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Product Policy and the Environment: The Example of Batteries

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Product Policy and the Environment: The Example of Batteries

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0 Preface

This case study on "Batteries" is part of the second step of the project "Product policy in support of environmental policy" which is conducted with the financial support of the European Commission within its programme "Socio-Economic Environmental Research". The entire project consists of four steps:

1. Inventory of environmentally oriented product policy instruments for each of the EC member states and for EU policy.
2. Case studies of selected instruments and policies with a significant environmental orientation.
3. An evaluation of selected product policy instruments with respect to their effectiveness in increasing the market share of environmentally oriented products and in decreasing the demand for environmentally harmful products.
4. The development of strategic proposals for the optimisation of product policy instruments, especially those that would encourage enterprises to develop relevant product development strategies.

The findings of the first step - inventory - have been published in:

* an interim report summarising the country reports and containing the most important results (IÖW-Schriftenreihe 72/94),
* twelve country reports describing the existing product policy in each of the former Member States of the European Union (IÖW-Schriftenreihe 72/94 - B, D, DK, E, F, GR, IRL, IT, LUX, NL, P, UK) and
* a report describing the trends of product policy of the EU itself (IÖW-Schriftenreihe 72/94 - EU).

These reports are available at **Institut für ökologische Wirtschaftsforschung (IÖW), Giesebrechtstr. 13, D - 10629 Berlin**.

The instruments we have chosen for the in-depth-studies are eco-labels and public procurement, the product groups are paints/varnishes and batteries. For each case study, we will follow the historical development of the policy, and consider its effects and the evaluation of its effectiveness as far as this is possible on the basis of the knowledge available in the respective countries.

The findings of the second step - case studies - will be published in four reports within the publication series of IÖW (F. Rubik "eco-label", G. Scholl "batteries") and of IVM (F. Oosterhuis "paints/varnishes", N. van der Grijp "public procurement"). They are available at **Institut für ökologische Wirtschaftsforschung (IÖW), Giesebrechtstr. 13, D - 10629 Berlin** and **Instituut voor Milieuvraagstukken, Vrije Universiteit, De Boelelaan 1115, NL - 1081 HV Amsterdam** respectively.

The final report including the results of the entire project, especially of the third and fourth step, will be published in summer 1995. Information is available at **Institut für ökologische Wirtschaftsforschung (IÖW), Regional-Office Baden-Württemberg, Bergheimer Straße 97, D - 69115 Heidelberg, Tel. +49/6221 / 167954, Fax. +49/6221 / 27060**.

The most decisive reasons behind the choice of batteries as one product group have been:

* they have been subject to environmental policy,
* further environmental policy measures are expected in the future,
* the variety of applied instruments is quite large,
* the product is being consumed and subject to environmental regulation in at least one Southern European Member State,
* extent to which all stages in the life cycle play a role,
* sufficient information is available,
* inclusion of a Southern European country.

Furthermore, the case study draws special attention to selected Member States of the European Union. We have chosen Germany and Italy for a deeper investigation of the product group of batteries. We also look at the battery-oriented measures being taken in Denmark and some other European countries, but in a less detailed way. The selection has been based on the following criteria:

* number of national battery producers,
* regulatory density, i.e. to which degree the treatment of (used) batteries is regulated by prescriptions, ordinances and other product oriented environmental policy instruments[1] ,
* implementation of innovative instruments (those that do not belong to measures of command and control),
* information access.

The case studies of Germany and other European countries have been performed by IÖW in Heidelberg, the Italian case study has been elaborated by Anna Melone of Ambiente Italia in Milano.

I would like to thank everyone who contributed to this paper; especially Petra Schmitz, Pia Bayer, and my colleague Frieder Rubik, our very helpful draughtsman of figures Johannes Stauder and also Joop de Boer, Nicolien van der Grijp and Frans Oosterhuis from IvM for their fruitful comments.

Heidelberg, April 1995

[1] The assessment according to this criterion is based on the inventory of product policy instruments as it has been carried out in the first stage of our project.

1 Objectives and approach

1.1 Introduction

Nowadays, environmental policy is focusing on environmental impacts emanating from products along their life cycle. A wide range of product policy instruments have been introduced in order to cope with these impacts: product bans, labelling prescriptions, take-back obligations, disposal charges, eco-labels etc.

Batteries are one product dealt with by several of these instruments. An EC Directive on Batteries and Accumulators Containing Dangerous Substances includes labelling prescriptions and calls for the installation of a recollection system. This Directive also proposes deposit-refund schemes for achieving sufficient return quotas.

The main impetus of environmental policy for addressing batteries is the large percentage of heavy metals - mercury, cadmium, lead - of at least some of the battery systems, which can disperse into the different environmental compartments during their disposal with the normal household waste (landfilling, incineration). Therefore, it is one objective of battery-oriented environmental policy to ensure the separate collection and the environmentally proper treatment of spent batteries. Moreover, the promotion of environmentally sound battery systems and the reduction of the battery use in cases where this is possible might represent objectives which are sometimes part of "official" policy programmes and sometimes part of information campaigns taken, for example, by environmental organisations.

It will be the task of this case study to assess the effectiveness, efficiency and feasibility of environmental policy directed to batteries. For this purpose we will study the formulated objectives, evaluate the applied and discussed policy instruments meant to achieve these objectives, against the background of selected criteria and we will focus on the actors which are involved in the implementation and application of the policy.

