case studies and the expert interviews within this project, the following recommendations can be formulated:

i) According to the "complexity" of the EEE recycling system, the legal framework must focus not only on the involvement of the different types of actors. Especially the design of links/interactions between these actors – i.e. producers, distributors, users, collectors, recyclers – is of importance. Clearly defined <u>responsibilities</u> for the process of collection as well as clarity concerning the distribution of the <u>financial</u> burden allows the actors to develop appropriate measures.

ii) A high volume of returned WEEE is necessary for the efficiency of the whole recycling system. To ensure high volumes in the field of consumer products, <u>collection</u> should be very close to the households. The term "close" refers here firstly to return channels (decentralised collection facilities, pick-up services) and secondly to the provision of households with appropriate information (information folders, newspapers etc. on the one hand and qualified personnel in the collection centres on the other hand).

iii) Take back <u>fees</u> usually reduce the willingness of households to bring their end-of-life EEE to collection facilities. For some product groups (e.g. washing machines) a general tax on community level is reasonable (e.g. washing machines exist in nearly every household, which is not true for computers).

iv) The long term predefinition of collection and recycling <u>quotas</u> can be a helpful orientation for the different actors of the recycling system and stimulate innovation. But this topic should be handled with circumspection and care. Firstly, Europe-wide regulation has to take into consideration the given regional and national disparities in the advancement of WEEE recycling. Secondly, the views on the appropriate collection and recycling quotas (even in one single nation/region) differ widely. For both issues it seems to be appropriate for policy makers to enter into negotiation processes with producers, recyclers and municipalities on the one hand and follow a step-by-step introduction mode of collection/recycling levels on the other hand considering regional/national state of the art.

v) Not only the reduction of material variety should be targeted, but also the implementation of industry-wide <u>material information</u> systems which would ease the sorting processes substantially. It has to be stated that from industries' point of view such information systems are questioned.

Altogether it can be stated that in some European countries the awareness and the readiness of the different EEE recycling actors to act is sufficiently given. But of course, the opinions on what is desirable and where are the limits are widely differing. Nevertheless, a significant part of the relevant actors is strongly interested in European wide mid and long term orientation standards (e.g. industry because of the common market) and therefore generally welcoming regulation.

Bibliography

AEA Technology (1997): Recovery of WEEE: Economic & Environmental Impacts. Final Report. (A report produced for European Commission DG ENVIRONMENT). Brussels.

Ashford, N. A. (1993): Understanding technological responses of industrial firms to environmental problems: Implications for government policy. In: K. Fischer and J. Schot (eds.): Environmental Strategies for Industries. Washington D.C.: Island Press, 277-307.

BMU (1998): Verordnung über die Entsorgung von Geräten der Informations-, Büro- und Kommunikationstechnik. (Draft ordinance on the recovery of IT equipment). Bundesministerium für Umwelt, Bonn.

BMUJF (1996): Pilotsammlung von Elektrogeräten in Bregenz. Abfallwirtschaft Bd. 29. Bundesministerium für Umwelt, Jugend und Familie, Vienna.

BMUJF (1997): Entwurf zur Sammlung und Behandlung von Elektro- und Elektronikgeräten. (Draft ordinance for the collection and treatment of electric and electronic equipment). Bundesministerium für Umwelt, Jugend und Familie, Vienna.

Bontoux, L., F. Leone, M. Nicolai and D. Papameletiou (1996): The recycling Industry in the European Union: Impediments and Prospects. EUR 17271 EN IPTS, Seville.

Brousseau, E. (1998): The link between regulation and innovations: some preliminary remarks. In: IPTS (ed.) Towards a European Solution for the Management of Waste from Electric and Electronic Equipment. (A report prepared by the IPTS for the Committee on Environment, Public Health and Consumer Protection of the European Parliament). Seville.

Buchinger E., H. Fegerl, E. Fugger and C. Rammer (1999): Innovation in Recycling Industries: Electric and Electronic Equipment. Part 1 – Regulatory Context and Major Drivers. Report OEFZS-S-0013 Austrian Research Centers Seibersdorf.

European Commission (1998): Second Draft Proposal for a Directive on Waste from Electrical and Electronic Equipment. Brussels.

ENDS (1999): Danish electronic waste recycling law passed. Environmental Data Service Ltd.

ENEA (1995): Priority Waste Streams, Waste from Electrical and Electronic Equipment. (Information Document). Rome.

FEEI (1996): Comparison of Systems for Collection, Recycling and Disposal of End-of-life Electrical and Electronic Equipment. Vienna.

Fugger, E. and N. Schwarz (1999): Disassembly and Recycling of Consumer Goods. In: Proceedings of the European Conference on Recycling and Recovery - “R´99“. Geneva.

Hafkesbring et al. (1999): Abschätzung der innovativen Wirkung umweltpolitischer Instrumente in den Stoffströmen Elektroaltgeräte/Elektronikschrott.

Hannequart, J. P. (1999) Waste Recycling in European Law. In: Proceedings of the European Conference on Recycling and Recovery - “R´99“. Geneva.

Hemmelskamp, J. (1996): Environmental policy instruments and their effects on innovation. ZEW discussion Paper, Mannheim/Germany.

Hemmelskamp, J. and F. Leone (1998): The impact of EU-regulation on innovation of European Industry. Institute for Prospective Technological Studies, Seville.

Hemmelskamp, J., G. Licht, E. Oldenboom and J.W. Velthuijsen (1995): The Impact of Parameters provided by Environmental Policy on the Innovative Behaviour of Companies in selected European Countries. Foundation for Economic Research of the University of Amsterdam/ Zentrum für Europäische Wirtschaftsforschung Mannheim.

Houwelingen J.A. van (1998) The Evolution of Competencies in Recycling. PolyRec Recycling Adviezen Eindhoven.

IPTS (1998): Towards a European Solution for the Management of Waste form Electric and Electronic Equipment. (A report prepared by the IPTS for the Committee on Environment, Public Health and Consumer Protection of the European Parliament). Seville.

Jaffe, A. and K. Palmer (1996): Environmental regulation and innovation: a panel data study. Washington: RFF.

Jafffe, A., S.R. Peterson, P.R. Portney and R. Stavins (1995): Environmental regulation and the competitiveness of U.S. manufacturing: what does the evidence tell us? Journal of Economic Literature 33(1), 132-163.

Kemp, R. (1993): An economic analysis of cleaner technology: Theory and evidence. In: K. Fischer and J. Schot (eds.): Environmental Strategies for Industries. Washington D.C.: Island Press, 79-113.

Kemp, R. (1998): Environmental regulation and innovation: key issues and questions for research. In: IPTS (ed.) Towards a European Solution for the Management of Waste from Electric and Electronic Equipment. (A report prepared by the IPTS for the Committee on Environment, Public Health and Consumer Protection of the European Parliament). Seville.

Kemp, R., X. Olsthoorn, F. Oosterhuis and H. Verbruggen (1994): Policy instruments to stimulate cleaner technologies. In: H. Opschoor and K. Turner (eds.): Economic incentives and environmental policies. Kluwer Academic Publishers, Dordrecht.

Kemp, R., K. Smith and G. Becher (1999): How should we study the relationship between environmental regulation and innovation? Paper presented at the International Conference “Innovation-oriented Environmental Regulation: Theoretical Aprpoaches and Empirical Analysis”, Potsdam/Germany, May 27-29, 1999.

Lechner, P. (ed.) (1996): Elektrogeräte – Stand der Technik: Sammlung, Demontage, Verwertung und Wege in die Zukunft. Waste Reports 1/96.

Linde, C. van der (1994a): Competitive implications of environmental regulation in the refrigerator industry. Management Institute for Environment and Business, Washington.

Linde, C. van der (1994b): Competitive implications of environmental regulation in the dry cell industry. Management Institute for Environment and Business, Washington.

Long, L.B. (1997): Environmental regulation: The third generation. *The OECD OBSERVER* No 206, June/July.

MEB (1994): Competitive implications of environmental regulation. Management Institute for Environment and Business, Washington.

OECD (1997): Environmental Policies and Innovation: Analytical Framework. Paris: OECD.

Rothwell, R. (1992): Industrial innovation and government environmental regulation: some lessons form the past. Technovation 12(7), 447-458.

SAEFL (1998): Ordinance on the return, the taking back and the disposal of electrical and electronic appliances. Switzerland.

Scheidt, L.-G. and Zong Shuqiang (1994): An Approach to Achieve Reusability of Electronic Modules. In: Proceedings, International Symposium on Electronics & the Environment.

PART 3

RECYCLING IN THE BUILDING AND CONSTRUCTION SECTOR

HUGO VERHEUL, ARNOLD TUKKER (TNO)

3.1 INTRODUCTION

3.1.1 Overview of the building and construction sector

Compared to e.g. the electronics sector and paper sector, the building sector is relatively complicated when it comes down to recycling activities. First, the building and construction sector covers many different activities. They range from conventional house building, utility building to road construction and similar activities. The waste flows generated by the sector are equally diverse. They range from stony construction waste, wood, plastics, and even road construction material such as asphalt. Obviously, all these materials demand their own waste management and recycling strategy. Furthermore, the construction sector has one important feature that the above mentioned electronics and paper sector don't have. The construction sector has proven to be able to use large quantities of waste that is produced in totally different societal sectors as a secondary raw material. Thus where the electronics and paper sector may be able to ensure that materials from their product cycle are reused elsewhere, or use waste materials from their own product cycle, the construction sector can use waste materials from other product cycles. Finally, the relation between the actors involved in the building- and construction process is rather complicated. Also this has a clear influence on the feasibility of the implementation of recycling schemes and innovation processes.

The building- and construction sector can be divided in two ways. First, the sector can be divided according to the *object* of building. Second, the sector can be divided according to *activity* in the production chain.

Concerning the first division, within the sector usually the following parts are discerned:

1. The housing and utility sector. This sector includes:
    a. the housing sector, which provides the construction, maintenance and renovation of houses.
    b. the utility sector, which provides the construction, maintenance and renovation of offices, industrial buildings, and similar buildings.
2. The infrastructure sector. This sector includes:
    c. road construction;
    d. other specialist infrastructure (artefacts such as bridges and tunnels, channels etc.)

Concerning the second division, one has to make a distinction between:

1. the commissioner of a building- and construction project. They can be parties such as authorities or authority-related organisations (such as housing corporations), private companies, or investors in real estate;
2. the designers. The designers may act under the same umbrella company as the constructor of the object (see below), but this is not necessarily the case. Often, independent architects or consulting engineers are responsible for the design, and the constructor is selected in a separate bid;

3. the contractor (constructor). The contractor is responsible for executing the factual construction work. He is selected by the commissioner, usually in an open tender procedure, and has to perform the work within the specifications of the tender document (which is based on/includes the design mentioned above). Consortia of contractors execute particularly the large projects. Even in smaller building projects subcontracting of specialised tasks (e.g. painting, delivery of the electrical system) usually takes place. During the construction work, already various waste flows are generated. Such wastes are dealt with by the waste treatment system discussed under point 7
4. the building supply industry. Obviously, all materials and building elements used in the construction work have to be produced, usually by other parties than the contractor himself. A large number of supply chains can be mentioned, ranging from the cement chain (quarrying, cement kilns, concrete producers) to specialist chains such as (e.g. window) frame production (e.g. oil and salt extraction, chlorine production and ethene production, PVC production, PVC window frame production);
5. usually, the raw material producers (such as cement production and quarrying) are mentioned as a specialist category in this building supply industry. The may apply several secondary raw materials from other industries, for example power generation plants who produce coal fly ash;
6. the maintenance sector. The maintenance sector is most important for infrastructural works; the contractors already mentioned under point 3) mostly execute renovation of buildings.
7. the demolition sector. Several companies are specialised in dealing with constructions at the end of their useful life.

3.1.2 Structure of this section

The structure of this Part of the Report is as follows:

- Section 3.2 describes the sector stakeholders and their linkages;
- Section 3.3 identifies the main drivers and barriers for construction and demolition waste recycling;
- Section 3.4 analyses three examples of innovations, and the effect of regulations on their development;
- Section 3.5 draws the main conclusions and gives policy recommendations.

3.2 SECTOR STAKEHOLDERS

The main stakeholders regarding construction and demolition waste recycling are:

- The firms in the construction and demolition industry themselves, as mentioned in Section 3.1.1. Most firms in the construction and demolition industry are small, but in almost every EU country there are some large firms with a considerable market share.[9]
- Their branch organisations, which reflect the heterogeneity of the construction sector. Most countries have different branch organisations for e.g. cement producers, architects and designers, rubble crushing firms, et cetera.
- Government organisations. At the national level environmental and housing departments are involved in construction and demolition waste recycling. The involvement of regional and local governments depends on the level of decentralisation in a country. In Denmark, for example, local authorities have a lot of discretion in setting environmental and recycling demands.[10] Public actors also play a role as market parties, especially in road construction.
- Universities and research institutes. Both university departments and specialised building research organisations are a major source of innovation in the construction industry.

Regarding networks between the stakeholders, the following remarks can be made:

- As Section 3.1.1 already indicated, subcontracting is a common practice in the construction industry. The typical work division between contractors, subcontractors and supervisors differs throughout the EU; see Tukker (1999) for a more extensive description.[11]
- Most relevant subsectors in the building and construction industry appear to be well organised. However the total number of branch organisations involved still makes it difficult to manage policy initiatives in the sector.
- In most countries, housing and environment is the responsibility of separate departments, which sometimes causes coordination problems.[12]

---

[9] Tukker, Innovation and Recycling: the Building and Construction Sector, TNO-STB 1999.

[10] Van Hal, Sustainable Building in Denmark, Delft University of Technology, internal paper.

[11] Tukker, Innovation and Recycling: the Building and Construction Sector, TNO-STB 1999.

[12] Van Hal, Sustainable Building in Denmark, Delft University of Technology, internal paper.

3.3 DRIVERS AND BARRIERS FOR RECYCLING

3.3.1 Technological versus organisational innovations

According to several respondents, technological innovations are *not* an important limiting factor in the optimisation of construction and demolition waste recycling.[13] The recycling of construction and demolition waste requires technologies such as crushers, sieves and other sorting equipment. These are not very complicated technologies, and they appear to be available or they can be readily developed. The availability of technologies for construction and demolition waste recycling also appears from a vast number of demonstration projects, which have shown the potential for recycling. In Denmark, for example, two demonstration projects have been carried out in which an old building was demolished and the materials were re-used for a new building. The projects showed that is possible to recycle a considerable amount of the building material: 75 per cent of the wood was recycled, 80 per cent of the slate, and 50 per cent of the old bricks. [14] In The Netherlands, the building of the Ministry of the Environment is made out of 100 per cent recycled concrete.[15]

Organisational innovations, or rather the lack of them, appear to be a much more important barrier to further recycling of construction and demolition waste. The aforementioned Danish demonstration project concluded that the organisation of the demolition and rebuilding process was the most difficult aspect. The separation of different waste streams during the demolition process and the matching of supply and demand for recycled materials appear to be a major barrier for recycling. Several interviewees (refs) confirm this. A major overview of construction and demolition waste recycling activities and related policies also sees selective demolition (the on-site separation of waste streams, see section 4.2) as an important success factor for construction and demolition waste recycling.[16]

3.3.2 Landfill options

The alternatives to the recycling of construction and demolition waste are in incineration or dumping the waste on landfills. According to respondents, the possibilities of landfilling are one of the most important factors influencing the amount of waste that is recycled.[17] These possibilities vary from country to country. Several EU countries impose a tax or a partial ban on waste that is offered to a landfill site (see figure 3.1).

---

[13] Hobbs, Van der Waal, interviews.

[14] Hal, Anke van, Casus: Sustainable building in Denmark (Recycling of Building Elements), internal paper for PhD study, Delft University of Technology, 1999, Lauritzen, Erik K., and Torben C. Hansen, Recycling of Construction and Demolition Waste 1986-1995, Danish EPA, 1995.

[15] Van der Waal, interview.

[16] Symonds, Construction and demolition waste management practices, and their economic impacts. Report to DGXI, European Commission, 1999.

[17] Mulcahy, Van der Waal, Rasmussen, interviews.

An economic analysis of the re-use and recycling of construction and demolition waste in the Symonds report confirm this.[18] The report distinguishes three technological levels of recycling activity in a country:

1. Use of mobile crushers and sieving plants;
2. 1 plus metal removal and more complex sieving and sorting;
3. 2 plus hand sorting, washing plant, and facilities for recycling other waste streams such as wood.

The report concludes that, although there are regional differences related to population density, there is a strong correlation between the technological level and the possibilities for landfilling. The results are summarised in figure 3.1.

Figure 3.1.

Correlation between technological level of recycling and landfill possibilities.

(source: Symonds 1999)

country	**technological level**	**cost/ban of landfill**
Spain	1	2-5 EURO/tonne (in Catalonia)
Italy	1-2	2.25 EURO/tonne
United Kingdom	2	~16 EURO/tonne
France	2	12-13 EURO/tonne
Germany	3	ban on mineral demolition waste
The Netherlands	3	ban on waste that can be recycled
Denmark	3	tax: 50 EURO/tonne

3.3.3 Technical standards

Respondents also mention technical standards as a barrier to recycling.[19] Technical standards play an important role in the construction industry, due to the importance of safety and long-term quality. There are different types of technical standards:

- recipe-based, prescribing the use of certain raw materials for the making of construction materials. In The Netherlands, for example, a maximum of 20 per cent of recycled material may be used as raw material for concrete.[20]

---

[18]Symonds, Construction and demolition waste management practices, and their economic impacts. Report to DGXI, European Commission, 1999..

[19]Mulcahy, Nielsen, interviews.

- standards describing the physical properties of the materials that are produced. Denmark, for example, has a standard prescribing the minimum and the maximum size of the stones used in asphalt.[21]
- standards prescribing the required performance of the materials, such as strength, brittleness, et cetera.

It will be clear that especially the first type of standards is a barrier to innovation. On the other hand, technical standards are needed to guarantee safety and quality. Section 3.5 provides some recommendations on how the detrimental effects of technical standards on innovation can be reduced.