1.2 Scope and method

Batteries are used for several and different purposes and, according to their field of application, can be distinguished into the following battery types (Genest, 1987, p.320):

* equipment batteries or batteries for consumer appliances
* starter batteries for cars
* traction batteries, e.g. for fork-lift trucks and electric cars
* stand by power systems, e.g. for emergency power supply.

The last two categories - traction batteries and stand-by power systems - are often subsumed under the category of batteries for industrial use. The different categories listed above correspond with different and separated markets on which the batteries are bought and sold.

The following table provides the German production figures for different battery categories. Figures that exactly correspond with the four categories are not available.

Table 1.1: Production figures for batteries in Germany for the year 1992 (Statistisches Bundesamt 1992, p. 85)

Category	Value [1,000 DM]
1. Lead accumulators	
1.1 < 7 kg	n.a.[a)]
1.2 Traction batteries	515,773
1.3 Starter batteries	923,690
1.4 Others > 7 kg	254,057
2. Other accumulators	222,960
3. Primary batteries	407,874

a) not available

The table shows that starter batteries account for the largest part of the battery production according to their value. However, since primary, i.e. non-rechargeable batteries are a lot cheaper than starter batteries they account for a considerable quantity. In addition, one has to note that the reported *production* figures do not reflect the battery *consumption* in Germany because there arealso import and export flows: for the year 1991 the balance of trade for primary and starter batteries was just positive and for traction batteries and stand-by lead accumulators negative, as it is shown in table 1.2.

Table 1.2: Import and export of batteries in Germany (Deutscher Bundestag 1994, p.4)

	Import 1991 [t]	Export 1991 [t]
Primary batteries	17,300	18,490
Starter batteries (lead)	53,400	64,400
Traction batteries	10,500	6,300

Speaking of **"batteries"** in the following we include **primary (non-rechargeable) batteries** and **secondary (rechargeable) batteries**, also called accumulators.

In this case study we focus on the category **"private use of batteries in consumer appliances"**, including both, rechargeable and non-rechargeable batteries. These batteries are also called equipment or household batteries. The confinement to equipment batteries can be justified for several reasons:

* From an environmental policy point of view the problem of batteries in consumer applications seems to be the most serious one, at least because of the considerable quantities of (heavy) metals discarded into the different environmental compartments through the household waste in a more or less uncontrolled way.

* The systems in industrial use are maintained by professional personnel and collected by their producer after use. This ensures a relatively high return quota (Genest/ Reimann 1985, p. 221).

* The same holds true for starter batteries (lead accumulators), although they are recovered mainly for economic reasons. In Germany for example, the return quota amounts to approx. 90 %. Furthermore, 30 % of the national lead consumption is covered by the recycling of used starter batteries. (Genest/ Reimann 1985, p.218 f)[2] However, one has to take into account the increasing number of cars - for Germany 50 million cars are expected by the year 2010 (Süddeutsche Zeitung, 16.6.94)- possibly resulting in more severe environmental impacts emanating from starter batteries.

* Household batteries are not confined to narrow application areas, but can be used in a large scale of different appliances. Consequently, environmental policy has to cover widespread areas instead of regulating highly specialised fields.

* Different actors are involved, such as consumers, professional users, producers of batteries and appliances, wholesalers and retailers, communities and municipalities, consumer and environmental organisations and policy makers.

* The draft version of the German battery ordinance excludes "batteries for specific purposes" such as stand-by nickel-cadmium accumulators and traction batteries and batteries applied in the areas of the post services, army[3] and industry.

The research methods used in the case study encompass

* studying information gathered in cooperation with correspondents and subcontractors in different countries and

* exploitation of expert information and available documentation.

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[2] However, for Germany it has also been stated that 20 - 25 % of used starter batteries do not reach recycling channels, but instead are disposed of either wildly or through the household waste, leaving 30,000 t of lead in unknown channels, thereby exerting considerable negative environmental impacts. (Ministerium für Umwelt Rheinlandpfalz 1994). Moreover, the "official" ten percent of non-recollected lead accumulators account for a very high quantity in absolute figures, so that even this alleged small percentage may not be neglected from an environmental point of view.

[3] In Germany, the army consumes approximately 10 million primary (mainly alkali-manganese) and 1 million of secondary (mainly nickel-cadmium) equipment batteries per year. Concerning the primary cells a specific problem occurs: Batteries for military uses are, on average, stored longer than for private use. Thus, to improve their properties of self-discharge these batteries contain a relatively higher content of mercury. To ensure the proper disposal of these batteries, the army negotiates a special disposal treaty with their main supplier (VARTA) and, additionally, increasingly substitutes primary cells with rechargeable secondary cells. Military officials state that the improper disposal of batteries is nearly impossible, since, normally, new batteries are only given out in exchange of a used battery.

Interviews with key persons (scientists, representatives of industrial, consumer and environmental organisations and of governmental institutions) have been conducted. Additionally, information from producers of batteries is collected via questionnaires.