3.3.4 Price of the recycled material

The demand side of the building and construction sector also provides drivers and barriers for recycling. Especially for higher-grade recycling, i.e. the re-use of granulated construction and demolition waste in concrete, the economical barriers are large. The Symonds report concludes that, with the exception of The Netherlands, no EU country will achieve a situation where recycled materials represent a significant share of the total aggregates market, and that this is due to the high price of recycled material relative to primary materials.[22] Section 4.1 also deals with this issue.

[20] Stuip, J., Experiences with the application of secondary materials in the building and construction industry, In: Product innovation and eco-efficiency, edited by Judith Klostermann and Arnold Tukker, Dordrecht: Kluwer, 1998.

[21] Nielsen, interview. See also section 4.3 of this report.

[22] Unfortunately, it has not been possible to collect data on prices of recycled versus primary waste within the context of this project.

3.4 REGULATIONS AND INNOVATIONS: THE LINKS – EXPLORED THROUGH INDUSTRY EXAMPLES

3.4.1 Example 1: Korrelmix® – quality certification for recycled aggregates

Description of Korrelmix

Korrelmix is a quality certification system for granulated demolition waste. The stony fraction of demolition waste is granulated by so-called rubble crushing firms. The granulated material is reused mainly as gravel replacement in the construction of fundaments of roads. The use as secondary aggregate in concrete is also possible, but this is not yet applied on a large scale (see below).

The quality certification system of Korrelmix consists of environmental as well as technical demands. Rubble crushing firms who meet those demands are allowed to use the brand name Korrelmix® for the granulated material that they sell. The firms are inspected regularly by employees of the branch organisation BRBS (Association for the Interests of Recycling of Construction and Demolition Waste).

Development of Korrelmix

The development of Korrelmix has been an initiative of the industry itself. It was initiated by the branch organisation for rubble crushing firms (BRBS) in the early 1990s. The reason for this was a market demand for certified aggregates. Customers lacked trust in the quality of the recycled aggregates. A certification system would increase the customers' confidence.

The development and diffusion of the certification system has been strongly boosted by its incorporation in the Implementation Plan for Construction and Demolition Waste, which was issued in 1993. The plan was a voluntary agreement between government and industry, involving several branch organisations, the Ministry of Housing and the Environment, the Ministry of Transport, and the representative body of the regional governments (IPO). Its official goal was to achieve 90% reuse or recycling and 5% prevention of construction and demolition waste. To achieve this goal, 70 actions were defined. Other actions include waste prevention in the design phase, research into the chemical and physical quality of sieved material, and the development of performance-based technical standards.[23]

One cluster of actions within the plan concerned the development and implementation of a quality certification system for recycled aggregates. Within this cluster, the Korrelmix certification system was further developed. Also, the public market parties who were involved in the Implementation Plan for Construction and Demolition Waste committed themselves to the use of certified recycled material for road building, thus creating a guaranteed market for Korrelmix aggregate. This was an important success factor for Korrelmix, because in general recycled aggregates more expensive than primary aggregates.

[23] Ministry of Housing, Spatial Planning and the Environment, Spearheads Construction and Demolition Waste, The Hague 1998 (in Dutch).

The Korrelmix certificate has diffused rapidly. Eventually, 90 to 95 per cent of the rubble crushing firms had a Korrelmix certificate. Besides its incorporation in the Implementation plan, three other factors stimulated the diffusion of the Korrelmix quality system. First, the BRBS obliged its members to implement the Korrelmix certification. Second, crushing firms experienced that the Korrelmix certificate made it easier to receive an environmental permit, although officially the certificate and the permit were not connected. The third driver was the landfill ban for waste that can be recycled, which has been implemented in 1997. Since then it is forbidden to dump construction and demolition waste on landfill sites, unless it can be proven that no other use can be found for it. According to the Dutch Ministry of the Environment, this landfill ban has had only limited effects on innovations, since it was implemented when 50 per cent of the crushing firms had already stopped bringing construction and demolition waste to landfills.

In July 1999, the Korrelmix certificate will be replaced by an independent certification system, which is part of the new Building Substances Decree (Bouwstoffenbesluit), which is effective since January 1999. This independent certification system is a reaction to the increasing market demand for an independent system, rather than a certification system from the industry itself. In particular, it is meant to gain confidence from local governments in recycled aggregates. The demand for an independent certification system had already resulted in an official technical guideline for recycled aggregates in 1995. The new certification system is partly based on the Korrelmix system. The environmental aspects of the new certification system are based on the Korrelmix system, whereas the technical aspects have been taken over from the 1995 guideline.

Effects of Korrelmix on recycling

The policy aim of Implementation Plan for Building and Construction Waste had already been achieved in 1996: over 90% of the construction and demolition waste is reused.[24] In the 1980s this was around 60%.[25] However, most of the construction and demolition waste is being used in the construction of fundaments of roads. It is only marginally applied in higher-grade applications such as concrete for housing. The main reasons for this are the higher price of recycled aggregated compared to primary materials, and technical guidelines which allow the use of no more than 20% recycled material in concrete for housing. It is possible, however to receive exemption from these guidelines for demonstration projects. For example, the Dutch Ministry of the Environment, as already mentioned, is made out of 100% recycled concrete.

The main effect of the Korrelmix brand name and quality certification system to the increased recycling of construction and demolition waste is that it has helped to create a market for recycled aggregates. The certification system has created confidence by road building contractors in recycled materials. This has enabled them to guarantee the purchase of certified materials.

However, its effects have been limited to application in road construction: Korrelmix has not contributed to an increase in the use of recycled materials in concrete. This is

[24] Since the amount of comstruction and demolition waste prevention is not monitored it is not known if the 5% prevention goal has been realised.

[25] Ministerie van VROM, Speerpunten Bouw- en Sloopafval, Den Haag 1998.

probably due to the fact that private contractors mainly carry out housing and utility building, whereas in road construction the main contractors are mostly public organisations. These public organisations are inclined to support government policies by using recycled materials, even at a higher cost. *The fact that the application of recycled aggregates in concrete is still very limited shows that a certification system like Korrelmix is in itself not sufficient to overcome barriers like the higher price and technical guidelines.*

<u>Relationship between regulation and the Korrelmix innovation</u>

The description of the development of Korrelmix already showed that is closely related to government regulation in the field of construction and demolition waste recycling. The initiative to develop a quality certification system has not been taken in reaction to regulation. Its incorporation in the Implementation Plan for Construction and Demolition Waste, however, has been a critical success factor. This plan, which can be seen as a voluntary agreement, allowed for such agreements as the purchase guarantee given by public contractors.

The 1997 landfill ban has not had a great effect on the development of Korrelmix. It did have an effect on the further diffusion of the innovation, because it enforced crushing firms to recycle the waste that they collected.

The development of the independent certification system within the Building Substances Decree shows that Korrelmix in turn has also influenced regulation. The new certification system is partly based on guidelines from Korrelmix.

<u>Conclusions</u>

The following conclusions can be drawn from this case:

1. A quality certification system can stimulate confidence and thus market demand for recycled aggregates in the building and construction sector. Given the organisational complexity of the construction industry (see section 3.1.2 of this report) it makes sense to connect such a certification system to the product rather than the firm itself.
2. Government can also utilise its role as a dedicated market party to stimulate innovations in construction and demolition waste recycling.
3. The openness and flexibility of voluntary agreements allows for such measures as a purchase guarantee, in which the government role as a dedicated market party may take shape.
4. Technical guidelines are a barrier to further use of recycled aggregates. This barrier can be overcome by proper exemption guidelines, which create *niches* for innovations. An example is the building of the Dutch Ministry of the Environment.
5. The influence of legal regulations such as a landfill ban appears to confine itself to the later diffusion stages of the innovation process, enforcing late adopters and laggards to implement the innovation. This is because bans are only politically acceptable when sufficient alternatives to landfilling are available.

3.4.2 Example 2: Selective demolition in the United Kingdom

Description of selective demolition

Selective demolition is the organised removal and/or treatment of certain materials and components prior to the demolition of the main structure. Different materials, such as concrete, masonry, metals, and wood are collected separately instead of being sorted afterwards or resulting in a mixed waste stream. Materials may be removed because of their own economic value, or because the failure to treat or remove them will contaminate or otherwise reduce the value of the resultant waste stream.[26]

Selective demolition as a practice is still in a very preliminary stage in the United Kingdom. It happens incidentally, for example when valuable materials can be collected, such as old bricks that can be used for the restoration of buildings with an architectural value.

Selective demolition is a diffuse practice, which makes it difficult to pinpoint its conception and development. Neither are there specific guidelines or regulations to stimulate or enforce selective demolition, although it is in principle supported by the UK Department of Environment, Transport, and Regions. This case study will therefore focus on two demonstration projects, which are aimed at investigating the possibilities of selective demolition and at knowledge transfer to the industry.

Demonstration projects related to selective demolition

Project 1: Identifying waste streams and options for selective demolition in Nottingham

The first demonstration project is initiated by the Nottingham Trent University. It will be investigating construction and demolition waste streams in and around Nottingham on a very detailed level. The project looks at waste streams from a holistic viewpoint, including construction and demolition sites as well as landfill sites. Besides identifying the waste streams, the project also aims to identify the reasons why construction and demolition firms are throwing away certain materials. To this aim, focus group sessions will be organised with all the parties of the Nottingham construction industry. In the third place, options for recycling, waste prevention, and the pre-sorting of waste materials. The project will take 2 to 3 years, including the dissemination of results.[27]

According to the project leader, projects like this are partly "reinventing the wheel".[28] Similar investigations have been done in other countries like Germany and The Netherlands. The main aim of this project is therefore to convince the industry of the feasibility of selective demolition and other recycling activities, by showing the economic advantages of certain options.

---

[26] Hal, Anke van, Casus: Sustainable building in Denmark (Recycling of Building Elements), internal paper for PhD study, Delft University of Technology, 1999. Lauritzen, Erik K., and Torben C. Hansen, Recycling of Construction and Demolition Waste 1986-1995, Danish EPA, 1995. Symonds, Construction and demolition waste management practices, and their economic impacts. Report to DGXI, European Commission, 1999.

[27] Trevorrov, A., 1999, The development of a demonstration project to increase the use of recycled material resources in construction, project proposal, Nottingham Trnet University.

[28] Trevorrow, interview.

The project is financed from the Landfill Tax Credit Scheme. A landfill tax has been implemented in the United Kingdom in 1996. The current tax level is 2 pounds per tonne for inert waste and 10 pounds per tonne for non-inert waste. Within the Landfill Tax Credit Scheme, up to 10% of the tax revenues are diverted to projects to improve construction and demolition practices. This includes recycling activities, but e.g. also projects to reduce nuisance from demolition sites. The Landfill Tax Credit Scheme is executed by the Environmental Trust, a non-departmental government organisation. One of the conditions for the financing of projects from the credit scheme is the co-financing of projects by third parties.

One of the participants of the Nottingham project is Tarmac Recycling, a daughter company of Tarmac PLC, the largest construction firm in the UK with 24,000 employees. Tarmac Recycling is part of the firm's quarrying branch. It was established in 1996, as a reaction to the implementation of the landfill tax. Tarmac expected a reduction of the demand for quarried materials and an increase in the demand for recycled materials. In order to maintain its overall market share, it was decided to establish Tarmac Recycling. The firm collects inert waste, pre-sorts and crushes it at its own site, and produces recycled aggregate. At the moment, selective demolition is only carried out incidentally by Tarmac. The main barriers are the lack of demand for reused materials and the demand for speed in the demolition process. The demolisher has to be on and off the site as quickly as possible, which leaves little room for the sorting of waste streams.[29]

Project 2: Waste on the Web - Materials Information Exchange in Leicester

The second project is an initiative of the Leicester City Council, as a contribution to its local environmental agenda. On demolition sites of the city, a demolition notification is now legally obliged. After the notification, the possibilities for reuse of certain materials are investigated. This investigation is carried out in combination with the safety assessment, which already was obligatory. The aim of the project is to support selective demolition by finding simple and economically viable sales outlets for materials at the demolition site.

For the identification of outlets of materials from demolition, the City is using the Materials Information Exchange (MIE), which has been set up in 1997 by the Centre for Waste and Recycling of the Building Research Establishment. The MIE is an Internet site on which firms or individuals can offer or request certain reused construction materials. The Internet site serves as an aid to match supply and demand of reusable materials from demolition.[30]

If the project proves successful, Leicester City Council will also offer the identification of options for reuse to private contractors. This can only be done on a voluntary basis, since there is no legal framework enabling the Council to oblige private contractors to carry out such an assessment. An obligation to make such an assessment or a more comprehensive demolition plan is currently being considered by the UK Department of the Environment, Transport, and Regions.

---

[29] Egan, interview, confirmed by Hobbs, interview, Mulcahy, interview, and, for Denmark, Lauritzen, Erik K., and Torben C. Hansen, Recycling of Construction and Demolition Waste 1986-1995, Danish EPA, 1995

[30] The internet address is: http://www.bre.co.uk/bre/breweb/breweb.html

Drivers and barriers to selective demolition

As said before, selective demolition is still in a preliminary stage in the United Kingdom. The main drivers for selective demolition are:

- The existence of niche markets for valuable materials;
- The landfill tax, which makes reuse and recycling economically more attractive;
- Demonstration projects like the ones mentioned above.

However, there are also some serious barriers for the further diffusion of selective demolition:

- The demand for speed in the demolition process, which leaves little time to identify materials for reuse. According to the interviewees, this is the most important barrier to selective demolition.
- The knock-on effect of current building permission procedures: once the contractor has been given the necessary permissions, the old building has to be demolished as quickly as possible. This reinforces the demand for speed.[31]
- The construction industry's lack of awareness of the potential financial benefits of selective demolition.
- The uncertain around markets in reused materials.
- Lack of standardisation of materials, especially in older buildings. This makes it more difficult to reuse materials such as bricks, because of the variation in size and other characteristics. Newer buildings are more standardised, so this problem will gradually be solved.[32]
- Lack of technical standards for reused or recycled materials. This creates reluctance with contractors due to potential liability claims.

Relationship between regulation and selective demolition

The main current government policies which affect selective demolition have been mentioned above:

- the Landfill Tax;
- the Landfill Tax Credit Scheme, which is an important financial resource for research and demonstration projects relevant to selective demolition.

The demonstration project in Leicester also shows that regulation can also counteract the demand for speed. Contractors could be obliged to notify demolition projects or to make a demolition plan in which they identify options for reuse and recycling.

[31] Mulcahy, interview.

[32] Mulcahy, interview.

Conclusions

The following conclusions can be drawn from this case study:

1. The main barriers for further diffusion of selective demolition are the demand for speed in the demolition process and uncertainty regarding the demand for certain materials to be reused.
2. If selective demolition is seen as an (organisational) innovation, its further development concentrates on improving the matching of supply and demand of reused materials. This is done by investigating waste streams and by initiatives like the BRE Internet site.
3. The main driver behind the further development of selective demolition appears to be universities and research institutes, rather than the industry itself.
4. Given the complexity of selective demolition and its preliminary stage of development, legal regulations are not an appropriate way to support construction and demolition.
5. The demand for speed can be counteracted by such government measures as an obligation to notify demolition activities or to make a demolition plan.
6. The financial support of demonstration projects appears to be an important policy instrument in this stage of the innovation process. The Landfill Tax Credit Scheme shows that such support can be connected to other instruments.

3.4.3 Example 3: In-situ recycling of asphalt in Denmark

Description of in-situ recycling

Asphalt is the common term for mixtures of a binder and a granular material of mineral origin, usually crushed natural stone. Bitumen, or a mixture of bitumen and water is used as a binder. Asphalt is used as wearing course or as base course material in road construction. Waste asphalt is generated when roads are reconstructed, re-routed or re-paved. In Denmark, the total amount of asphalt waste was 853,000 tonnes in 1997. This is around 25 per cent of the total amount of construction and demolition waste.

Waste asphalt can be recycled in two ways: in mobile plants on the location where the new road is constructed (*in-situ* recycling), and in stationary asphalt plants (*ex-situ* recycling). In both cases, the old asphalt is crushed and heated, and mixed with binders such as bitumen or cement and (Lauritzen and Hansen 1997, Symonds 1999). This case concentrates on the innovations related to the in-situ recycling of asphalt in Denmark.

Advantages of in-situ recycling are:

- the demand for bought-in (usually primary) aggregate is reduced;
- fewer lorry movements are needed;
- the process is quicker, thus reducing disruption to traffic;
- costs are usually lower than for traditional construction methods.
- it enables asphalt recycling in areas where stationary plants are absent.

The recycling of asphalt is common practice in Denmark. Up to 100 per cent of the old asphalt is being recycled. Approximately 30 per cent of the granulate for new asphalt consists of recycled asphalt. No statistics are available on the ratio between in-situ and ex-situ recycling, but experts estimate that the majority (70 to 80 per cent) of the asphalt is recycled in stationary plants, and that this ratio has not changed dramatically over the last years.

Development and use of the innovation

Recycling of asphalt in Denmark started out in 1980, when the Danish Road Directorate and representatives of Asfaltindustrien, the branch organisation of the asphalt producers, went on a joint study trip to the United States, to investigate the possibilities of asphalt recycling. The main aim of the study trip was to find out whether recycled asphalt would be able to provide the same quality as primary asphalt. This was especially important for the asphalt industry, which would not accept any quality loss due to the use of recycled material. For the Danish Road Directorate, the main reason to investigate the possibilities of asphalt recycling at that moment were financial. Denmark has little natural resources for primary granulates, and would therefore be forced to import raw materials for asphalt. The recycling of asphalt appeared to be an attractive alternative.