1.3 Outline

The structure of the case study is as follows. In chapter 2 it starts with the description of the technological (2.2) and economic (2.3) aspects of the product group of batteries and their different fields of application. Not merely the status quo is described but also future developments, as far as they can be anticipated. The environmental relevance of batteries is discussed afterwards (section 2.4). The chapter ends with a brief discussion of the actors relevant for the battery issue (section 2.5) and a list of policy objectives resulting from the preceding findings of chapter two (section 2.6).

The main focus of the case study, however, is on the description of the environmental policy instruments applied to batteries (chapter 3) and on their evaluation by means of selected evaluation criteria (chapter 4).

The description of battery-oriented environmental policy starts with the measures taken at the level of the European Union (section 3.2) and focuses on the policies of Germany (section 3.3) and Italy (section 3.4). Moreover, we will briefly depict policy measures of other countries as far as they appear to represent instructive examples for the battery discussion (section 3.5: Denmark, Belgium, The Netherlands and Switzerland). Finally we will compare the different country-specific approaches (section 3.6).

In chapter 4 we assess and evaluate the policies of Germany (section 4.2) and Italy (section 4.3). These sections are subdivided according to the policy objectives we have found relevant for batteries in section 2.6. The policies are evaluated against the background of the following criteria:

* environmental effectiveness,
* economic efficiency,
* acceptance,
* flexibility,
* side-effects on alternative product groups.

The section 4.4 "barrier analysis" will summarise the major bottlenecks of an effective environmental policy on batteries (awareness, information, economic, organisational, technical barriers) and assess the relevance of these barriers for Italy and Germany. Section 4.5 "comparison and conclusions" compares the assessment of the German and Italian situation and encompasses the most important conclusions that can be drawn from the evaluation.

Chapter 5 contains a final discussion of the policy objectives, of the applied instruments, of the product group of batteries and of the involved actors.

2 The product group of batteries

2.1 Introduction

This chapter aims at describing the product group of batteries from several perspectives. First, the technological and economic aspects of battery systems as hey effect battery markets are discussed (chapter 2.2 and 2.3), including a focus on the fields of application of the different battery systems. The analysis of the status quo is supplemented by the description of the future developments concerning both, the battery systems and their fields of application. Chapter 2.4 is devoted to the qualitative analysis of the environmental impacts emerging from batteries along their life cycle. Chapter 2.5 provides an overview of the actors involved in the battery issue and in the final chapter 2.6 some summarising conclusions are drawn with respect to the possible objectives of a battery-oriented environmental policy.

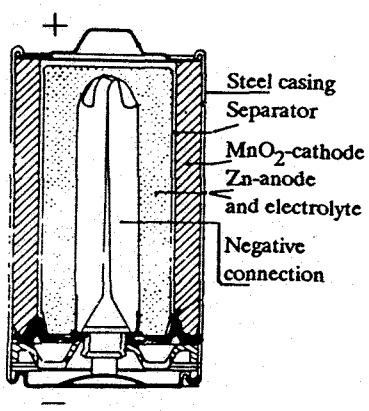
2.2 Technological Aspects

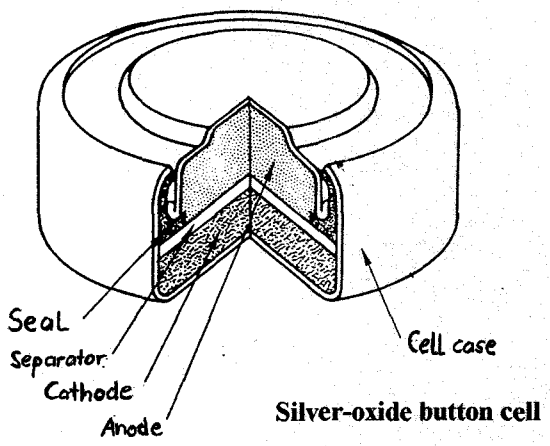
2.2.1 Battery systems

Batteries are electrochemical energy storage units, in which electrons are passed between a positive electrode (cathode) and a negative electrode (anode) through an electrolyte (Institute for Risk Research, 1992, p.1). The positive pole consists of a metal, the negative pole of a metal-oxide. Furthermore, a battery includes the separator, which separates the anode from the cathode in order to prevent a short circuit, and the collector which collects the electrons and transports them out of the battery. All these parts are enclosed in a water tight case. (Ralston Energy Systems 1990)

Figure 2.1: Essential elements of a battery (Ralston Energy Systems 1990)

Cylindrical alkali-manganese





Silver-oxide button cell

Box 2.1 below lists several aspects which are of importance for the **characterisation of batteries.**

Box 2.1: General battery features (Baumann 1993, p. 12 f.)

- battery *type*: design of the battery (button, cylindrical, prismatic),
- battery *system*: the chemical system which is used to produce energy (e.g. zinc-carbon or zinc-silveroxide),

- battery *format*: size, height and diameter (cylindrical batteries exist in eleven normed versions and button cells in six normed versions),
- *rechargeability* of batteries: primary elements (non-rechargeable) can only be used once, whereas secondary systems (rechargeable) can be used several times,
- *user-replaceability* of batteries: some appliances use permanently built-in batteries, i.e. these cannot be replaced after the battery is used up or the appliance has broken down and they have to be discarded along with the apparatus,
- *energy density*: amount of energy that is delivered per unit of weight or volume,
- *life span*: period of time between first production and final use of a battery; it depends on variables such as rate of self discharge, temperature, proper treatment, use intensity, recharging process and quality of the cell.