In-situ recycling of asphalt was introduced in Denmark around 1990[33], when 2 mobile plants were imported from an Italian firm. One plant was bought by a single asphalt producer, the other by a small consortium of firms. Government actors have not financially supported the purchase. The reason to implement these mobile plants was a large re-paving project in the Copenhagen area. The old asphalt of the roads to be re-paved had a very homogeneous structure, i.e. the variety in the size of the stones in the asphalt was small. This made the project technically particularly suitable for in-situ recycling, because there was less need to add primary granulate to the new asphalt. Besides these technical reasons, the financial advantages due to a reduction of transport costs were the main reason to buy the mobile recycling plants.

In addition to the purchase of the mobile asphalt recycling plants, the Danish asphalt industry has developed several process developments to improve the in-situ recycling of asphalt. These innovations include the infrared heating of the old asphalt. These innovations have been developed by the industry itself, and were mainly aimed at improving the technical performance of the mobile recycling plants.

After finishing the aforementioned project, the Danish home market appeared to be too small for 2 mobile recycling plants. One of the plants has regularly been brought into action in other Scandinavian countries. The Asfaltindustrien estimates that the market share of in-situ recycling will remain the same in the coming years. Mobile recycling will primarily be applied for large projects where the old asphalt has a homogeneous structure, such as highways. The application range of mobile recycling is also limited because Denmark has good facilities for ex situ recycling. There are around 50 stationary asphalt plants, which are all equipped to use old asphalt as raw material. The implication is that the logistical advantages of mobile plants are limited.

[33] The respondents were not sure about the exact year. Pihl, Nielsen, interviews.

Effects of regulation on the innovation

Government regulations have not specifically supported the development and use of in-situ recycling of asphalt, in distinction of ex-situ recycling. The decision to use either in-situ or ex situ recycling is made by the contractors that build the roads, based on technological and financial considerations rather than policy incentives.

Innovations in the recycling of asphalt as such, however, have been supported by several policy measures. *In the first place, the technical standards for asphalt had to be slightly modified in order to allow for recycled asphalt*. The existing tolerance for the variety in the size of the stony particles was too small for recycled asphalt. Once it was clear that the quality of the new asphalt would not deteriorate due to the use of recycled asphalt, it was decided to change the standards. The decision-making concerning these standards took place in Road Working Group 3.10, in which members of the Road Directorate, the asphalt industry, and consultancy firms are represented.

The most important incentive for the recycling of asphalt, however, has been the landfill tax that has been implemented in 1987. The tax level has increased continuously, and is now 50.43 Euro per tonne. The costs for offering construction and demolition waste for recycling on the other hand is approximately 5.38 Euro per tonne.

Conclusions

The implementation of in-situ recycling and the subsequent process innovations in Denmark have been very much an industry initiative. Government policy has effectively supported the recycling of asphalt by changing the technical standards and by implementing a landfill tax. The direction of the technological response of the asphalt industry has not been influenced by government policy. This is due to the characteristics of both the landfill tax and the technical standards. These standards only describe the required characteristics of the end product, and not of the production process.

In this case, this has proved to be a good policy strategy, because it has resulted in the development of two complementary technologies: in situ and ex situ recycling. It is doubtful whether such a structure would have evolved had government actors supported a specific technology. A precondition for such a policy strategy, however, appears to be sufficient technological competence of the sector itself.

3.5 CONCLUSIONS AND RECOMMENDATIONS

the following conclusions can be drawn regarding the relationship between regulation and innovation in construction and demolition waste recycling:

1. *Technological innovations do not play an important role in the optimisation of construction and demolition waste recycling*. The availability of technologies for the processing of waste streams and the production of recycled aggregates is not a bottleneck. Organisational innovations such as certification systems and logistical improvements, aimed at improving waste collection practices and increasing the market demand for recycled materials are a more dominant factor affecting the potential for recycling.
2. The complex and heterogeneous character of the building and construction sector complicates the development of effective regulations and other policy instruments.
3. There is a two-way relationship between organisational innovations and regulation. Regulations are often a reaction to initiatives from the industry or research institutes.
4. The feasibility of *organisational innovations is very much determined by regional and local conditions and the trust and cooperation of local construction firms*. Therefore the diffusion of these innovations will have a strong reinvention character.
5. *Landfill taxation appears to be an effective policy instrument to support innovation in construction and demolition waste recycling*, especially if, like in the UK, tax revenues are diverted to demonstration projects. *The effect of landfill bans on innovation, on the other hand, appears to be limited*. It mainly stimulates the diffusion process by obliging late adopters and laggards to adopt certain innovations in the recycling practice.
6. Technical standards play an ambivalent role in the development of innovations in construction and demolition waste recycling. Due to their often recipe-like character, prescribing the use of primary materials, *standards form an impediment to innovation. On the other hand, technical standards and quality certification systems are necessary to create market confidence in recycled materials.*

Based on these conclusions, the following policy recommendations can be formulated:

1. The local, reinvention-type character of organisational innovations in construction and demolition waste recycling calls for a *high degree of discretion for local and regional governments.*
2. *Technical standards should be performance-based*, defining the physical characteristics of products related to their applications. Recipe-based standards, defining the constitution of the raw materials, inhibit innovations.
3. Technical standards should be accompanied by proper exemption procedures for demonstration projects.
4. Governments should exploit their role as dedicated market parties in the support of innovations. Purchase guarantees can improve the acceptability of other regulations with industry.

5. The *development of quality and certification systems should be encouraged*. Industry initiatives in this field can be monitored and formalised.

Bibliography

Hal, Anke van, Casus: Sustainable building in Denmark (Recycling of Building Elements), internal paper for PhD study, Delft University of Technology, 1999.

Hendriks, Ch.F., Certification system for aggregates producced from building waste and demolished buildings, in Environmental Aspects of Construction with Waste Materials, edited by J.J.Goumans et al., Elzevier, 1994.

Klosterman, J.E.M, and A. Tukker, Environmental Stansards in the Construction Industry, TNO 1996. (in Dutch).

Klostermann, Judith and Arnold Tukker (eds.), Product innovation and eco-efficiency. Dordrecht: Kluwer, 1998.

Lanting, R.W., Actors in the construction industry involved in the issue of secundary materials, TNO, 1992 (in Dutch).

Lauritzen, Erik K., and Torben C. Hansen, Recycling of Construction and Demolition Waste 1986-1995, Danish EPA, 1995

Ministry of Housing, Spatial Planning and the Environment, Enforcement Compilation Processing of construction and demolition waste, The Hague 1992 (in Dutch).

Ministry of Housing, Spatial Planning and the Environment, Spear points construction and demolition waste, The Hague 1998 (in Dutch).

National Center for Sustainable Building, Demonstration project 100% granulate in concrete, www.dubo-centrum.nl/nieuws/archief/granlaat (in Dutch).

Stuip, J., Experiences with the application of secondary materials in the building and construction industry, In Klosterman and Tukker (eds.), 1998.

Symonds, Construction and demolition waste management practices, and their economic impacts. Report to DGXI, European Commission, 1999.

Trevorrow, A., The development of a demonstration project to increase the use of recycled resources in construction, Nottingham Trent University, 1999.

Tukker, A., Innovation and recycling: The building and construction sector, TNO-STB 1999.

PART 4

RECYCLING OF PLASTICS

UWE KUNTZE (ISI – FRAUNHOFER)

4.1 INTRODUCTION

4.1.1 Background

Waste management of plastics is within the focus of public attention and forms an important part of environmental policy in all European countries. As with waste management in general, that of plastics should be designed in such a way that it contributes to the government goals to (e.g. in Germany) decrease CO_2 emissions by 25% between 1990 and 2005, to increase resource productivity[34] by a factor of 2.5 between 1993 and 2020 and to increase waste use by 15% until 2010[35].

In Europe, good progress has been achieved in the recycling of *pre*-consumer plastics (see Section 1.3.2) waste, and there is little scope for further optimisation. But for *post*-consumer plastics waste the share recycled is much lower. According to APME[36], of 17.5 million tons of plastics waste in 1997 a share of 25% was recovered (incl. energy recovery). Material recycling amounted to 1.8 million tons (10.2%), of which mechanical recycling accounted for 1.4 million t (8.3%) and feedstock recycling for 0.3 million t (1.9%). Moreover, the amount of *post*-consumer plastics waste exceeds the amount of pre-consumer waste by a factor of 3.5 to 5 (depending on the information sources and the year of analysis), and this ratio will increase considerably in the future due to waste arising from long-term applications, the share of which will grow in the next few years[37].

What feeds the growing volume of plastics waste are the roughly 120 million t of plastics articles which are presently in use in Western Europe. Additionally some 25 mill. t of plastics enter Western European markets each year. The recovery and recycling of plastics continue to grow. A forecast by SOFRES/TNO[38] predicts that mechanical recycling of post-use plastics waste has the potential to reach 9.9% (2.1 million tonnes) in 2001 and 10.6% (2.7 million tonnes) in 2006. This is equivalent to a growth rate of 8.4% a year between 1995 and 2006.

From the regulations in the EU member states and on the level of the Union, this paper covers only those provisions which directly or indirectly deal with plastics waste. Furthermore, this paper covers basic regulations which apply to all sorts of waste management and recovery, as far as these regulations also apply to plastics recycling. Examples for such regulations are the Austrian Waste Management Act, the German Closed Substance Cycle and Waste Management Act or the Swedish Eco-Cycle Bill. The term *"regulation" is used here as a generic term*, covering laws, directives, decrees,

[34] Defined as Gross Domestic Product in prices of 1991 over the consumption of non-renewable resources, e.g. fuels, rock, stone and mineral products.

[35] Bundesumweltministerium: Mit dem Entwurf eines umweltpolitischen Schwerpunktprogrammes neue Etappe in der Umweltpolitik eingeleitet – Merkel: Für eine Umweltpolitik mit Augenmaß. Press release. Bonn, 28.4.1998

[36] Association of Plastics Manufacturers in Europe (APME), Brussels: Personal communication, 4 March 1999

[37] Patel, M.; Jochem, E.; Radgen, P.; Worrell, E.: Plastics streams in Germany - an analysis of production, consumption and waste generation. *Resources, Conservation and Recycling*, 24 (1998), pp. 191-215

[38] APME: Plastics recycling has potential to double by 2006. Media Information 28 May 1998, Association of Plastics Manufacturers in Europe (APME), Brussels

ordinances and other forms of governmental norm setting. In this context, we even cover "voluntary agreements" between industry and governments, because such voluntary agreements often replace governmental norm setting which would have been taken if not a "voluntary agreement" had been concluded. The terms used to describe the national regulatory situations may not always be the correct ones in the respective national legislative environment. This is due to the fact that a wide variety of differing sources of information had to be used to draw up this paper, mostly material translated at least once to a different language (and a different legal system and understanding, i.e.). But in the end it is the substance of the regulation and not the term that makes the difference.

Though packaging represents only a small fraction of the total waste streams in terms of tonnage, due to its diverse and dispersed nature and its high visibility in municipal solid wastes (MSW), it is the object of most of the existing plastics waste legislation. Most experience is available for post-consumer plastics waste from the packaging sector. Accordingly, the report on the first phase of this project[39] also covered mainly this subject. While this topic is being widely researched, other sectors of post-consumer plastics waste did not attract equivalent consideration. This is why in this second phase of the project, some of these other sectors have been agreed as subject of investigation.

The current report thus concentrates on the relations between (environmental) regulation and recycling in the fields of

- plastics in end-of-life vehicles
- plastics in electric and electronic waste and
- plastics in construction and demolition waste.

4.1.2 Plastics in end-of-life vehicles

Cars and other vehicles account for around 7% of European plastics consumption. Many different plastics are used in cars in many different ways. Plastics are used for fuel tanks, bumpers, dashboards, instrument housings, upholstery, battery boxes, cables and others. Even structural, load-bearing parts like body panels, wheels and seat frames are increasingly being manufactured from plastics. Plastics content has doubled from 50 kg per car in the 1970s to about 100 kg in the 1990s; the reasons for this encompass cost aspects, safety considerations (e.g. fuel tanks), the reduction in the weight of new car models and the introduction of a variety of new features (e.g. airbags) which could not have been realised with other materials. Plastics use in Europe's car manufacturing industry has risen to nearly two million tonnes today.

End of life vehicles (ELV) are currently recycled through a shredding process in which nearly all of the metals (approx. 75% of the weight of a vehicle) and an increasing proportion of the plastics, foams, rubber and textiles are recovered. Large plastic parts are often dismantled before shredding. The remaining fraction, the so-called automotive shredder residue (ASR, some 2 million tonnes per year in Europe), which mostly is disposed of in landfills, still contains plastics, among other materials.

---

[39] Kuntze, Uwe: Plastics Recycling in Europe - Regulation, Actors, Approaches for Innovation, Karlsruhe (Fraunhofer-Institut für Systemtechnik und Innovationsforschung (ISI), March 1999

4.1.3 Plastics in electric and electronic waste

Electric/electronic goods comprise computer/office hardware, electric equipment, telecommunications, large and small electro-domestics (e.g. refrigerators, washing machines), consumer electronics (audio, video), lamps and the like. According to estimates they account for 2-3% of the total waste streams in the EU, with a forecast of a 3-4% increase per year.

The plastics share in electric/electronic goods is 21% to 23%, forming the second largest material fraction[40]. There is a growing trend to use plastics and the total number of products sold increases, not least due to mass products like the "walkman" or mobile telephones.

The waste share of the professional sector (about 50%) is for a large part recovered and recycled. Reportedly, a large fraction of the used but reusable electronic equipment of the EU is exported to Eastern Europe, the Middle East and Africa.

Electric and electronic waste is partly covered by general waste regulations in the member countries, some regulations only cover partial aspects like take-back obligations for refrigerators (because of CFCs).

Specific legislative approaches such as in Austria, Finland, Germany and Sweden still are in a draft form (mid 1998). Voluntary agreements exist in Austria, Denmark, Finland, France, Sweden (with stringent recommendations from the Swedish Ecocycle Commission) and the UK. More countries are contemplating a move towards a regulation, though many are waiting for the European Commission to take action. The EU has started moving on a proposal to require take-back of a wide range of electronic items, from appliances to medical equipment to computers to toys. An EU project group on waste from electric and electronic equipment submitted an information document (second Proposal for a Directive on Waste from Electrical and Electronic Equipment, 1998) as well as recommendations; strong debate continues over which equipment should be covered, whether old equipment must be taken back free and who should pay for the systems.

Where specific regulations have been adopted (Denmark, Greece, Italy, Netherlands) they cover direct take-back schemes (in Denmark combined with separate collection of such equipment by the municipalities), mainly for audio/video, computers, printers and telecommunications equipment and larger electro-domestic products like refrigerators, freezers, air conditioners, washers, dryers, stoves.

4.1.4 Plastics in construction and demolition waste

The building and construction industry is second (after packaging) in its importance as a source of plastics, accounting for about 25% of European consumption with about 5 million tonnes annually. Plastics consumption of the sector is predicted to rise by more than 60% to almost 8 million tonnes in 2010. A SOFRES report shows that Germany, France and the UK accounted for 60% of total plastics' use in the building and construction sector in Western Europe[41]. Germany was the largest user, accounting for

[40] Eva Buchinger et al.: Innovation in Recycling Industries: Electric and Electronic Equipment. Part 1: Regulatory Context and Major Drivers, OEFZS-S-0013, Seibersdorf, March 1999, citing figures from ZVEI 1994

[41] APME: Plastics' use in building and construction to rise to 8 million tonnes by year 2010. Media Information 11 June 1998, Association of Plastics Manufacturers in Europe (APME), Brussels

27% (1.29 million tonnes), followed by France 18% (891 000 tonnes) and the UK 14% (710 000 tonnes). In the Netherlands 5% (267 000 tonnes) was consumed which represented one quarter of the country's total plastics consumption, the highest percentage in Western Europe.

Plastics building products are diverse. They include mainly PVC applications like

- pipes and fittings of many types and sizes, ranging from household guttering to large gas and water mains and industrial pipework
- window frames/wall panels and cladding/doors/roofing and floor materials
- electric equipment, cables.

Other major uses include thermal insulation material and packaging material.

These applications have been developed almost entirely over the past 30 – 40 years, and their service lifetime is expected to be at least as long as this, and in many cases as much as a century. Therefore relatively small amounts to date are available for recovery. Indeed, the long-life characteristics of these plastics explain their increasing popularity for construction applications. Waste from construction (and demolition) of buildings therefore contains increasingly more plastics fractions.

The majority of waste arises as miscellaneous scrap on construction sites, where its collection and disposal could be organised according to the same principles as in the distribution sector.

Until recently, and in some cases still now, the practice in most of the EU member states was to dispose of construction waste at assigned sites under little control. As the problem is closely linked to landfills, most legislation on construction waste originates from landfill standards such as the German TA Siedlungsabfall. The trend is to allow only the direct landfilling of non hazardous (inert) mineral materials, assuming that all organic materials can either be recycled, composted or incinerated.

4.2 SECTOR STAKEHOLDERS AND DRIVERS FOR RECYCLING

4.2.1 Introduction

In all EU member states, the main players pushing forward recycling are those organisations that fulfil the task of organising the collection and recovery of plastics waste. Certainly, one of the main driving forces on the level of the European Union was the taking effect of the EU Packaging and Packaging Waste Directive. This directive paved the way for a broad public involvement with and understanding of questions concerning recycling.

Of course, there is an extensive interchange in the driving forces between the interests of regulation (public administration, legislative bodies), collection and recovery organisations, recycling companies, manufacturers of plastics and of plastics goods, and companies producing plants, machines and equipment needed for recycling to be economically organised. And though the economic interests are certainly one of the most powerful driving forces, it should not be neglected that public opinion and civil interests groups form conditions for and consequences of recovery and recycling, thus also converting into economic interests.

As policy is pushing for ever higher recycling targets, material streams of decreasing quality must be recycled as cheaply as possible and more markets must be found for recycled products. Innovation and R&D are becoming a priority with the main areas of interest being: improving the quality of recycled products, adapting recycling processes to handle material of lower quality, and optimising pre-treatment (automatic sorting, separation, cleaning, etc.). Upstream, innovation at product design will help recyclability. This requires investments in R&D in order to achieve high levels of innovation in the whole recycling chain, not least in the organisation of collection and sorting systems, since this is where a large part of the costs of recycling comes from.