The following table provides a list of the batteries which are normally used in the different electronic appliances. These are the systems we will take into account.

Table 2.1: Overview of considered battery systems

System	Type[a)]	Rechargeability
Zinc-carbon	c, p	primary
Alkali-manganese	b,c,p	primary
(Zinc-) mercury-oxide	b	primary
(Zinc-) silver-oxide	b	primary
Zinc-air	b,c	primary
Lithium	b,c	primary
Nickel-cadmium	b,c (sealed)	secondary
Nickel-hydrid	c	secondary
Lithium	b	secondary
Lead-accumulator	p (small)	secondary

a) [b] button, [c] cylindrical, [p] prismatic

The lead accumulator exists in two versions: a small one for use in appliances and a bigger one for use in cars as starter batteries. The latter type has been excluded from the case study. A reason for including the small version is the fact that it can serve as a substitute for NiCd accumulators in some application areas.

The rechargeable nickel-cadmium battery is available in two versions, sealed and open. A restriction to sealed nickel-cadmium batteries seems plausible for three reasons:

* major part of cadmium consumption in this system,[4]

[4] For Germany Bätcher et.al. (1992, p.121) estimate a percentage of 48% of the total cadmium consumption in this application area. Putois (1992, p.10) claims that 75% of the world market for nickel-cadmium batteries are used as portable (sealed) batteries, 25% are used as larger, industrial batteries (open version).

* wide range of application (open systems are mainly used in military and industrial applications, whereas the sealed system is used in the whole range of portable consumer goods),
* the open NiCd accumulator is increasingly substituted by improved rechargeable lead batteries (Bätcher et.al., 1992, p. 122) and thus will increasingly lose importance.

From an environmental point of view the dangerous substances contained are the core issue of the battery issue.[5] Among them are the heavy metals mercury, lead, cadmium, zinc, nickel and the metal lithium. Furthermore, the salt mangandioxide is of importance. Their environmental relevance is discussed in more detail in chapter 2.4.

During recent years a couple of **technological innovations** have occurred in the field of batteries. Technological innovations can be brought about either by strengthening the energy efficiency of the battery system, by improving or modifying the materials used or by substituting certain chemical substances of a battery with alternative substances, i.e. substituting the entire battery system by another system.

Kaiya (1992, p.80 ff.), for example, reports a technological innovation of the first kind for the case of nickel cadmium batteries. Matsushita Battery Industrial Co. Ltd., Japan, has developed higher capacity nickel-cadmium batteries by improving components such as electrodes, separators and the battery case.

The **alkali-manganese** battery has been celebrated as the "rising star of the eighties" (Wirtschafts Woche, 10.06.1988), since, compared to the zinc-carbon battery, it has considerable performance advantages: its life-span is six times longer than that of a zinc-carbon battery (International Management 1993), its performance is between two and eight times higher and it is less sensitive to low temperatures (Ralston Energy Systems 1990, p.20). Furthermore, the mercury content of alkali-manganese batteries has been reduced during recent years. This reduction, which has now reached a mercury content of approximately 0 %, has been brought about by the use of tensides or the use of pure zinc in the battery. It has been reported that a US producer has developed a re-useable, i.e. rechargeable for a few times, alkaline battery system (Financial Times, 1993), planned to be on sale in the US by the end of 1993.

Another product innovation is represented by the **zinc-air** button cells. During storage, these cells are sealed. To be operative the seal has to be removed. Since the cells start discharging then, they are suitable especially for continuous use, e.g. in hearing aids. In table 2.2 the advantages and disadvantages of the zinc-air battery in comparison with the system it aims to substitute, namely the mercury oxide battery, are summarised.

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[5] Annex I provides a detailed list of the chemicals that are included in the considered systems.

Table 2.2: Zinc-air compared to mercury-oxide battery[6]

Advantages of zinc-air systems	Disadvantages of zinc-air systems
- low mercury content - higher energy density - double life span	- sensitive to humidity - sensitive to fluctuations in oxygen availability - higher sales price

Lithium batteries, which are cadmium- and mercury-free, entered the battery market in the late eighties. They are available as primary and as secondary elements as well. For the use in consumer appliances the lithium-manganese-dioxide is the most important. Its features are: high energy density, long life-span (7-12 years), low self-discharge (<1% per year), relatively insensitive to temperature and most appropriate in case where small energy is needed over a long period of time (FAZ, 1989, Bätcher et.al., 1992). The primary lithium cell can be used in watches, portable calculators, electronic toys and photographic equipment. Recently, a rechargeable lithium cell, which is "thin and flexible as a credit card" (New York Times, 1994), has been developed. It can be used in portable telephones or electronic equipment such as laptop computers. Normally, because of its construction the secondary lithium cell is not compatible with Nickel-cadmium batteries. Appliances have to be especially designed for the use of lithium cells. Only in the case of memory back-up can they serve as a substitute to nickel-cadmium accumulators.

The latest product innovation is rechargeable **nickel-hydrid** batteries to serve as a substitute for the nickel-cadmium accumulator in almost every field of application. The following table summarises the advantages and disadvantages of the nickel-hydrid cell in comparison with the nickel-cadmium accumulator.