The profitability of recycling is a complex issue but the cost of collection and sorting is clearly the most important factor that determines the overall profitability of recycling operations. Innovation activities stimulated by the attempts (or: necessity) to cut down recycling costs have in the past already led to different developments like, e.g.

- the drastical reduction of outer secondary packaging
- a substantial reduction in the number of different sorts of plastics used in products
- in some cases even in changes of products, like for instance the introduction of detergent concentrates, rechargeable batteries and a product design for easy dismantling.

R&D activities in the plastics recycling business are impressive. The roles of the different actors in the field can tentatively be described as follows:

Plastics producers appear to have taken three positions towards recycling regulations:

- defensive: the objective is to block or delay regulations to avoid costs associated with recycling
- accomodative: the objective is to minimise the damage/costs of recycling, the focus is to make recycling reasonable
- proactive: the objective is to improve the own market position.

Recycling is less threatening to *processors* than to producers, because it does not take away their markets. Nonetheless, processors dislike negative publicity about plastic wastes and fear the imposition of restrictions on their products. Many plastics processors are involved in plastics recycling through either purchasing waste or selling recyclates or both. For most of these companies, though, recycling is a minor part of their business.

Unlike traditional recyclers, *plastics end-users* are pursuing recycling more to relieve regulatory pressure than to make a profit.

Concerning national differences, our general hypothesis is that a difference towards the inclination to innovation can be expected following the specific formation of the respective "national system of recycling". Following the discussion about "national systems of innovation"[42] where it has been shown that a large variety of factors are necessary and work together to form an innovation-prone situation, we are certain, the same holds true for the specific situation concerning innovations for (plastics) recycling.

Voluntary agreements might at first sight appear to constitute a significantly different in policy style to governmental regulation, which in turn might be expected to substantially affect the propensity to innovate. However, recent German investigations confirm that this is not a significant factor for explaining differences in the propensity to innovate[43].

Regarding the factors that might constitute significantly different conditions for a propensity to innovate: the regulation of

- collective vs. individual recycling responsibilities
- covering all plastics waste – household waste – industrial/commercial plastics waste
- non-profit vs. profit making recycling organisation

in the policies of all EU member countries does not substantially differ, so no differences in national patterns of innovation can be expected from these factors.

4.2.2 Plastics in end-of-life vehicles

The main actors involved in the recycling of end-of-life vehicles (ELV) are scrap yards and retailers, the operators of shredding plants, the steel and non-ferrous metal industries and the local authorities for the disposal of automotive shredder residue (ASR). Additionally and above all, the entire car manufacturing industry is involved in improving the recyclability of cars, and, with respect to the plastics content, the plastics

[42] cf. e.g.: Nelson, R.R. (ed.): National Innovation Systems, a Comparative Analysis. New York, Oxford (Oxford University Press) 1993; Meyer-Krahmer, Frieder (ed.): Globalisation of R&D and Technology Markets, Consequences for National Innovation Policies. Technology, Innovation and Policy, Series of the Fraunhofer-Institut für Systemtechnik und Innovationsforschung (ISI), Vol. 9, Heidelberg (Physica) 1999

[43] Klemmer, P.; Lehr, U.; Löbbe, K.: Umweltinnovationen, Anreize und Hemmnisse. Schriftenreihe Innovative Wirkungen umweltpolitischer Instrumente, Band 2. Berlin (Analytica) 1999; Kühn, I.; Osório-Peters, S.: Innovationswirkungen freiwilliger Selbstverpflichtungen im Umweltschutz – Fallstudien zum FCKW-Ausstieg in Deutschland und den USA. in: Klemmer, P.: Innovationen und Uwelt, Fallstudien zum Anpassungsverhalten in Wirtschaft und Gesellschaft. Schriftenreihe Innovative Wirkungen umweltpolitischer Instrumente, Band 3. Berlin (Analytica) 1999; Brockmann, K.L.; Osório-Peters, S.: Innovationswirkungen freiwilliger Selbstverpflichtungen im Umweltschutz – Spieltheoretische Analysen und Fallstudien zum Klimaschutz in Deutschland und den Niederlanden. in: Klemmer, P.: Innovationen und Uwelt, Fallstudien zum Anpassungsverhalten in Wirtschaft und Gesellschaft. Schriftenreihe Innovative Wirkungen umweltpolitischer Instrumente, Band 3. Berlin (Analytica) 1999

industry. In fact, all European car manufacturers and plastics producers are working on recycling questions.

Because of the ASR, the increasing cost of landfills threatens the profitability of the recyclers who live essentially from the sale of ferrous metal fractions, some non-ferrous metals and dismantled parts.

A first draft of a German ELV directive in 1993 caused all European car manufacturers to work on new concepts to improve current ELV disposal practices. Their goal was to avoid legislation and to solve the problem on a basis of a voluntary agreement.

At the level of the European Union, an "ELV Project Group", composed of representatives from all concerned industries, associations and governments presented an EU strategy to DG ENVIRONMENT in March 1994. The voluntary agreements on ELV recycling accepted by the automobile industry in France (1993), Germany (1996), Spain (1996) followed these recommendations to a large extent. Ministers have reached an agreement on the key elements for a European Directive on End-of-Life Vehicles in their meeting in December 1998 and the Directive has been finally approved in May 2000.

There are voluntary agreements or national systems for ELV take-back in eight EU member states (A, F, D, I, NL, E, S, UK), two further member states have submitted proposals (Belgium, Portugal). Denmark, Finland, Ireland and Luxembourg are debating the matter.

4.2.3 Plastics in electric and electronic waste

Probably the most important actors in this field are the producers of electric and electronic equipment. Most of them have started to adapt the design of their products to the requirements of recycling. Many have issued "design for recycling" guidelines and some even use recycled materials in their products (e.g. Siemens in its computer housings or Electrolux for their vacuum cleaners). Re-use and refurbishing are options that seem to become more important, following pioneer products that are marketed as a service such as the photocopiers of Xerox and Kodak. Modular concepts including sufficient standardisation (e.g. personal computer cases) will allow the extension of product lives through easy exchange of modules and upgrading.

The final recycling after wearing out the possibilities of product life extension will lie at the hands of recycling companies and the process industry; most steps of the recycling process, such as dismantling, sorting, shredding etc., are mechanical. Recycling companies and process industry are driving actors with respect to innovation in the recycling process. In some cases, electronic equipment manufacturers also have entered the business of collection and recycling, like for instance Siemens with the take-back of their PCs, or IBM in Italy who founded a separate company for the collection and recycling of computer components.

Furthermore, a number of initiatives by all sorts of charity organisations to collect, repair and sell second hand electric and electronic products as well as municipalities' take-back schemes (in association with distributors and manufacturers) will allow a substantial rate of recovery and recycling.

4.2.4 Plastics in construction and demolition waste

Opportunities for improving the management of construction waste originate mainly from the development of best construction practices. They primarily consist of minimising surplus and trim, while organizing separate collection and re-use or recycling of unavoidable construction waste such as packaging. The additional cost incurred is small compared to the total building cost. In some cases, best practices can even result in savings.

According to the Danish EPA, charges on waste disposal have contributed to a decrease of 16% of household waste going to landfill, a decrease of 63% in construction and demolition waste and a decrease of 22% in other types of waste. From 1987 to 1996 a 26% decrease in net delivered waste to municipal sites was registered[44].

For recycling in the building sector, pilot studies have shown that, when planned as an integrated dismantling, recycling and reuse process, a recycling rate of 95% can be achieved at no additional cost compared to conventional tearing down and landfilling[45].

The main actors in this field are construction enterprises, demolition and dismantling enterprises, transporters, local authorities and the operators of recycling plants for the different materials. Especially with regard to the plastics waste, the largest fraction of which is PVC, a major stakeholder and driver for recycling is the chemical industry as providers of the material.

[44] OECD: The implementation of environmentally-related taxes: replies by pilot countries, COM/ENV/EPOC/DAFFE/CFA(99) 36, Paris, April 1999

[45] Rentz, Ruch, Nicolai, Spengler, Schultmann: Selektiver Rückbau und Recycling von Gebäuden, dargestellt am Beispiel des Hotel Post in Dobel, ecomed Verlag 1994

4.3 REGULATIONS AND INNOVATION: THE LINKS – EXPLORED THROUGH INDUSTRY EXAMPLES

4.3.1 Introduction: Approaches to plastics waste recycling

In the past, the starting point for the development of recycling processes for plastics had been less the regaining of valuable material but rather a reduction in the volume of waste. However, as plastic recycling is still very expensive, large amounts of post-consumer plastics continue to be disposed of in landfills. Prominent problematic wastes are, beside packaging plastics (especially because of its large volumes), electric and electronic waste (because of their load of difficult or hazardous additives, like flame inhibitors) and the automotive shredder residue, because of its very heterogeneous material mix.

The development of public regulation was, accordingly, directed towards a reduction of disposal volumes and the treatment of hazardous components/materials. From these aspects there developed a "natural" hierarchy of waste streams to be regulated. It is not astonishing therefore that the search for innovations as well as recycling regulations in Europe primarily was directed towards the waste streams:

- (plastics in) packaging
- end-of-life vehicles
- electric and electronic waste, covering mass products like brown goods (audio/video), white goods (household appliances like refrigerators, stoves, etc.) and grey goods (office telecommunications and computing equipment) and, recently
- construction and demolition waste.

The *path of innovations* concerning the recycling of plastics waste largely follows these directions, primarily taking into account the problematic fields connected to the recycling aims.

Before recycling, all these wastes have to be *collected, sorted, separated and processed*. Practical recycling depends critically on the ability to separate them from each other. Again this process is expensive and still accompanied by various technical problems. For instance, the low weight of many plastics items (e.g. 60% of plastics packaging weighs less than 10 grammes) complicates automatic processing, and material savings due to down-gauging and new product designs (e.g. liners, pouches) makes this a bigger problem for future recycling activities.

Post-use plastics present problems of identification, separation and also contamination. Especially the contamination of post-consumer plastics, the poor miscibility of many types of plastics and the deterioration of material properties due to additives and softeners cause problems. These difficulties are often aggravated in the second and all of the following recycling loops. But where sufficient volumes of readily classifiable materials are available - pallet wrapping or sacks used by industry and agriculture, for example - recycling is successfully achieved.

Spectrometry is among the techniques used to ensure precise identification of those materials which, after processing, are often employed in the manufacture of equipment. But there is still a need for effective marking systems for plastics as the number of functionally optimised plastics is still rising with identification problems following.

Recycling changes the mechanical properties of plastics to some extent which makes it difficult to recycle large quantities of a particular type straight back into the same production process. Furthermore, recycling of mixed plastics presents a fundamental problem of polymer incompatibility. However, the introduction of so-called "compatibilisers" which create stable polymer bridges between plastics of different molecular structure, may facilitate use of mixtures. Compatibilisers already make it possible to produce a type of plastics alloy from secondary material.

Examples for *barriers on the demand side* are limitations in the use of recyclates. While in some cases norms covering security or health aspects and the like impede the use of recyclates, in some sectors prejudice against secondary materials remains a significant obstacle to wider plastics recycling. But environmental and other pressures are gradually changing attitudes and over specification in standardisation for some products, e.g. non-pressure pipes, garbage bins and cable ducts.

Both the existing problems and the scope for enhancing recycling depend on the sector where the waste is generated. Factors like the available quantities, the purity, the type of contamination and the extent to which it can be removed determine sector-specific present status and the respective potential for the future. In the case of electrical and electronic plastics waste e.g. one third is suitable for mechanical recycling according to a joint APME/VKE project[46].

Following a study[47] for the Association of Plastics Manufacturers in Europe (APME) there is a realistic potential of about 2.7 million t for mechanical recycling of plastics waste by the year 2006. While this would mean more than doubling the present level (1.2 M t), APME states "it is the demand side which we believe to be the critical factor"[48]. According to this statement the following basic conditions should be met for successful mechanical recycling of plastics waste:

- availability of continuous homogeneous, identified waste plastics streams from reliable collection/sorting schemes,
- availability of an efficient recycling process
- existence of one or several marketable outlets which can accept the quality of recyclate produced.

Under such conditions APME recommends the following lines of activities which might also be read as suggestions for political action in the field of mechanical recycling:

- take end-of-life considerations into account at the product design phase, while ensuring other benefits such as prevention or energy savings are not compromised
- promotion of best practice on a European scale on all aspects of plastic waste management
- selective collection and/or dismantling to focus on those products with an identified demand for mechanical recycling
- improving identification and sorting technologies to ensure a higher quality recyclate with improved market outlets

[46] APME (Association of Plastics Manufacturers in Europe) / VKE (Verband Kunststofferzeugende Industrie): Feedstock recycling of electrical and eledtronic plastics waste. Technical paper, Brussels/Frankfurt, November 1997

[47] TNO/SOFRES: Potential of post-user plastics waste recycling, 1995 – 2006, Brussels (APME) 1998

[48] Neil Mayne: The potential for post-user plastics waste recycling in Western Europe in the period up to 2006, in: R'99

- encourage demand for thick-walled applications which use mixed plastics.

Innovation activities have, therefore, concentrated on measures to improve the chances of mechanical recycling. Examples include the automation of sorting technology, design for disassembly / recycling and a trend towards single-resin systems (e.g. in automobile interiors)[49]. Further potential exists in co-extrusion[50], compatibilisation[51], blending, the use of reinforcing agents and stabilizers and innovative technology for purification and processing. Furthermore, there is a consensus among experts that the number of outlets for mixed plastics re-granulates and agglomerates is very limited and that the enforced use of mixed plastics from the packaging sector reduces the recycling potential for other types of commingled plastics waste (e.g. that derived from the automotive sector or from electric and electronic waste).

4.3.2 Plastics in end of life vehicles

For decades some 75 per cent by weight of an End-of Life-Vehicle (ELV) have been recycled. The material composition in ELVs is 75% metals and 25% others, of which: 50% organic materials (plastics, elastomers, derived natural products) and 50% inorganic materials (glass, fillers, dust, rust etc.). In current ELVs the plastics proportion is around 6 percent of weight.

Disproportionate growth in the use of these materials over the last 10 years compared with the metallic fraction of the car has now focused attention on the plastics fraction. The proportion of plastics components in motor cars has risen from around 5 per cent by weight in 1970 to the present level of around 10 to 12 per cent by weight. Collaborative projects between a materials producer and a car manufacturer for the recycling of specific materials led to car components in particular models made from identifiable plastics material, often with high-tech properties and therefore potentially valuable for recycling.

While lower kerb weights have (among other factors) contributed to lower fuel consumption and CO_2 emissions, the increased use of plastics poses a problem of disposal at the end of life of the vehicle or component concerned. Paradoxically, it seems, lower levels of exhaust gases have been achieved at the cost of increased terrestrial pollution. This is becoming more expensive and is a major issue, particularly in smaller countries where available land is fast running out.

Proceeding from the current state of the art, the recovery of plastics from ELVs calls for the dismantling of plastic components before the vehicle reaches the shredder. The dismantled plastic components must then be sorted into material batches in quantities which permit their industrial processing.

Several schemes for recycling plastics car components have been established since the mid 1980s. Many of these are research projects which seek to determine the extent to

---

[49] Siebenlist, J.: Leichtbau mit Kunststoffen ist ein absoultes Muß. VDI-Nachrichten (Verein deutscher Ingenieure), 3.4.1998, page 22

[50] Europa Chemie 35-36/97, Anonymous: PET-Recycling: In Europa bereits 80 000 Jahrestonnen. Europa-Chemie 35-36/97, p.19.

[51] De Groote, P.; Godard, P.: Mixed plastics compatibilisation. Study prepared by the Université Catholique de Louvain for the Association of Plastics Manufacturers in Europe (APME)

which cars can be dismantled at the end of their useful lives. There is a general aspiration that the findings can be applied to:

- the design of future models;
- the determination of the technological and economic feasibility of reclaiming and refurbishing a wide range of parts; and
- the investigation of possible recycling solutions.

Among these projects are:

- the German PRAVDA programme (Projektgruppe AltautoVerwertung der Deutschen Automobilindustrie) covering different sectors of plastics usage in cars
- the British CARE (Consortium for Automotive REcycling) initiative
- the Eureka RECAP project for the RECycling of Automotive Plastics

These are discussed below.

PRAVDA (PRojektgruppe Altautoverwertung der deutschen Automobilindustrie)[52]

In Germany, around 2.5 million passenger cars are taken out of use per year. There is (valid as of April 1998) a Directive on ELV which obliges car owners to dispose of ELVs only at certified acceptance points (mostly car repair shops) or ELV-processing companies. The Directive furthermore obliges car producers to take back ELV – not older than 12 years – at no charge. A first draft in 1993 caused all European car manufacturers to work on new concepts to improve current ELV disposal practices. Their goal was to avoid legislation and to solve the problem on a basis of a voluntary agreement. Such a voluntary agreement by the association of German car manufacturers (VDA) was reached in February 1996. According to this agreement, the amount of non-reusable ASR shall be reduced from currently 25% to 5% by the year 2015.

Compliance with this voluntary pledge demands the deployment of all technological options in terms of mechanical recycling, chemical recycling and energy recovery. For this purpose, the PRAVDA consortium decided that detailed studies had to be carried out to determine the best recycling options[53]. PRAVDA-2, following a feasibility study on the national level (PRAVDA-1), examined the possibilities of mechanical recycling of plastics (PE, PP, ABS, PMMA, PA and PUR) from ELVs. This major project was carried out 1993 - 1996 and was based on co-operation between the automotive industry, raw material suppliers, dismantlers, plastics-reprocessing companies and moulders. It was designed to establish which quantities of selected, large-size plastic components can be handled under industrial conditions, and at what cost this is possible.

As a first step the total process chain from dismantling to the production of parts was analysed, as well as the characteristics of the various materials. Costs were estimated and recommendations given for recycling plastics from ELVs in future. The second step was the production of sample parts and their testing by the car producers.

---

[52] PRAVDA consisted of nine major German automobile manufacturers, 14 European chemical groups and seven major German recycling companies and car dismantlers.

[53] Reinhard S. Hoock, Jürgen Schult, Ulrich Schlotter: Mechanical Recycling of Plastics from End-of-life Vehicles - Scope and Limitations –Summary of the PRAVDA-2 Project, VDA/VKE, Frankfurt, 1998

The quantities of industrial plastics obtained through optimised sorting with an acceptable and viable cost to benefit ratio (cost of mechanical recycling versus value of the material) nevertheless proved to be very limited. Based on sophisticated analysis about current ELV´s the following quantity forecast for Germany is given:

1995:
1.5 mio. ELV´s to be scrapped, 50 kg plastics per ELV; potential for mechanical recycling: 30 000 tons (45 000 tons remaining in the shredder fluff)

2000:
2.0 mio. ELV´s to be scrapped, 70 kg plastics per ELV; potential for mechanical recycling: 56 000 tons (84 000 tons remaining in the shredder fluff).

These figures only show the potential volumes of plastics which it is technically feasible to obtain by mechanical recycling of current ELVs in Germany. These materials account for approximately 40 per cent of the plastics to be found in the current ELV population (100 per cent = 50 kg). This quantity represents the upper limit, i.e., the maximum potential.

Full utilisation of this potential would depend on the following factors:

- Sufficient quantities for reprocessing at recycling plants
- Adequate quality (purity)
- Adequate marketing potential for materials with recycled contents
- Reasonable cost to benefit ratio.

Component tests and trials with recycled materials have shown, furthermore, that the quality of materials with recycled content currently achievable offers only limited scope for use in these materials' original applications. Their reuse is linked with a more or less substantial loss of mechanical properties. Alternative applications for such material qualities will have to be examined individually.

The cost / benefit ratio depends largely on the purity of the components disassembled and delivered to the plastics recycler. The studies carried out show that a lot still remains to be done in this area.

Another problem with the exploitation of this potential is however the involvement of 11 groups of materials as well as the current number of approximately 4,000 recovery operators. As a result, there are not many cases (eg PE, PP, PUR) with an adequate quantitative flow of materials.

The PRAVDA consortium comes to the following conclusions: the target to effectively reduce the amount of shredder fluff cannot be reached by mechanical recycling of plastics alone[54]. Rather, an economically feasible distribution of plastics recycled by dismantling ELVs, on the one hand, and by processing shredder light fractions, on the other would be required in order to meet this objective. Feedstock recycling and energy recovery would have to be considered as equal options, if landfill has to be avoided.

CARE (Consortium for Automotive REcycling)

It is estimated that over 23 million cars are operating in the UK and about 1.3 million vehicles come to the end of their lives each year.

[54] Reinhard S. Hoock, Jürgen Schult, Ulrich Schlotter: Mechanical Recycling of Plastics from End-of-life Vehicles - Scope and Limitations –Summary of the PRAVDA-2 Project, VDA/VKE, Frankfurt, 1998

The average end of life vehicle (ELV) weighs nearly 1 tonne and currently about 73% of the vehicle is recycled either in part through re-use or by metallic recycling. The total UK weights are estimated to be:

Total ELV weight 1.4 million tonnes (100%)
Total ELV weight recycled 1.05 million tonnes (75%)
Total ELV to landfill 0.35 million tonnes (25%)

This represents about 0.3 % of the total UK controlled waste arisings.

CARE (The Consortium for Automotive Recycling) is a collaborative project of Vehicle Manufacturers and Dismantlers. Their objectives are:

- To reduce to an absolute minimum the amount of automotive waste material going to landfill.
- To generate increased demand (and hence value) for materials currently being sent to landfill.
- To eliminate pollution risks, such as soil and water contamination, by vehicle fluids from the car disposal process.

Another important activity for the CARE manufacturers is to create a more stable market for recycled materials.

CARE's membership is currently made up of ten car manufacturers (which collectively account for 75 per cent of car sales in Britain) and a growing number of dismantling and recycling operators. The vehicle dismantling operators are spread country-wide.

CARE operates on the basis of mutual co-operation between its motor industry members and the participating dismantlers. In order to display and use the CARE logo, a dismantler has to meet the group's minimum standards in terms of environmentally responsible processes and professional business management. Dismantlers in the CARE group have direct access to product information from the relevant manufacturers to assist, for example, in the identification and segregation of the various types of plastic on a specific model of car.

The project encompasses all makes and types of car now being taken off the road in Britain. It is estimated that in the first year the dismantlers involved in the CARE group processed some 20,000 cars.

All the participating car producers are committed to a policy of specifying recycled materials, wherever they meet the functional and quality criteria for current and future models. This will contribute to an increased demand for such material, improving the economics of any recycling process.

In order to achieve the targets for reduced landfill from ELV disposal, and to comply with the best environmental practice of re-use, recycle, recover, the reclamation of non-metallic materials for recycling is fundamental to the success of CARE's objectives. Around 10% (100kg) of a vehicle's weight is made up of plastic which has the potential for recycling and hence the generation of income to the dismantler. CARE has developed potential recycling routes for several non-metallic materials which when adopted, could reduce the amount of residual material going to landfill, to 18%, as of today, instead of the current 25%. By 2015 the aim is to reduce the amount of vehicle weight going to landfill to 5%.

The CARE team has been working successfully with the dismantlers and material reprocessors in exploring a number of options to achieve added value through increased quality. The initial outcome of the work suggested that specific materials (Polyester, ABS, Polypropylene) should be targeted for recovery based upon their abundance within the vehicle, the potential market demand for the material and their ability to be segregated with a degree of confidence. The value of these materials to the dismantler in a clean sorted condition can be in the order of £100 - £250 per tonne.

Another important topic for the work within the CARE project has been to examine what opportunities exist to optimise the logistics which can be expected to vary from dismantler to dismantler and region to region.

In the medium term the project will develop to include the following activities:

* Establish an increased number of dismantlers operating CARE processes
* Feeding back practical findings to the vehicle manufacturers to allow the future improvement of new vehicle designs to facilitate greater recycling
* Establish the optimum information presentation and content on vehicle composition to help the disposal process
* Develop segregation and recycling routes for additional non-metallic materials
* Disseminate information on proven techniques and processes to allow their generalisation across the whole industry
* Ensure that disposal processes are conducted to the highest environmental standards.

Though independent from each other, CARE and the British automotive industry's voluntary inter-sector agreement on the treatment of end-of-life vehicles (ACORD, signed July 1997) are closely linked. ACORD[55], the Automotive Consortium On Recycling and Disposal was established by the UK Car Manufacturers in the same year 1991, in which the European Commission identified end of life vehicles (ELVs) as a priority waste stream. ACORD's objective is to achieve a reduction in the amount of automotive shredder residue (ASR) going to landfill, whilst reflecting and respecting the wide variety of interests involved. ACORD is working closely with CARE to develop mutually beneficial objectives, expand the core membership of CARE to include more vehicle manufacturers, and coordinate a programme of activities. The objectives are almost identical to those of ACORD, but with the emphasis on demonstrating the technical feasibility of recovery and recycling processes, paving the way towards achieving the commonly shared overall target of 85% by 2002.

RECAP: RECovery and re-use of plastic materials derived from Automobile Production and scrapping

The EUREKA project 506 - RECAP - brought together partners from the full production chain - plastic resin manufacturers, components suppliers and car makers - in an attempt to develop an integrated approach to increasing the recovery and re-use of plastic materials derived from automobile production and scrapping. The line-up of partners from Italy, France and the Netherlands contained: EniChem, the project leader, and DSM are both leading suppliers of plastics, while Reydel is part of the Compagnie

[55] Society of Motor Manufacturers and Traders Ltd.: ACORD First Annual Report, 1998

Plastic Omnium group, a major "own-brand" component supplier. The two partners from automotive manufacturing were Fiat Auto and PSA Peugeot-Citroën.

The project covered the areas of waste management, technology development and new design and prevention.

- Waste management involved developing systems for coding materials, waste routing methods, carrying out recycling yield and cost efficiency assessments, and determining the true market value of the recyclable material produced.
- The technology development team concentrated on separation techniques which would allow the production of sufficiently homogeneous recyclable material from dismantled parts, and the development of a "recycling to feedstock" technology to recover hydrocarbons and other chemicals suitable for re-use as raw materials in the petrochemical industry.
- Work in the design and prevention fields looked at how design rules could be changed to make dismantling easier and recycling more profitable in the future: dash boards and door panels were identified as typical mulitimaterial components which could be redesigned and made from a single plastic.

With the exception of first quality scrap generated in the production of automobile components, technical and economic feasibility reasons had until the start of the project (1991) not permitted the recovery and re-use of plastic wastes or shredding. The objective of the project was the development of technologically and economically feasible options for the recovery and re-use of plastic materials arising during the production, scrapping and shredding of automobiles.

A further target was to develop automotive parts which use existing raw materials or recycled materials and existing processes in such a combination that the parts should be easily recyclable. The final phase of the project was to seek to implement the successfully piloted operations and processes on the full industrial scale. Right from the beginning, the partners put a high priority to the commercial aspects of their goals.

The project was expected to lead to a significant decrease in the quantity of plastic based waste materials (arising from all stages of motor vehicle assembly and scrapping) and to a reduction in the volume of non- (bio) degradable materials consigned to landfill. This, in turn, would provide an improved and environmentally more acceptable pathway for dealing with plastic wastes. According to Paolo Cortesi of EniChem, by the year 2000 the average end-of-life vehicle will contain 45kg of plastic which could be easily dismantled for reprocessing. Techniques developed under RECAP are expected to enable that by the year 2000, 40% of the plastics from ELVs could be dismantled and 16% of the total plastics content of the car could be mechanically recycled although this is regarded as not economical under present conditions[56].

The technology developed in RECAP is not restricted to the automotive industry. Other sectors, such as white goods manufacturers, are starting to become aware of their recycling responsibilities and RECAP techniques could be adapted for their use.

[56] APME: Plastics consumption and recovery in Western Europe. Association of Plastics Manufacturers in Europe (APME), Brussels, 1995

Regulation and innovation in plastics recycling in the automotive industry

Analysing the driving forces, approach and results of these three examples leads to very similar results. The increasing occurrence of plastic-based materials in motor vehicles, coupled with the mounting pressures against the disposal of plastic wastes and the call for increased recycling and re-use of plastic materials[57], had created a situation in which the,until then, normally accepted economic criteria for the automobile industry would be unlikely to continue to apply. Therefore, following earlier R&D projects investigating the role of car building materials better adapted to recycling needs (e.g. EUREKA-project CARMAT), from the early 1990s practically on all European automotive markets car manufacturers combined forces with different allies from the wider automotive industry (component suppliers, material suppliers, recyclers, etc.) to defend the industry's interests against public policy plans for regulations concerning a reduction of the amount of ELV's waste to be disposed of in landfills. The resultant investigations could be interpreted as *"a fight against a pre-set recycling target"* in the anticipated regulation. In this context, it is questionable whether the largely parallel industry lead paths of investigation (leading to largely similar results) rendered simultaneous investigations with public support unnecessary.

It is interesting to note that, although all European car manufacturers as well as their material and components suppliers are present on all national European (or rather: World) markets, the consortia that have developed are heavily based in their actual "home markets". This is most probably caused by the fact that the respective home markets may be regarded as large enough (between 1.5 and 2.5 million scrap vehicles per year) to be analysed and organised separately. The differences between individual national regulations or between these and the expected European regulation do not seem to be of major importance for the strategic considerations of the participating companies from the automotive industry, although details enter into the profitability calculations of each single solution analysed.

A common result from all analyses reviewed is that usually more plastics waste can be recycled than could be sold, because the cost:benefit ratio under present conditions is not favourable for mechanical recycling. In other words, the market for recycled materials is insufficiently developed. This result is at least partly based on current attitudes towards "used material". The automotive industry is known to apply extremely high standards to functional and aesthetic aspects, arguing that their clients demand these standards. Apart from environmental arguments favouring incineration of plastics waste, the utilisation of these high standards is leading to a pressure towards feedstock-recycling and energy recovery.

Based on the TNO/SOFRES study[58] APME states that, although end-of-life vehicle legislation will further stimulate the recovery of plastics from this sector, the percentage of plastics recycled from this application is not forecast to exceed 10%, and overall demand for recycled resin in automotive parts is not forecast to increase beyond 4% by

[57] Commission of the European Communities: Document SEC (89) 934 final, "Communication from the Commission to the Council and to Parliament on a Community Strategy for Waste Management", 18 September, 1989

[58] TNO/SOFRES: Potential of post-user plastics waste recycling, 1995 – 2006, Brussels (APME) 1998

2006. Specification restraints would make it difficult to exceed this level[59]. Demand for recyclates is generally seen to be a limiting factor for mechanical plastics recycling.

With regard to European regulation, it must be noted that mechanical recycling probably involves more than 10,000 dismantling facilities, mostly SMEs[60], working in highly differing surroundings, and this fragmentation and variability needs to be duly recognised.

The *motivation to participate* in the respective innovative projects must be seen as being highly complex, depending on the role of the respective partner in the innovative venture. While pending regulations indeed exerted an important impulse besides the existing business strategy of presenting the company as environmental leader, the role of the suppliers was much more determined by considerations of keeping close contact with the needs of their customers and accompanying them to new ventures. As a side effect, they developed new technologies which might add to a stock of eventually usable technologies.

A consideration which had not been put forward by the interviewees is that *there may be a trade-off between recyclability and energy/emission efficiency*[61]. The resolution of the possible trade-offs —or the optimisation of possible synergies— seems therefore a task assigned to the industry and the combined search for lightness, recyclability and safety can be a strong driver for innovation in the medium-to-long term. The process towards recyclability is thus more complex when the other environmental and safety improvements are considered.

4.3.3 Plastics in electric and electronic waste

Electronic products entering the waste stream today were not designed with recycling in mind. A lack of information on product composition, material variety and hazardous constituents present obstacles to recycling, particularly for plastics. Cost-effective recycling in the future will require product design changes that reduce disassembly time and increase the reuse and recyclability of components, including:

- product simplification;
- standardisation of components, product configuration;
- modular designs, including components for reuse;
- standardisation of material types;
- easily detachable parts;
- reduction in number of pieces requiring dismantling
- accessibility of components; and
- reduction in material types to reduce sorting.

Such initiatives are already underway.

An innovative research programme in this area is the EUREKA project *"CARE Vision 2000"* (Comprehensive Approach for the Recycling of Electronics). In this Europe-wide

---

[59] Mayne, Neil: The potential for post-user plastics waste recycling in Western Europe in the period up to 2006, in: R'99

[60] Peuch, Patrick: Car evolution end-of-life vehicles treatment and recovery technologies in Europe 1995 – 2015, in: R'97

[61] Zoboli, Roberto: Implications of environmental regulation on industrial innovation: the case of end-of-life vehicles. Sevilla (IPTS), December 1998, EUR 18688 EN

project, manufacturers of electronic goods work together with research institutions. The aim of the project is to recycle electronics scrap at the highest level of utilisation.

In the CARE system, every electronic product will contain an information module. This module stores all producers' information that can be useful to the recycler, such as the types of materials the product contains, the toxic substances that need to be removed etc. Another interesting possibility is to use the module to record information on the 'life history' of a product to be able to determine its remaining 'life value'. For instance, the number of hours a cathode ray tube in a television has operated determines whether or not this part can be reused in a new product or as a repair part. As CARE concentrates on the information part and not on the use of plastics it will not be considered further in this study.

The German Institute for Environmental Technology and Environmental Analysis (IUTA)[62] has worked since 1991 on pilot projects to *identify the amount and type of materials* from electric and electronic waste *available for recovery and disposal.* In 1993/94 IUTA dismantled a representative mixture of 1,400 tonnes of electric and electronic consumer equipment[63]. Plastics accounted for about 15% of which one third was suitable for mechanical recycling and two thirds needed to be disposed of by other means (unidentified materials, composites, or materials containing toxic additives). The aim of the project was to identify recyclability and costs. The *participating industry wanted to acquire better knowledge for consultation on the draft electronics waste ordinance*, the coming into force of which was expected soon. Only in 1993 equipment manufacturers joined the group, in case that they would be made obliged to take back their products. At that time, apart from computer manufacturers, the industry branch was not yet – and partially is not now - aware of seeing electric and electronic waste as valuable materials. Today, given that automated plastics identification equipment will become less costly, a market for recyclates is emerging, but industry is hesitant towards innovation. *Regulation would bring in a new impulse for market development, while the pending decisions rather hamper developments.*

Concerning innovation projects in the field of plastics identification it is being argued that the *motivation of large electronics companies can also be constituted through regulatory provisions*. For example, the EU project "High quality plastic materials from electronic wastes by use of combined identification methods and new handling technologies" combines among other partners Sony and Philips. In expectation of the European electronic waste directive, *electronics manufacturers prepare for not being dependent on recycling companies if product responsibility should be extended*. For this reason, most electronics manufacturers also have pilot recycling equipment installed internally. Furthermore, highly efficient plastic identification systems might help clear problems arising from product liability.

While the initiatives for innovations for plastics recycling in the computer industry are covered in Part 2 (see above), this section of the report takes a deeper look at the innovations in the audio/video industry, especially the "green" TV set.

---

[62] J. Schiemann, IUTA, personal communication June 1999

[63] APME/VKE: Feedstock recycling of electrical and electronic plastics waste. Technical paper, November 1997, Brussels/Frankfurt a.M.

Development of a "green" TV set

Since 1996, innovative TV set and component manufacturers in Germany have been developing a Green TV with financial support from the German Federal Ministry of Education and Research (BMBF). The joint research grouping comprises the companies: Grundig, Deutsche Thomson-Brandt, Loewe-Opta, Harman Audio Electronics (previously Nokia Audio Electronics) and Philips Components. A specific feature of the project was the pre-competitive cooperation of these companies – some of which are competing in the same market sectors - in technology development, which is an element of German technology support policy that is continuously gaining importance since a couple of years. The ongoing work is supported by several research institutions as well as the relevant industry association, ZVEI.