Table 2.3: Nickel-hydrid compared to nickel-cadmium accumulator[7]

Advantages of nickel-hydrid systems	Disadvantages of nickel-hydrid systems
- higher energy density - rapid charge possible - lead-, mercury- and cadmium-free - maintenance not necessary - 15-20% capacity premium	- smaller high power delivery - more sensitive to temperature - expensive (3-4 times as much) - require precise termination of charge

The forthcoming development concerning nickel-hydrid cells will draw special attention to an optimisation for high capacity delivery and an optimisation of designs for high power delivery[8].

With regard to all these technological innovations, especially all those which are claimed to provide environmental benefits (e.g. reduction of mercury content), one has to consider the function of the respective material within the battery system. Mercury in primary batteries, for example, has the function to suppress self-discharge and thus to improve the storage properties

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6 Cp. Baumann et.al. (1993) and Congress of the United States/Office of Technology Assessment (n.y., p.156). Own inquiries.

7 Cp. Bätcher et.al. (1992, p.135) and Phillips, J. (1992, p.96).

8 Cp. Gates Energy Products (1990).

of the battery. By a reduction of the mercury content, therefore, the storage properties deteriorate, still providing an unchanged performance over an smaller life-span. This may give rise to increasing quantities of the respective battery system, thereby lowering the positive environmental effects that derive from the reduced mercury content. However, this trade-off between quality and quantity is suggested to be not complete in the case of mercury (RSU, 1987, p.233), i.e. that the environmental gains from its reduction do dominate the environmental losses from increased quantity.

2.2.2 Fields of application

Batteries are spread over a large number of applications, among these are household appliances, lighting devices, cordless tools, gardening tools, entertainment electronics, computers, communication appliances and toys. This almost all-purpose applicability of batteries is responsible for the huge amount of batteries consumed, for the large number of different battery types and formats and for the various battery systems. Depending on the respective application of the battery there are different properties of importance and, depending on the expected properties, different materials and chemical substances have to be used. To quote one example, the German army still prefers to use nickel-cadmium accumulators instead of cadmium free nickel-hydrid accumulators since the latter may not withstand low temperatures.

Certainly one reason for the intensive and increasing use of batteries is the flexible handling of appliances which are independent of an external power supply. They are not confined to stationary use and therefore provide, besides the fulfilment of their function, a certain surplus utility in the form of increased mobility. This surplus utility is, for example, obvious in the case of mobile telephones.

The following table is to provide an overview of the different fields of application for the respective battery systems.

Table 2.4: Fields of application

System	Fields of application
1. Non-rechargeable	
1.1 *Cylindric*	
Zinc-carbon	lighting, toys, portable radios, tape recorders, scientific calculators, shaver, remote control
Alkali-manganese	flash lights, film camera, watches, dictating machine, walkman, toys
Lithium	cameras
1.2 *Button*	
Alkali-manganese	scientific calculator, cameras, flash lights, watches
(Zinc-) mercury-oxide	hearing aid, watches, exposure meter, cameras
(Zinc-) silver-oxide	scientific calculator, photo, hearing aid, watches, exposure meter, measuring instruments, video games
Zinc-air	hearing aid, scientific calculator, photographic equipment
Lithium (esp. manganese-dioxide)	cameras, watches, memory back up, bicycle and other micro computers
2. Rechargeable	
2.1 *Cylindrical*	
Nickel cadmium	walkman, video games, toys, recorders, radios
Nickel hydrid	notebook, mobile telephone
2.2 *Button*	
Nickel cadmium (sealed)	hearing aid, scientific calculator
Lithium	computer (memory back-up)
2.3 *Built-in*	
Nickel cadmium	camcorder, wireless gardening and electrical hand tools, toys, video games, electric razors, flashlights, toothbrush, emergency lighting, vacuum cleaners, portable computers, video recorders, pocket lights, mobile telephone
Other built-in batteries	toys, watches
2.4 Lead accumulator (small)	emergency light, medical appliances, camcorder, measuring instruments, alarm systems, photographic equipment

The category 2.3 "built-in" encompasses two subcategories here: on the one hand "permanently installed" and non-replaceable batteries, on the other hand replaceable batteries of the "cassette type". Furthermore, the cassette type can be distinguished into "cassette type of standard pattern" and "cassette type of non-standard pattern".

The following table provides a kind of synthesis of the preceding sub-sections. Different battery systems and their possible substitutes are summarised. The proposed substitution is based on a rough estimate of the relative environmental soundness of the alternative.

Table 2.5: Battery systems and possible substitutes

Battery system	Alternative	Application areas	Advantages of the alternative
Zinc-carbon	Alkali-manganese	Several	Longer life-span of the alkaline battery.
Mercury-oxide	Zinc-air	Hearing-aids	Lower content of mercury.
Several	Lithium (non-rechargeable)	Several	Mercury and cadmium free.
Nickel-cadmium	Lithium (rechargeable)	Computer (memory back-up)	Mercury and cadmium free.
Nickel-cadmium	Nickel-hydrid	Several	Lead-, mercury- and cadmium free.
Non-rechargeables	Rechargeables (nickel-cadmium)	Several	Reduction of the overall battery use.

2.3 Economic aspects

2.3.1 The markets for equipment batteries in Europe

With regard to market figures one has to note first, that the figures for the production and consumption of batteries in most cases are based on information which is voluntarily provided by the manufacturers, importers and large distributors of batteries[9]. The official statistical material provided by the files of the national statistical agencies is restricted to highly aggregated levels and does not refer to single battery systems. With the implementation of the Single Market in 1993 the recording of the import and export figures has become even more difficult since the obligation to fill in customs documents expired.

Figures for the overall **European market** are rare and not very detailed. The following table shows that

* the non-rechargeable alkali-manganese and zinc-carbon batteries (cylindrical type) account for the biggest part of the battery consumption,
* the amount of consumed rechargeable batteries is still very modest compared to the figures for the two major non-rechargeables,
* the mercury- and cadmium-free lithium battery has still a very small market share.

Table 2.6: Breakdown of the European mass consumption of batteries for 1991 (ADEME 1993)

Battery system[a)]	Absolute amount [million pieces]	Relative percentage [%]
Zinc-carbon	1696	49.9
Alkali-manganese	1413	41.7
Button cells	222	6.5
Rechargeable batteries[b)]	60	1.8
Lithium	5	0.1

a) It is not clear to the author if overlaps have been avoided (e.g. in the case of lithium button cells or rechargeable lithium cells)

b) The figure for rechargeable batteries seems to be underestimated. The figures for Germany already account for 43 million pieces of nickel-cadmium batteries in the year 1990 before reunification.

The following table provides an overview of the sales of equipment batteries in **Germany**. The figure below shows the development for three aggregated groups. Source of information is the organisation of battery producers and importers.

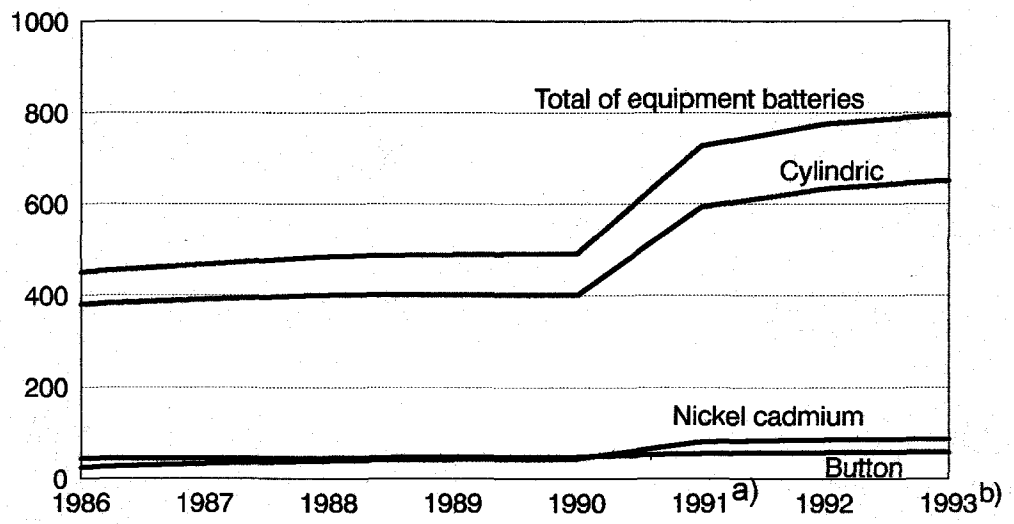
9 Only in Switzerland is there a statutory order obliging producers and importers to inform annually about the sales figures of the different battery systems.

Table 2.7: Battery sales in Germany (in mio. pieces, ARGE BAT 1993)

System	1986 Mio[d)]	1988 Mio	1990 Mio	1991[a)] Mio	1992 Mio	1993[b)] Mio
1. Non-rechargeable	422,5	445,0	448	646	689.1	708
1.1 *Cylindrical*	380	400	400	592	632	650
Zinc-carbon	240	235	225	330	345	346
Alkali-manganese	140	155	175	262	287	304
1.2 *Button*	42,5	45,0	48.0	54.0	57.1	58.0
Alkali-manganese + (Zinc)-Silver-oxide	23,0	23,5	27,0	34,8	36,1	36,3
(Zinc-) mercury-oxide	14,5	13,0	9.5	14.4	12.0	11.0
Zinc-air	3,5	5,5	6.0	5.0	7.0	8.0
Lithium	1,5	3,0	5.0	5.0	7.0	8.0
2. Rechargeable						
2.1 Nickel cadmium (sealed)	23,5	38,5	43.0	80.0	85.0	86.5
2.2 Lead accumulator (small)[c)]	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
3. Total of equipment batteries	**450**	**484**	**491**	**726**	**774.1**	**794.5**

a) Since 1991 all Länder.
b) Estimation
c) Only for private use.
d) Million pieces.

Figure 2.2 Development of battery sales in Germany (in mio. pieces, based on ARGE BAT 1993)



a) Since 1991 all Bundesländer b) Estimation

The absolute sales figures of table 2.7 result in the following relative percentages of battery systems according to the numbers of batteries sold.