Originally, the initiative for this project came from the Federal Ministry for the Environment which, during the preparation of the electronics waste ordinance, led intensive talks with industry and its association in the early 1990s. After a definition phase during 1994/95, the project called "Contributions to the development of a closed-loop economy, formulated for the exemplary case of a complex mass-produced product - the TV set" started in 1996.

The project aims at developing environmentally sound technologies. The demands here the environmentally acceptable use of materials and energy, together with recyclability in conjunction with cost-effectiveness - a confluence of developments that will be of great future importance to the electronics industry. TV sets are exceedingly cost-sensitive large-scale production consumer electronics appliances that combine practically all tasks encountered in electronics. The research of the partners concentrated on the following areas:

- Replacement of the conventional printed circuit board by recyclable circuit supports
- Optimization and size reduction of electronic devices
- Development of a loudspeaker concept with improved efficiency
- Initiation and optimization of the use of recycled glass in picture tube production
- Development of energy-saving circuitry concepts.

In addition, efforts focus on modularization, extension of service life, and minimization of contaminant contents. Due to this characteristic, and with the MID technology variants used, through this project models shall be provided for the environmentally acceptable and nonetheless economic design of a great variety of electronic products.

The project was scheduled to terminate in August 1999, when two functioning prototype TV sets were to be presented. Activities within the project also comprise the question of implementing the prototype technologies into components of a TV set, and testing their reliability as well as the determination which serial production processes could be used for the new technologies.

In the context of this study, the most interesting subprojects are those of Grundig who concentrated on recyclable TV sets made of plastics, and of Thomson-Brandt who developed a recyclable power module based on plastics.

GRUNDIG: recyclable TV sets made of plastics

This subproject focuses on the strategy of materials recycling, for which facilities have been established throughout Germany for electric appliances. Grundig can refer to many years of experience in this field. Grundig is therefore pursuing the goal of using thermoplastics to the greatest possible extent. These are excellently suited to materials recycling, and particularly for the electronic circuit supports, which hitherto have had to be disposed of as hazardous waste. The technology chosen for this is MID (Moulded Interconnected Devices). Using this technology, three-dimensional circuit supports are produced that offer all the design freedom of injection moulding. In particular, further mechanical functional elements can be integrated in the MID and produced in one single operation that would otherwise consist of different materials and need to be assembled separately.

In accordance with the technological and functional requirements, the MID chassis is composed of three modules:

- The signal module is a part of the housing floor, and provides the base for the other modules. It has a level process surface, and contains the connections for the scart sockets and the tuner, and also the multipoint connector to the operating module. It furthermore contains receptacles for devices that are not available in SMD (surface-mounted device) forms. The body of the signal module consists, as does the housing of the TV set, of ABS, a low-cost industrial thermoplastic.
- The operating module has a three-dimensional structure, and contains, beside the multipoint connector to the signal module, the devices for user operation of the TV set. It is also made of ABS, and is manufactured in a double injection-moulding process.
- The power module, which is being developed by Thomson-Brandt, is made of a high-performance thermoplastic and supports all the devices in which power is converted when the set is in operation. The material is highly thermostable, solderable and intrinsically self-extinguishing.

For the housing, a design was developed that represents the high ecological standard of the project. It takes up only the minimum necessary space, and is optimized so as to require the minimum possible material input while still serving the function of being optically attractive to the user. The housing material is typified recycled ABS, consisting of 50% post-user material and 50% production residues from all processing stages. The housing is, as are all chassis modules, free of flame inhibitors.

Grundig's motives to participate in the project can be derived from its corporate philosophy - recycling and the closing of materials cycles is said to be a longstanding topic. In this context, Grundig runs a plastics recycling plant for product and production waste. From this plant they gain the recyclate which they use for their TV sets (1/3 recyclate). Besides this general philosophy, the project offered the opportunity to test a new technique and its economic effects, as well as the scope for application for other purposes. The idea of providing for final disposal was not central for this project as these costs are taken over by the consumer.

Grundig expects that the solutions found will be realised, possibly not in the form of a complete "green" TV but in form of "green" components, also being transferable to other equipment. A further development time of at least 1 1/2 years is expected. But they also have plans to use the technology for more economical solutions.

Although their motivation is largely intrinsically based in coherence with considerations to gain economic advantages, they claim that regulations exert an impulse for business activities because they change the economic conditions on the market.

THOMSON-BRANDT: Novel devices and circuitry concepts

The Deutsche Thomson-Brandt concentrated on circuitry and interconnection technology. The circuitry determines the dimensions of the devices. Effects become apparent particularly in the power module. With a switched-mode power supply unit, higher pulse frequencies lead to smaller capacitors and transformers with less materials input and power loss.

This novel interconnection technology permits recycling and extends service life. Circuit support is designed in MID, made of high-temperature thermoplastics (HTTs). Thermoplastic, flame-inhibitor-free plastics permit recycling. The selected plastics, PEI and LCP, are highly thermostable, solderable and intrinsically self-extinguishing. They are suitable for diverse applications. Their mechanical and thermal properties permit use both as circuit supports and in devices such as switching transformers and windings. This allows a reduction of materials diversity, and thus facilitates the recovery of pure materials. For better recyclability, the interconnection technology has been realised with lead-free solders.

Thomson's motivation was more focused on testing the new technology than on recycling. Circuit support continues to be omitted from the draft electronic waste ordinance, although this was not certain at the beginning of the project. The new technology will certainly not be used (still technical problems, too expensive) but the knowledge will be used to find a better solution which will also cover recyclability as secondary objective.

Ecological and economic perspectives

The new technologies have the purpose of satisfying the requirements of a closed-loop economy, conserving resources, abating emissions and reducing demands on scarce landfill volume. *For a number of the pursued development lines, unresolved questions still remain with regard to industrial-scale implementation, and with regard to the degrees of freedom in materials and process selection.* A final ecological and economic analysis of the new developments can thus not yet be presented.

Resource conservation: Through the circuitry technologies developed by Thomson Brandt, the materials reduction in the devices (smaller dimensions of capacitors and windings) and the higher pulse frequencies in the power supply unit provide resource savings. Grundig's housing is made of 100% recycled material. The freedom of design provided by MID technology permits savings of 10% of the plastics granulate used in housing design. Extrapolated over one million sets, this means savings of about 6300 tonnes of crude oil.

Reduction of materials diversity: Grundig/Thomson's main contributions in the field of injection-moulded MID circuitry supports lie in the standardisation of materials achieved through the use of thermoplastics, which permit recycling at the level of materials (as opposed to the lower level of resources). By using MID technology, TV electronics could in future be reduced to two plastics: One plastic for the housing, signal module and operating module, and one high-temperature resistant plastic for all power components. MID technology allows the integration of operating elements and cable and plug-in connections into one operating module. In the reference technology used up to now, the operating module consists of ten different individual parts which after use represent a scarcely recyclable mixture of diverse materials and composites.

Reducing contaminant loads: By using a high-performance thermoplastic which is intrinsically self-extinguishing for the power module and through constructive devices concerning the chassis and signal and operating modules, there is no need to use additive flame inhibitors, thus contributing substantially to the important goal of a reduction of contaminant loads.

Cost appraisal: A full economic analysis of the individual developments is not yet possible. *The example of MID technology shows that* if the cost comparison between thermoplastics and conventional printed circuit boards is conducted solely on the basis of the materials, the comparison is to the detriment of the new developments. If, however, the costs of function elements such as cable connections and operating elements are included, then *cost reduction potentials are indeed available* through being able to dispense with these discrete devices and components. Moreover, production costs could be further reduced through a higher degree of automation. When in an integrative cost appraisal the lower costs in the usage phase and disposal costs are included, it can be expected that the new developments are more economical.

A broad array of individual measures leads in total to results which, despite the use of expensive basic materials, do justice to both recycling and resource conservation within an integrated resource and environmental profile analysis without excessively burdening production costs.

It should be added here that also development projects aiming at other technical solutions have been undertaken which aim at a substitution of plastics altogether, for instance through using un-housed electronic elements or ceramic supports in SMD technology[64].

Regulation and innovation in plastics recycling in electric and electronic waste

In 1991, the German government issued a draft for an electronics waste ordinance originally set to be enforced in the beginning of 1994. It created broad interest within the recycling industry accompanied by substantial investments. Many cities and municipalities anticipated the forthcoming regulation by setting up a structure for the collection and handling of electric and electronic equipment. Industry and consumer representatives together with government started (long and intensive) negotiations. At the end, the goal of a completely accepted agreement was failed. The fact that the electronics waste ordinance has been delayed several times has had detrimental effects. All interviewees agree that *during the announcement phase of the ordinance a thrust towards a multitude of technical and organisational innovations was affected, which after the long years of delay elapsed*.

At present, industry is said to be passive. Those who still carry on have rather been those who already were active beforehand: companies that define environmental protection as part of their corporate identity, having a steady inclination to engage in this field.

[64] cf. Jürgen Lang; Harald Hiessl: Recyclinggerechte Gestaltung technischer Produkte am Beispiel Fernsehgeräte, in: Umweltbundesamt (Hrsg.): Innovationspotentiale von Umwelttechnologien. Innovationsstrategien im Spannungsfeld von Technologie, Ökonomie und Ökologie; Technik, Wirtschaft und Politik (Schriftenreihe des Fraunhofer-Instituts für Systemtechnik und Innovationsforschung (ISI)), Band 32, Heidelberg (Physica-Verlag) 1998

In 1995, a first step was taken towards a "lean" voluntary agreement only covering IT equipment (computers, screens, printers, keyboards, typewriters, copying equipment, fax machines, telephones, presentation equipment) which will be taken care of by a group called CYCLE within the electric and electronic industry association ZVEI. Through this voluntary agreement, producers, distributors and importers oblige themselves to implement measures concerning product design, take back systems and recycling/recovery.

The *prime role of business strategies and profitability* becomes very clear from the examples of this section: even when corporate philosophy prioritises environmental concern the projects must be profitable; and even when recycling is not a primary objective of a project - if it is profitable, it will be done. Of high importance therefore are the market conditions under which the companies are working. And *as soon as regulation changes these market conditions, companies adapt their strategies and projects*.

Referring to the TNO/SOFRES study[65], APME expects that while evolving legislation for take-back at the end of life will increase collection rates still only 2-3% of electric and electronic plastics waste will be mechanically recycled by 2006. Constraints included problems due to dismantling difficulties, identification and the presence of flame retardants. Demand could be higher if more ABS and PS became available[66].

4.3.4 Plastics in construction and demolition waste

Like the whole report, this section concentrates on post consumer plastics waste. In the context of construction and demolition waste this means waste from renovation or the demolition of buildings. In order to facilitate understanding, elsewhere in this section we will generally use the term “demolition waste”.

The building trade consumes some 20 to 25% of total plastics consumption. Consequently, Plastics recycling is a relevant topic.

Plastics building products are diverse. They include pipes and fittings of many types and sizes, ranging from household guttering to large gas and water mains and industrial pipe-work. Other major uses, mainly PVC applications, include

- window frames/wall panels and cladding/doors/roofing and floor materials
- thermal insulation material
- electric equipment, cables, and
- packaging material.

These applications have been developed almost entirely over the past 30 – 40 years, and their service lifetime is expected to be at least as long as this, and in many cases as much as a century. Therefore relatively small amounts to date are available for recovery. Indeed, the long-life characteristics of these plastics explain their increasing popularity for construction applications. Waste from renovation and demolition of buildings therefore contains increasingly more plastics fractions, though still not much.

Generally, *the main bottleneck for the recycling of demolition waste is the knowledge of the exact composition of the demolition materials sent to recycling plants*.

[65] TNO/SOFRES: Potential of post-user plastics waste recycling, 1995 – 2006, Brussels (APME) 1998

[66] Mayne, Neil: The potential for post-user plastics waste recycling in Western Europe in the period up to 2006, in: R'99

Demolition waste from PVC

About two thirds of plastics in the building industry are made from PVC. Among these the most important are pipes and fittings, window frames, floor materials and wall panels.

While technically there has not been much development in recent years, the main innovation in this field has been the establishment of nation-wide take-back systems, e.g. in the Netherlands and in Germany.

Return schemes across Europe for pipe systems were set up in 1989 by the Dutch based group Wavin in cooperation with five other Dutch companies under the umbrella of the Dutch Federation of Plastics Pipes Producers (FKS). In the Netherlands, a high user of pipes, this led to a system with 50 collection points spread throughout the country where the waste can be delivered free of charge. Their aim is to recycle up to 100% of all pipe waste by the year 2000. This would be in the order of 5000 tons/year. The collected waste is distributed to the six members of the FKS who are obliged to recycle this waste for use in piping products. A voluntary agreement signed between FKS and the Dutch government is part of the official government waste recycling policy.

In Germany, PVC producers and PVC converters have joined to found the association "PVC and environment" in 1988. This association has concentrated during the last years to build up recycling systems for window frames (since 1991) and pipes (since 1994).

An alliance between European PVC producers (BASF, Elf Atochem, EVC, Hoechst, Hüls, Norsk Hydro, Solvay and Wacker) and flooring manufacturers has developed economic methods for the recovery of PVC flooring waste; a recycling plant exists since 1990 which produces powder from used floor coverings. Since 1994 there is a recycling facility for roofing material.

This organisational innovation of setting up a collection and recycling system for the most important products is a *result of high public pressure against PVC* from environmental interest groups, as the PVC industry openly admits. A widespread public opinion against PVC *threatened business opportunities*, e.g. some Länder (federal states) and municipalities decided not to buy products made of PVC any more. So the industry thought about possibilities of gaining back estimation for the material. The collection and recycling system was seen to be a suitable way to go.

Pipes and window frames can be collected and sorted in relatively pure fractions so that a high value recycling can be realised after which the materials are fed back into the same applications. Co-extrusion, which was developed in the early 1980s, enables the use of recycled material for the core of the product whereas the outside layers are made of virgin material (laminates). This process is primarily applied for relatively thick products, e.g. window profiles and pipes, though it can be used for thin films, too.

While in the Netherlands high disposal costs mean that collection and recycling is economically viable, this is not the case in Germany where, at present, rather low-cost disposal is available in some regions (this will change from the year 2005 onwards). *The PVC industry cluster associated under "PVC and environment" currently covers the cost differential for recycling to maintain public acceptance of the material.*

According to TNO/Sofres, the long life of construction applications, geographical dispersal and contamination with non plastic materials will limit supply from this sector to 6% of total plastics waste[67]. Recyclate demand in this sector is estimated to reach 6%, but this could be significantly higher if more recyclate would be recovered. There is a good potential demand for PVC, and in this area thick walled applications using recycled mixed plastics could be employed.

Transparent Insulations

One of the most interesting innovations in construction is the transparent insulation of buildings' walls[68]. Transparent insulation allows solar heat to be used more efficiently for a building, while preventing the heat loss. On sunny days, a building wall becomes a solar absorber and a heat storage device. Solar radiation falling on the insulation is transferred to the building interior and warms the interior wall. In this case solar energy is gained directly without supporting energy. On cloudy days, heat losses are minimised through the effect of the insulation layer. Such a passive system can therefore produce good average efficiency also during colder periods. An important benefit of transparent insulation is increased interior wall temperatures, and thus increased thermal comfort and decreased wall condensation and mould growth.

As transparent insulation materials used with massive walls today, basically high transparent synthetic materials (PC, PMMA and others) are used in honeycomb or capillar-structures, for special applications also glass. Further there are aerogels, which as a filling between panes of glas combine good insulation and transmission.

Transparent insulation is subject to research and development since the early 1980s. Fully developed products of several companies have been on the market since about 1996. But in spite of the promising experimental results and demonstration projects only a small market has currently developed. The German industry federation for transparent insulation speaks of an actual production volume of about 8000 m^2 per year[69]. *Considering the difficulties to further develop the market, the question of recycling is not yet being taken up deliberately.* Perhaps the process of building product certification may contribute to regarding recycling aspects in the future – though, usually, building regulations rather concentrate on aspects like static performance, fire resistance etc. and not so much on recycling.

---

[67] TNO/SOFRES: Potential of post-user plastics waste recycling, 1995 – 2006, Brussels (APME) 1998

[68] cf. to, e.g., ETSU: Transparent Insulation Technology, a thematic brochure of the EU-Thermie programme, Harwell 1993

[69] Werner Platzer, Fachverband Transparente Wärmedämmung e.V., personal communication June 1999

4.4 CONCLUSIONS AND RECOMMENDATIONS

The results of this investigation suggest that *industrial innovation activities* in the field of plastics recycling *and public regulation* concerning this recycling *have been largely proceeding in parallel during the last decade*. Whereas important strands of industrial activities had been followed independent of public regulations, those have in turn initiated or spurred innovation activities in industry. Depending on the individual contexts, innovative impact ranges from organisational and management innovation in the industries involved to innovation and material competition in the design phases of the products. The general conclusion is that *policies and regulations, both in force and pending, can be considered an integral part of the innovation process in industry*.

Accordingly, like other investigations this study, too, has shown that *effects of regulations on innovation are not one-dimensional*. The most important factor for innovation clearly is the expected demand. Besides a multiplicity of other factors (like market and price development), demand is also shaped by the respective regulation combined with the effects of other environmental instruments such as, for example, environmental labelling. The functioning of the ELV chain with its various forms of flexibility and multiplicity of response, suggests that it would be unwise to search for a precise causal relationship between single instruments or provisions and specific innovative outcomes.[70]

As empirical investigations have shown, the challenge it is not so much around corporate compliance with environmental policies, but relates rather more to the question of the co-ordination of such frame conditions with entrepreneurial innovation strategies. Because of this the regulations following the German ecocycle law have produced substantially different and more far reaching effects, in terms of innovation, than the material bans which formed part of earlier regulations. *Regulations are being taken as constituting factor for market demand.* Complying with these regulations or even anticipating them opens a chance to win market share.

One important effect of regulations can lie in making a reference technology more expensive. When applying regulation like that it should be considered which substitution effects might be caused.

Innovation activities have concentrated on measures to improve the chances of mechanical recycling like the automation of sorting technology, design for disassembly and recycling. Following such considerations, the most important starting points for innovation as to plastics application and recycling can be analysed as being

- decreasing the amount of material to be used by improving material efficiency
- a tendency to reduce the variety of plastics materials and increase their compatibility in a product
- the substitution of plastics by other materials more easy to recycle
- design for disassembly, design for recycling
- dismantling, identification, sorting, separation/segregation, cleaning processes
- logistics, organisation of collection systems: refund, take-back schemes etc.
- recyclates and their fields of application.

---

[70] Zoboli, Roberto: Implications of environemental regulation on industrial innovation: the case of end-of-life vehicles. Sevilla (IPTS), December 1998, EUR 18688 EN

Such approaches have been found in all the three fields of application considered in this study.

As policy is pushing for ever higher recycling targets, material streams of decreasing quality must be recycled as cheaply as possible and more markets must be found for recycled products. A common result from all the analyses examined is that, because the cost:benefit ratio under present conditions does not favour mechanical recycling, more plastics waste can be recycled than could usually be sold.. This result is, at least partly, based on current negative attitudes towards "used material". For successful high quality recycling, the existence of *standards for secondary raw materials* is a prerequisite. Such standards are now being produced and markets for secondary raw materials of certified quality are emerging. *One of the biggest issues with plastics recycling is therefore material identification*. Accordingly, a great deal of innovative effort is being put into this topic by leading players as well as small innovative high tech firms. Innovation and R&D are becoming a priority, with the main areas of interest being: improving the quality of recycled products, adapting recycling processes to handle material of lower quality, and optimizing pre-treatment (automatic sorting, separation, cleaning, etc.).

The copious delays in the process of drafting, discussing, deciding, codification and changing regulations cause delays and uncertainties which raise the transaction costs. An early *involvement of all actors* in the field can provide a positive climate for innovation. Cooperation of all actors *in the value chain should be supported for efficient solutions*.

One central result of environmental regulation concerns the importance of political targets and announcements. In many cases it has become apparent that *the discussion phase preceding the final codification of a regulation is the most productive phase to bring about innovations*.

It must not be concluded though, that a mere announcement of measures would be sufficient to cause positive effects. The reaction to the long delay in the decision about the German electronic waste ordinance has proven that the originally positive effects of the discussion process can even turn negative. It follows that environmental policy must be credible and reliable. Environmental *policy therefore should be guided by longterm objectives and be realised following a stable direction*.

Positive effects can only be expected when a stop-and-go policy can be avoided, else restrictive attention will be more probable.

Bibliography

APME: Plastics consumption and recovery in Western Europe. Association of Plastics Manufacturers in Europe (APME), Brussels, 1995

APME (Association of Plastics Manufacturers in Europe) / VKE (Verband Kunststofferzeugende Industrie): Feedstock recycling of electrical and electronic plastics waste. Technical paper, Brussels/Frankfurt, November 1997

APME: Plastics recycling has potential to double by 2006. Media Information 28 May 1998, Association of Plastics Manufacturers in Europe (APME), Brussels

APME: Plastics' use in building and construction to rise to 8 million tonnes by year 2010. Media Information 11 June 1998, Association of Plastics Manufacturers in Europe (APME), Brussels

APME: Personal communication 4 March 1999, Association of Plastics Manufacturers in Europe (APME), Brussels

Brockmann, K.L.; Osório-Peters, S.: Innovationswirkungen freiwilliger Selbstverpflichtungen im Umweltschutz – Spieltheoretische Analysen und Fallstudien zum Klimaschutz in Deutschland und den Niederlanden. in: Klemmer, P.: Innovationen und Uwelt, Fallstudien zum Anpassungsverhalten in Wirtschaft und Gesellschaft. Schriftenreihe Innovative Wirkungen umweltpolitischer Instrumente, Band 3. Berlin (Analytica) 1999

Buchinger, Eva; Fegerl, Heinz; Fugger, Erwin; Rammer, Christian: Innovation in Recycling Industries: Electric and Electronic Equipment. Part 1: Regulatory Context and Major Drivers. Austrian Research Center Seibersdorf (OEFZS-S-0013), March 1999

Bundesumweltministerium: Mit dem Entwurf eines umweltpolitischen Schwerpunktprogrammes neue Etappe in der Umweltpolitik eingeleitet – Merkel: Für eine Umweltpolitik mit Augenmaß. Press release. Bonn, 28.4.1998

Commission of the European Communities: Document SEC (89) 934 final, "Communication from the Commission to the Council and to Parliament on a Community Strategy for Waste Management", 18 September, 1989

De Groote, P.; Godard, P.: Mixed plastics compatibilisation. Study prepared by the Université Catholique de Louvain for the Association of Plastics Manufacturers in Europe (APME)

ETSU: Transparent Insulation Technology, a thematic brochure of the EU-Thermie programme, Harwell 1993

Europa Chemie 35-36/97, Anonymous: PET-Recycling: In Europa bereits 80 000 Jahrestonnen. Europa-Chemie 35-36/97, p.19.

European Parliament and Council Directive 94/62/EC of 20 December 1994 on packaging and packaging waste, Official Journal L 365, 31/12/1994

Freeman, C.; Soete, L. : The Economics of Industrial Innovation, third edition, London/ Washington (Pinter) 1997

Hoock, Reinhard S; Jürgen Schult; Ulrich Schlotter: Mechanical Recycling of Plastics from End-of-life Vehicles - Scope and Limitations –Summary of the PRAVDA-2 Project, VDA/VKE, Frankfurt, 1998

Kemp, R.; Becher, G.; Smith, K.: Environmental Regulation and Innovation: A Framework for Analysis and Research Guide, January 1999

Klemmer, P.; Lehr, U.; Löbbe, K.: Umweltinnovationen, Anreize und Hemmnisse. Schriftenreihe Innovative Wirkungen umweltpolitischer Instrumente, Band 2. Berlin (Analytica) 1999

Kühn, I.; Osório-Peters, S.: Innovationswirkungen freiwilliger Selbstverpflichtungen im Umweltschutz – Fallstudien zum FCKW-Ausstieg in Deutschland und den USA. in: Klemmer, P.: Innovationen und Uwelt, Fallstudien zum Anpassungsverhalten in Wirtschaft und Gesellschaft. Schriftenreihe Innovative Wirkungen umweltpolitischer Instrumente, Band 3. Berlin (Analytica) 1999

Kuntze, Uwe: Plastics Recycling in Europe - Regulation, Actors, Approaches for Innovation, Karlsruhe (Fraunhofer-Institut für Systemtechnik und Innovationsforschung (ISI), March 1999

Kuntze, U. et al.: Innovationswirkungen ausgewählter Beispiele des Ordnungsrechts im Bereich der Umweltpolitik, in: Rainer Walz, Uwe Kuntze (eds.): Ordnungsrecht, Abgaben und Innovationen, Ausgewählte Beispiele im Umweltbereich.; Schriftenreihe Innovative Wirkungen umweltpolitischer Instrumente, Band 4. Berlin (Analytica) 1999

Lang, Jürgen; Hiessl, Harald: Recyclinggerechte Gestaltung technischer Produkte am Beispiel Fernsehgeräte, in: Umweltbundesamt (Hrsg.): Innovationspotentiale von Umwelttechnologien. Innovationsstrategien im Spannungsfeld von Technologie, Ökonomie und Ökologie; Technik, Wirtschaft und Politik (Schriftenreihe des Fraunhofer-Instituts für Systemtechnik und Innovationsforschung (ISI)), Band 32, Heidelberg (Physica-Verlag) 1998

Leone, F.; Hemmelskamp, J. (eds.): The Impact of EU-Regulation on Innovation in European Industry, Sevilla (Institute for Prospective Technological Studies, IPTS) 1998

Mayne, Neil: The potential for post-user plastics waste recycling in Western Europe in the period up to 2006, in: R'99 Recovery, Recycling, Re-integration; Congress Proceedings (Collected Papers of the R'97 International Congress, Geneva Switzerland February 2 - 5, 1999), published by EMPA 1999, St. Gallen

Meyer-Krahmer, Frieder (ed.): Globalisation of R&D and Technology Markets, Consequences for National Innovation Policies. Technology, Innovation and Policy, Series of the Fraunhofer-Institut für Systemtechnik und Innovationsforschung (ISI), Vol. 9, Heidelberg (Physica) 1999

Nelson, R.R. (ed.): National Innovation Systems, a Comparative Analysis. New York, Oxford (Oxford University Press) 1993

OECD: The implementation of environmentally-related taxes: replies by pilot countries, COM/ENV/EPOC/DAFFE/CFA(99) 36, Paris, April 1999

Patel, Martin; von Thienen, Norbert: Recycling of Plastics in Germany, forthcoming 1999

Patel, M.; Jochem, E.; Radgen, P.; Worrell, E.: Plastics streams in Germany - an analysis of production, consumption and waste generation. *Resources, Conservation and Recycling*, 24 (1998), pp. 191-215

Peuch, Patrick: Car evolution end-of-life vehicles treatment and recovery technologies in Europe 1995 – 2015, in: R'97 Recovery, Recycling, Re-integration; Congress Proceedings (Collected Papers of the R'97 International Congress, Geneva Switzerland February 4 - 7, 1997), published by EMPA 1997, St. Gallen

Platzer, Werner, Fachverband Transparente Wärmedämmung e.V.: personal communication June 1999

Rentz, Ruch, Nicolai, Spengler, Schultmann: Selektiver Rückbau und Recycling von Gebäuden, dargestellt am Beispiel des Hotel Post in Dobel, ecomed Verlag 1994

Rogers, E. M.: Diffusion of Innovations, fourth edition, New York, London, et al. (The Free Press) 1995

Schiemann J., Institut für Umwelttechnik und Umweltanalyse (IUTA), Duisburg, personal communication June 1999

Schramm, E.; Buchert, M.; Bunke, D.; Lehmann, S.; Reifenhäuser, I.; Steinfeldt, M.; Strubel, V.; Weller, I.; Zundel, S.: Stoffflüsse ausgewählter umweltrelevanter chemischer Stoffe: Beispiele für ein Produktliniencontrolling. Umweltbundesamt Texte 80-96. Berlin (Umweltbundesamt) 1996

Siebenlist, J.: Leichtbau mit Kunststoffen ist ein absoultes Muß. VDI-Nachrichten (Verein deutscher Ingenieure), 3.4.1998, page 22

Society of Motor Manufacturers and Traders Ltd.: ACORD First Annual Report, 1998

Strubel, V; Gensch, C.-O.; Buchert, M.; Bunke, D.; Peter, B.; Ebinger, F.; Grießhammer, R.; Haas, R.: Beiträge zur Entwicklung einer Kreislaufwirtschaft am Beispiel des komplexen Massenproduktes TV-Gerät, Teilvorhaben 1: Ökologische Begleitung. Freiburg/Darmstadt (Öko-Institut) 1995

TNO/SOFRES: Potential of post-user plastics waste recycling, 1995 – 2006, Brussels (APME) 1998

Umwelt: Eine Information des Bundesumweltministeriums, Heft 9,1996 Bonn

Zoboli, Roberto: Implications of environmental regulation on industrial innovation: the case of end-of-life vehicles. Sevilla (IPTS), December 1998, EUR 18688 EN

ABAG-itm GmbH (European Topic Centre on Waste), Fellbach: Mr. Lutz Mertins

Arbeitsgemeinschaft PVC und Umwelt, Bonn: Mr. Michael Vetter

Association of Plastics Manufacturers in Europe (APME), Brussels. Dr. Herbert Fisch

Bayerische Motorenwerke (BMW) AG, München: Mr. Reinhard S. Hoock

Centre de Recherche pour Environnement, Energie et Déchets (CREED), Limay: Dr. Christelle Guy-Schmid

CGEA (Vivendi), Nanterre: Mr. Bernard Lanfranchi

EniChem S.P.A., Novara: Dr. Paolo Cortesi

Forschungsinstitut Kunststoff und Recycling, Willich: Dr. Edmund Dolfen, Mrs. Carmen Michels

Fraunhofer-Institut für Chemische Technologie (ICT), Karlsruhe: Dr. Thomas Hirth, Dr. Norbert Eisenreich

Fraunhofer-Institut für Umwelt-, Sicherheits- und Energietechnik (UMSICHT), Oberhausen: Dr. Ralf Beckmann

GRUNDIG Fernseh-Video Produkte und Systeme GmbH, Fürth: Dr. G. Winghofer

Institut für Energie- und Umwelttechnik (IUTA) an der Universität (GH) Duisburg: Mr. Jochen Schiemann

Institut für angewandte Systemanalyse (ITAS), Karlsruhe: Dr. Udo Jeske

Öko-Institut, Freiburg: Dr. Volker Strubel

Plastic Herverwerking Brakel B.V., Brakel: Mr. Dick Kramer-Freher

Polva Pipelife B.V., Enkhuizen: Mr. HansBeukers

Projektträger Umweltforschung und Umwelttechnik des Bundesministeriums für Bildung und Forschung (BMBF) bei der DLR, Bonn: Dr. W. Geppert

Rover Group Ltd., Warwick: Mr. Brian Johns

Deutsche Thomson-Brandt GmbH, Villingen : Dr. Hans Otto Haller

Verband Kunststofferzeugende Industrie (VKE), Frankfurt a.M.: Mr. Ulrich Schlotter

Fachverband Transparente Wärmedämmung, Gundelfingen:Dr. Werner J. Platzer

B.V. Wavin KLS Kunststof Leiding Systemen, Hardenberg: Mr. Jolt Oostra

PART 5

OVERVIEW OF LINKS AND LESSONS

5.1 INTRODUCTION

The main purpose of this study was to improve understanding of the links between regulation and innovation in recycling and to develop recommendations on how regulation can be better developed and implemented ton promote innovative action. The focus was on learning from the practical experiences of stakeholders with an interest in recycling, so at to reflect the true complexities of the impact of regulation and the complex interplay with other drivers and forces.

To provide as broad a picture as possible, and to ensure coverage of a variety of recycling situations, the study addressed three discrete industrial sectors; these were electric and electronic equipment, construction and demolition, and plastics. The findings of these three elements of research are presented above in Parts 2, 3 and 4 respectively.

This section draws together threads and material from the three sector studies to:

4. identify common themes and findings;
5. highlight the influences of sectoral, national and regional differences;
6. consolidate generic conclusions; and
7. propose options for improving regulation in the light of the research results.

5.2 KEY FINDINGS AND RECOMMENDATIONS

Key findings from the study are presented below. Associated recommendations are shown in *italics*.

Timing and planning of legislation

All three studies highlighted how proposed regulation can act as an important stimulus for innovation in industry. By responding early, companies seeks to achieve competitive advantage and, in some cases, influence the shape and focus of regulations. The initial response often takes the form of research to provide detail on the scale and types of material requiring recycling. This can valuable in revealing unforseen opportunities which themselves act as a stimulus for further innovation.

Examples of the influence of planned regulation include European car manufacturers concerted actions in anticipation of legislation governing end of life vehicles (see Section 4.3.2) and various types of innovation at Stena Technoworld in Sweden (see Section 2.4.2 Box 4), where take-back legislation is due to come into force in 2000.

- *Design timetables and plans for the development and implementation of regulation so that there is scope for industry to respond proactively, and with sufficiently flexibility to evolve in response to both innovations in the industry and the outcomes of dialogue between policy makers and other stakeholders.*

Notwithstanding the value of anticipation of regulation, timing is important – if there are delays in implementation, the impetus around innovation may be lost. Furthermore, expectations need to be managed, such that stakeholders do not become mistrustful of the policy makers stated plans and timetables. Routine failure to deliver on planned regulations could lead to industry choosing to ignore proposals until there is very clear evidence that they will be realised, at which point the benefits of early innovation may be lost. Experience suggests that the final consultation phase prior to the codification of new legislation is the most productive in stimulating innovation.

- *Plan and programme future policies such that expectations can be managed. Ensure that proposals are followed through or, where this is not possible, that the reasons for failure are transparent.*

Where businesses focus on the short term, this can act as a barrier to innovation. Stable operating conditions can help to encourage a longer term view, with regulatory certainty contributing to stability.

- *Seek to minimise regulatory uncertainty and provide a stable operating environment for recycling activities.*

Clearly defined and immediate challenges (such as the need to eliminate hazardous substances), often benefit from formal regulation. On the other hand, less distinct issues, where there is no urgent requirement for action, are generally well suited to more flexible mechanisms, such as economic instruments. This is particularly applicable in cases where there is a commercial benefit, such as product redesign.

- *In selecting regulatory tools, consider the policy objective, the timeframe, the business perspective and the linkages between.*

Stakeholder roles and responsibilities

Quotas may be of value in providing regulatory stability, and in encouraging long term focus. However, care is needed to ensure that local and regional disparities are taken into account in finalising scale and scope.

- *Engage in early consultation with the full range of stakeholders in planning quotas.*

The various stakeholders involved in recycling each have different priorities in innovating and improving outcomes. Even amongst organisations with similar interests competitive pressures need to be recognised. Greatest success will be achieved where synergy between the various interests can be achieved. The development of a “green” TV in Germany provides a good example of this (see Section 4.3.3).

Regulation will be most effective in stimulating innovation where it encourages early dialogue and collaboration between relevant stakeholders. There are often opportunities to pool and share experience which, in turn, helps to optimise recycling outcomes. Such opportunities can be brought about through financial incentives which encourage co-operation or by the anticipation of impending regulation.

- *Ensure that policy making reflects and builds upon the value that can be derived from stakeholder relationships in innovation.*

Public perceptions are of growing importance in stimulating environmental innovation and have a particular role in providing market pull (e.g through demand for products with a recycled component). Regulations in related areas can exploit this effect by ensuring that policy levers are designed to operate in synergy with pressure from consumers and other customers.

- *Develop policy instruments to build on and reinforce the pressures on industry derived from public perceptions.*

Demonstration projects provide a mechanism for reducing the risk associated with investment in innovation. With appropriate funding / support, they can also play an important role in encouraging stakeholders to consolidate effort in areas of mutual interest.