Table 2.8: Breakdown of the different battery systems according to the number of pieces in Germany (own calculation)

System	Percentage [%]					
	1986	1988	1990	1991a)	1992	1993b)
1. Non-rechargeable	93,9	91,9	91.2	89.0	89.0	89.1
1.1 *Cylindrical*	84,4	82,6	81.5	81.5	81.6	81.8
Zinc-carbon	53,3	48,6	45.8	45.5	44.6	43.5
Alkali-manganese	31,1	32,0	35.6	36.1	37.1	38.3
1.2 *Button*	9,4	9,3	9.8	7.4	7.4	7.3
Alkali-manganese+ (Zinc)-silver-oxide	5,1	4,6	n.a.	3,6	4,7	4,6
(Zinc-) mercury-oxide	3,2	2,7	2	2.0	1.6	1.4
Zinc-air	0,8	1,1	1.2	0.7	0.9	1
Lithium	0,3	0,6	1	0.7	0.9	1
2. Rechargeable						
2.1 Nickel cadmium (sealed)	5,2	8,0	8.8	11.0	11.0	11.0
Σ **{1. and 2.}**	99,1	99,9	100	100	100	100

a) Since 1991 all German Länder.
b) Estimation

However, with regard to this quantitative overview one has to note that sales figures for built-in batteries (primary and secondary cells) have been omitted, and for the more innovative systems such as rechargeable lithium cells and nickel-hydrid accumulators as well.

The tables indicate the following **trends** during the last couple of years for the **German battery market**:

* The number of all sold equipment batteries has increased steadily. Cylindrical alkali-manganese batteries have especially contributed to this growth in absolute figures.[10]
* The battery consumption per capita now amounts to almost ten batteries per year.
* Besides alkali-manganese batteries, the sales figures of zinc-air and lithium primary button cells and of secondary nickel-cadmium batteries show considerable growth rates.
* The number of sold mercury-oxide button cells has shrunk.

The different degrees of market penetration might correlate with the prices of the different battery systems. According to industry information they belong to the following price segments:

[10] The high growth figures for the year 1991 are caused by the German reunification.

Table 2.9: Price segments of the different battery systems (Philips Licht 9/92, p.20; own inquiries)

System	Costs of purchase
Zinc-carbon	low
Alkali-manganese	medium
(Zinc-) mercury-oxide	medium
(Zinc-) silver-oxide	high
Zinc-air	high
Lithium	very high
Nickel-cadmium	high
Lead-accumulator	medium

In 1993 the entire **Italian market** of batteries was estimated at 376 million pieces which equals 5 to 6 pieces of equipment batteries per inhabitant (excluding the button types). The corresponding total market value was 585 billion lira (ca. 320 mrd ECU). The table 2.10 below provides a quantitative overview.

Table 2.10: The Italian battery market (FAST 1990)

System[b)]	1984		1988		1993 (estimates)	
	Mio [a)]	percentage	Mio	percentage	Mio	percentage
1. *Cylindrical*						
Zinc-carbon	244	68.9	217	57.9	165	43.9
Alkali-manganese	82	23.2	126	33.6	173	46.0
2. *Button*						
Alkali-manganese	1.7	0.4	3.5	0.9	5.7	1.6
Mercury-oxide	13.7	3.9	14.1	3.8	11.4	3.0
Silver-oxide	10.9	3.1	9.9	2.6	8.7	2.3
Zinc-air	1.1	0.3	1.9	0.5	4.6	1.2
Lithium	0.6	0.2	2.6	0.7	7.6	2.0
TOTAL	**354**	**100**	**375**	**100**	**376**	**100**

a) Million pieces.

b) Figures for nickel-cadmium accumulators were not available.

Based on the last 10 year market trend the following conclusions can be drawn for the **Italian battery market**:

* the largest market segment is represented by the mass consumed models zinc-carbon and alkali-manganese (90 % of the total market);
* sales figures for zinc-carbon batteries decreased strongly from 69 % in 1984 to 44 % in 1993;
* sales figures for alkaline batteries rise from 23.2 % in 1984 to 46 % in 1993 (in contrast to the German situation, the market share of alkali-manganese batteries already exceeds the market share of zinc-carbon batteries);

* the sale of zinc-air and lithium batteries is increasing and that for mercury button cells decreasing.

The total weight for batteries sold in Italy in 1993 was 14,500 to 15,000 t equalling 250-260 g/year * inhabitant. 99 % of this weight is represented by commonly used batteries.

The most widespread model is the "1.5 V stilus" model (Size R6 according to the IEC "International Electrotechnical Commission" classification), which is about 90% of the total market of which 44 % is of the zinc-carbon type and 46 % of the alkaline type.