- *Support for demonstration activity should be continued. Priority should be given to demonstrators which involve the full range of relevant stakeholders and reflect the pragmatic relationships between them.*

In certain sectors, government purchasing policies can play an important role in stimulating recycling. By specifying that materials or products have a (possibly quite specific) recycled element, local and national authorities can establish precedents, demonstrate the effectiveness of the product or material and provide the market pull necessary for recycling to function effectively. (The same holds true for the reverse case of banning technologies with a negative impact.) Clearly this will be most effective in sectors where government is a significant purchaser.

- *Provide purchasing authorities with the flexibility to establish purchasing policies which stimulate recycling.*

Government involvement in innovation can help to define how new regulations develop. This is particularly true for organisational innovations, such as collection. Austrian trials to develop local collection systems for electric and electronic waste illustrate the value of this approach (see Box 5, Section 2.4.3).

- *Facilitate the support / involvement of national and local government in stimulating innovation where appropriate.*

Research to support innovation

Where impending regulation has lead to voluntary action by industry, there have been instances of broadly comparable research activities taking place in different locations across Europe. The CARE, RECAP and PRAVDA projects in the automotive sector (see Section 4.3.2) are good examples. With greater interaction and co-operation, there is the potential to reduce duplication and ensure more efficient targetting of resources.

- *In planning future research activities, target resources to plug gaps and complement ongoing activities. Consider the potential to providing a co-ordinating role.*

Market adjustment

Financial considerations are a critical factor influencing innovation in business. Thus, policy mechanisms which adjust the economic framework or market conditions could play an important positive role. This could work in various ways – for example, making the reference technology more expensive (e.g .increasing the costs of landfill) or creating a demand for recyclate (e.g. the case of Korrelmix in the Netherlands – see Section 3.4.1). There is also scope for other forms of legislation, such as voluntary agreements, to have a positive impact. A good example is the CARE project in the UK (see Section 4.3.2) where automotive manufacturers have a stated commitment to use recycled material wherever possible.

- *Use policy instruments as levers to adjust market conditions, either directly or indirectly, in ways which stimulate recycling.*

As a related matter, it is important to consider all the implications of policymaking if the desired outcome is to be achieved. Instruments which encourage recycling but take no account of the demand (or lack thereof) for recycled materials are unlikely to be successful in the long term. Conversely, where there is demand, this can act as an important lever to stimulate action and innovation earlier in the supply chain.

- *Ensure that the full recycling supply chain, including demand for recyclate, is considered.*

The role of standards

Technical standards can act as a barrier to innovation. These could take the form of requirements that a certain proportion of raw materials in a secondary one or material specifications based around physical attributes or performance. Clearly, the relevance of this varies between sectors, and was found to be particularly pertinent in the construction sector.

- *Ensure that the development of technical standards takes account of the possible implications for recycling.*
- *Incorporate exemption clauses into technical standards where appropriate.*
- *Be prepared to modify standards to reflect recycling priorities.*

Innovation around technologies and processes which improve material identification will facilitate progress in collection, sorting and dissassembly. This can be stimulated through standards for secondary raw materials. Such standards would need to take account of a wide range of considerations including fitness for purpose, safety and aesthetic aspects.

- *Develop appropriate standards, based on performance, for secondary raw materials.*

A quality certification scheme can stimulate confidence and, thus, market demand for products and materials derived from recycled material. This is well illustrated by the Dutch experience in developing Korrelmix. Furthermore, process, rather than organisational, certification is of particular value in fragmented industries. This should focus on performance rather than constituency.

- *Ensure that regulations do not hamper the development of certification schemes, and encourage these where they have value.*

Manufacturers' desires to achieve product differentiation in competitive markets act as a barrier to improving the disassembly element of reycling. The electric and electronic goods sector contains many examples.

- *Explore the scope for achieving a more sustainable balance between competitive forces (which encourage differentiation) and recycling considerations (eg standardisation).*

Innovation to improve collection, dismantling and sorting

To have greatest impact, regulations aiming to stimulate recycling should be targeted such that they encourage innovation where it is most appropriate to increase / improve recycling rates. For example, if dismantling processes are improved, but the amount of material being collected remains unchanged then the value of the innovation could be lost.

Improvements in collection, dismantling and sorting are critical to future progress in recycling. Organisational innovation which maximises efficiency at minimum cost will be of particular value. Areas of focus will vary from sector to sector. In the case of WEEE, for example, the need to engage households in collection is paramount (see Box 5, Section 2.4.3). In the construction sector, by contrast, mechanisms which reduce the impact of any delays in demolition associated with material re-use will be important.

- *Target regulations towards efficient, cost effective levers which stimulate collection, dismantling and sorting (for example, the requirement for demolition plans mentioned in Section 3.4.2)*

Strategic considerations

The scope for and potential of innovation varies between sectors. This relates to the overall structure of the sector (eg fragmented versus dominated by a few large players) and to the relationships between recycling stakeholders (e.g. whether there are specialist recycling businesses). For example, in the electric and electronic equipment sector, product innovations can be introduced relatively easily and have a considerable impact, whereas process innovation is rather less straightforward. In the construction and demolition sector the real challenges for recycling relate to organisation aspects. Progress is hindered by the fragmentary nature of the industry, the variability in local industry structures and the heterogeneity of the waste stream. Thus, innovation tends to be focused in areas where institutional contexts and stakeholder relationships and roles can be improved.

- *Ensure that policies take account of the specific areas of innovation potential in the sectors to which they are addressed.*

Instruments which allow for flexibility of response, such as broad recycling targets and voluntary agreements, can be particularly useful in stimulating a variety of innovative responses. The development of the Korrelmix certification scheme in the Netherlands is a good example (See Section 3.4.1). By contrast, regulation which is rigid can reduce the flexibility of response and limit innovation.

A particular advantage of a flexible approach at the European level is that it allows variabilities in sector structures (which reflect local cultures and institutional arrangements) to be accommodated.

- *Notwithstanding overriding environmental / sustainability priorities, provide sufficient flexibility at the European level of policy making to allow adaptation to local conditions in member states, and to provide stakeholders with choice in responding.*

Incentives for developers of new products and materials to consider recycling appear to be limited at present. There is significant scope to increase future recycling rates by ensuring that life cycle impacts, including disposal, are considered at the outset, with the potential for and value of recycling being given appropriate attention. This is especially import for technologies in the beginning phase of their life cycle. (These types of analyses help to highlight the financial benefits of improving waste management, including recycling.) EMAS could have an important role to play here.

- *Develop mechanisms to ensure that waste management issues (including recycling) are given full attention during technology development.*

International drivers, such as Kyoto targets and global competition put pressure on governments to become involved in innovation. This is highlighted by the example of the SCARE project (See Box 7, Section 2.4.4).

Product / material based policies and sector orientated policies both have a role in stimulating recycling. A matrix approach, combining these two strands, provides the flexibility to achieve both short and long term policy objectives. Thus, whilst product oriented policies have an important role to play in respect to hazardous substances, such as CFCs, sector oriented policies can take account of issues relating to collection, sorting and dismantling which vary across different types of supply chain.

The diverse range of findings show that there is no single paradigm which will stimulate innovation, encourage cost effective and efficient recycling, and be applicable in every case. More specifically, it is not possible to distil simple relationships between individual regulations and specific innovation outcomes. It is difficult to disentangle the various forces which influence innovation, and regulation often forms only one of a bundle of factors. This is highlighted by the experiences around recycling of end of life vehicles, where a multiplicity of responses have occurred. Different circumstances (sectors, countries etc) need to be considered individually with the mix of policy measures chosen to reflect specific requirements.

- *Recognise that there is no one simple answer to the question of how to stimulate innovation through regulation in recycling. Instead, adopt a holistic approach, which takes account of the various central and peripheral mechanisms and their complex and inter-related impacts. This needs to also reflect the roles and responsibilities of recycling stakeholders, the relationships between them and the balance of costs and benefits.*

APPENDIX 1

CONSULTATION PROFORMA

This proforma comprises a series of questions to form the basis of consultation with stakeholders in the recycling industry. It is not necessarily comprehensive, but seeks to present some introductory discussion points. The aim is not to provide a questionnaire, but rather guidance to form the basis / framework of a semi-structured discussion. Those using the proforma are encouraged to ensure that their consultation retains the flexibility to explore unanticipated issues around the links between regulation and innovation. Respondents should not be encouraged to chose from a list, but rather to respond in whatever way is appropriate. The example responses given below are included primarily for use where consultees have difficulty in explaining / describing their position.

Note that the overall aim of the research is not quantify innovation, but to generate insights into the role of innovation in stimulating or inhibiting innovation, and to highlight opportunities for improvement of regulatory mechanisms in the context of encouraging innovation.

Possible discussion topics

1. Tell me about your business / organisation?

    - purpose, characteristics, size, interest in recycling......

2. How is innovation organised in your organisation?

    - specific R&D department, particular technical discipline, ad-hoc......

3. Do you have continuous improvement strategies? How do these work?

4. Can you provide examples of innovation in recycling which have occurred in your organisation?

5. How would you classify these examples?

    - technical....

    - organisational: internal programmes, training / learning, communications, channels of responsibility, relating to (e.g. environmental targets ....)

    - marketing

    - relating to peripheral or core business activities

6. Could you attach a value to these innovations (could be in terms of absolute monetary value, a percentage of turnover, profit or cost reduction)

7. What factors stimulated these innovations?

    - anticipated regulatory change....

    - actual regulatory change....

- market conditions (new entrants, changing economic situation)....

8. If regulation was involved, please provide further details of the type and coverage of the regulation and how it stimulated innovation?

9. How did the innovations occur?

- via formal R&D channels....
- through an ad-hoc approach....

10. How did your networks, linkages and relationships with other stakeholders impact on the innovation processes? Was it different for different innovations? If so, how?

11. What have been the effects of these innovations - both long and short term, and intended and unintended?

- improved compliance (how?).....
- ensured compliance (how?)....
- more efficient operations.....
- improved product / process.....
- improved profitability (increased revenue, decreased costs).....

12. Is this what you had anticipated? If not, in what way?

13. Can you provide any examples of where regulation, either in force or anticipated, has hindered innovation in your business? How did this happen? Can you quantify the effect?

14. What other incentives for innovation are you aware of that could impact on your business? Why have these not had an effect?

15. Have you experienced any innovations which were not related to recycling activities, but had an impact on recycling? What happened? Was the outcome positive or negative? Were regulations involved and, if so, how?

APPENDIX 2
CONSULTEES

Waste Electric and Electronic Equipment

Bruens W. / Bruckmüller R. (Philips, Netherlands/Austria)

Burgdorf P. (Siemens Nixdorf, Recycling Center Paderborn, Germany)

Criens R. (Bosch-Siemens Haushaltsgeräte GmbH München, Germany)

Frey O. (ZVEI German electrical and electronic manufacturers' association, Germany)

Herman V. (ICL, Belgium)

Herrlin J. (ASG, Transport Company, Sweden)

Jeslind M. (NSR AB Helsingborg, Municipality, Sweden)

Kopacek B. (SAT Austrian Society for System Engineering, SCARE Office, Austria)

Ogrisegg F. (Salzburger Landesregierung, Regional Government, Austria)

Peetermans A. (Siemens AG, Germany)

Salhofer S. (University of Agriculture, Evaluator of Pilot Collection Projects, Austria)

Sjölin S. (Stena Technoworld AB, Recycling Company, Sweden).

Construction and demolition waste

Bueren, Ellen van, Research Institute Sustainable Building, Delft University of Technology, The Netherlands.

Collins, Rod, Building Research Establishment – Centre for Waste and Recycling

Egan, Steward, Tarmac Recycling, United Kingdom

Hobbs, Gilli, Building Research Establishment – Centre for Waste and Recycling

Mulcahy, Tony, Department of Environment, Transport and Regions, United Kingdom

Mulder, Evert, TNO Environment, Energy and Process technology, The Netherlands

Nielsen, Erik, Asfaltindustrien, Denmark

Pihl, Knud A., Danish Road Directorate

Rasmussen, Paul, Danish EPA (Miljøstyrelsen), Division of Industrial Waste

Sundahl, Jesper, Rambøll Consultancy, Denmark (email exchange)

Trevorrow, Tony, Nottingham Trent University, United Kingdom

Van der Waal, Jeroen, Ministry of Housing, Spatial Planning and the Environment, The Netherlands

Zoontjes, M.E., Association for the Interests of Construction and Demolition Waste Recycling (BRBS), The Netherlands

Plastics waste

ABAG-itm GmbH (European Topic Centre on Waste), Fellbach: Mr. Lutz Mertins

Arbeitsgemeinschaft PVC und Umwelt, Bonn: Mr. Michael Vetter

Association of Plastics Manufacturers in Europe (APME), Brussels. Dr. Herbert Fisch

Bayerische Motorenwerke (BMW) AG, München: Mr. Reinhard S. Hoock

Centre de Recherche pour Environnement, Energie et Déchets (CREED), Limay: Dr. Christelle Guy-Schmid

CGEA (Vivendi), Nanterre: Mr. Bernard Lanfranchi

EniChem S.P.A., Novara: Dr. Paolo Cortesi

Forschungsinstitut Kunststoff und Recycling, Willich: Dr. Edmund Dolfen, Mrs. Carmen Michels

Fraunhofer-Institut für Chemische Technologie (ICT), Karlsruhe: Dr. Thomas Hirth, Dr. Norbert Eisenreich

Fraunhofer-Institut für Umwelt-, Sicherheits- und Energietechnik (UMSICHT), Oberhausen: Dr. Ralf Beckmann

GRUNDIG Fernseh-Video Produkte und Systeme GmbH, Fürth: Dr. G. Winghofer

Institut für Energie- und Umwelttechnik (IUTA) an der Universität (GH) Duisburg: Mr. Jochen Schiemann

Institut für angewandte Systemanalyse (ITAS), Karlsruhe: Dr. Udo Jeske

Öko-Institut, Freiburg: Dr. Volker Strubel

Plastic Herverwerking Brakel B.V., Brakel: Mr. Dick Kramer-Freher

Polva Pipelife B.V., Enkhuizen: Mr. HansBeukers

Projektträger Umweltforschung und Umwelttechnik des Bundesministeriums für Bildung und Forschung (BMBF) bei der DLR, Bonn: Dr. W. Geppert

Rover Group Ltd., Warwick: Mr. Brian Johns

Deutsche Thomson-Brandt GmbH, Villingen : Dr. Hans Otto Haller

Verband Kunststofferzeugende Industrie (VKE), Frankfurt a.M.: Mr. Ulrich Schlotter

Fachverband Transparente Wärmedämmung, Gundelfingen:Dr. Werner J. Platzer

B.V. Wavin KLS Kunststof Leiding Systemen, Hardenberg: Mr. Jolt Oostra

APPENDIX 3
Abbreviations

APME	Association of Plastics Manufacturers in Europe
ASR	automotive shredder residue
EEW	electric and electronic waste
ELV	end of life vehicles
MSW	municipal solid waste

About the IPTS

The Institute for Prospective Technological Studies (IPTS) is one of the eight institutes of the Joint Research Centre (JRC) of the European Commission. It was established in Seville, Spain, in September 1994.

The mission of the Institute is to provide techno-economic analysis support to the European decision-makers, by monitoring and analysing science and technology related developments, their cross-sectoral impact, their interrelationship in the socio-economic context and future policy implications and to present this information in a timely and logical fashion.

Although particular emphasis is placed on key science and technology (S & T) fields, especially those that have a driving role and even the potential to reshape our society, important efforts are devoted to improving the understanding of the complex interactions between technology, economy and society. Indeed, the impact of technology on society and, conversely, the way technological development is driven by societal changes are highly relevant themes within the European decision-making context.

In order to implement this mission, the Institute develops appropriate contacts, awareness and skills for anticipating and following the agenda of the policy decision-makers. In addition to its own resources, the IPTS makes use of external advisory groups and operates a network of European institutes (ESTO) working in similar areas. These networking activities enable the IPTS to draw on a large pool of available expertise, while allowing a continuous process of external peer review of the in-house activities.

The interdisciplinary prospective approach adopted by the Institute is intended to provide European decision-makers with a deeper understanding of the emerging S & T issues, and is fully complementary to the activities undertaken by other Joint Research Centre institutes.

For more information: http//:www.jrc.es ipts-secr@jrc.es

About ESTO

The European Science and Technology Observatory (ESTO) is a network based on a core group of 17 European leading organisations with expertise in science and technology assessment. ESTO provides real-time information on the socio-economic significance of scientific and technological advances. The ESTO network is directed and managed by the IPTS.

Along with the 14 initial members, another group of institutes later became associated to the ESTO network covering all the 15 EU Member States as well as Israel. Membership is being continuously reviewed and expanded with a view to meeting the evolving needs of the IPTS and to incorporate new competent organisations from both inside and outside the European Union.

The ESTO network was formally constituted in February 1997 and its principal tasks are:

- to contribute to the *IPTS Report* with articles on relevant topics;
- to issue, on a periodic basis, a techno-economic analysis report, which reviews socio-economic developments either arising from technological change or driving it;
- to produce input to long-range foresight studies undertaken by the IPTS in response to EU policy needs;
- to provide quick responses to specific S & T assessment queries.

For more information: http//:www.jrc.es Contacts: esto-secretary@jrc.es

About the project partners

This project was coordinated by CEST (United Kingdom) and executed by the TNO-STB (the Netherlands), ARCS (Austria), ISI (Germany), with the support of the IPTS. The contacts for this project of each participating institute are listed below.

CEST	Celia Greaves (Project Manager):	cgreaves@cest.org.uk
ARCS	Eva Buchinger:	eva.buchinger@arcs.ac.at
TNO	Hugo Verhuel:	verhul@stb.tno.nl
ISI:	Uwe Kuntze:	uk@isi.fhg.de
JRC-IPTS	Fabio Leone:	fabio.leone@jrc.es