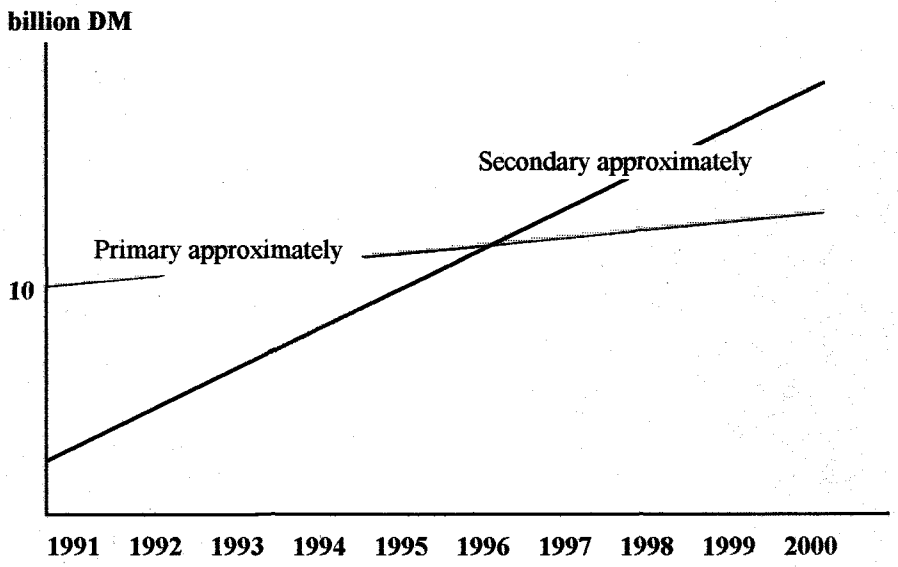
Similar trends as for the German and Italian market can be observed for the entire European battery market with the exception of silver-oxide batteries.

Table 2.11: Trends of the European battery market (ADEME 1993, p.15)

System	Trend
Zinc-carbon	falling
Alkali-manganese	rising
Mercury-oxide	falling
Silver-oxide	rising
Zinc-air	rising
Lithium	rising
Nickel-cadmium	rising

The world-wide trend for the nickel cadmium accumulators is assumed to fall slightly from 1995 on. It is substituted by the cadmium-free nickel-hydrid battery which will show considerable growth rates then (Cloke 1992, p.89). All in all, the increasing use of rechargeable batteries will continue and even exceed the figures for non-rechargeables on a global scale, as the following figure indicates.

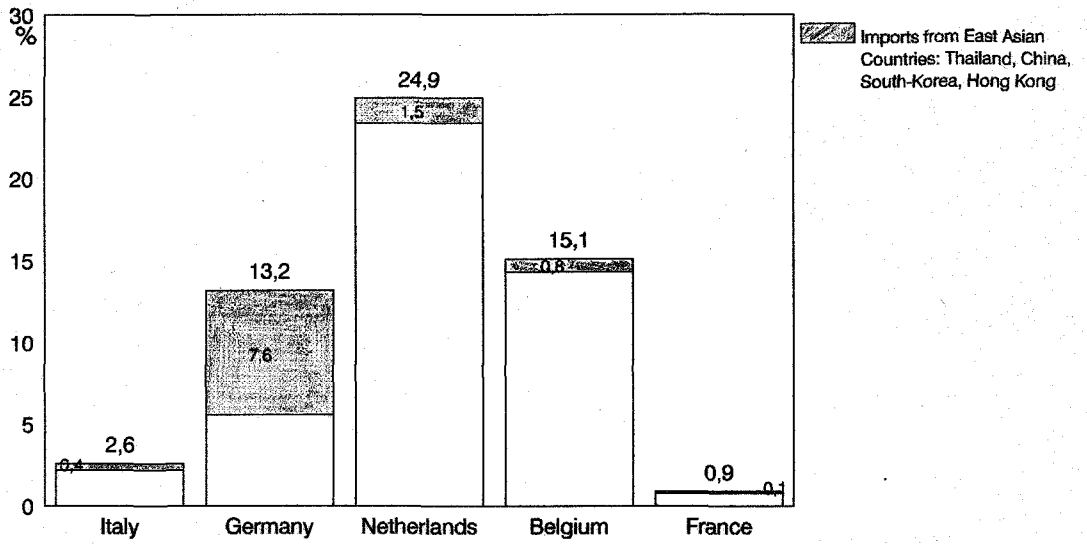
Figure 2.3: Market developments of primary and secondary cylindrical portable batteries world wide 1991-2000 (Cloke 1992, p.87)



The international market for equipment batteries is characterised by oligopolistic structures. A few, mainly US firms dominate here (Ralston Purina, Duracell, Rayovac), the only significant competitor in Europe being the German producer Varta. Duracell, Ralston and Varta together claim more than four fifths of western European sales by volume. (International Management April 1993, p.51)

Imports from east Asian countries sometimes reach considerable quantities. In some EC markets they account for approximately 10 % (International Management April 1993, p.51). This figure weighs even more heavy if one considers the fact that batteries manufactured in China and Korea have generally a high content of mercury (ADEME 1993, p.23). The following figure 2.4 provides more detailed import figures for the case of non-rechargeable batteries. It distinguishes imports into EC countries according to the countries they come from.

Figure 2.4: Breakdown of the import of primary batteries into the EU according to the country of origin for the year 1991 (ADEME 1993, p.25)



The figure shows that relative import figures of primary batteries vary very much among Member States. Sometimes, they are negligible (e.g. in France), sometimes they account for almost one fourth of total consumption (in the Netherlands). The imports from East Asian countries reach a considerable percentage only in Germany.

Among the most important suppliers of batteries in Germany are Varta, Daimon-Duracell, Philips and Ralston-Ucar (Wirtschaftswoche 10.06.88). The German battery industry employs 15,000 workers and has a domestic turnover of 2.5 billion DM (Hiller et.al. 1992, p.1). There are several smaller producers of special purpose accumulators. The only domestic producer of primary and secondary equipment batteries is Varta, reaching a turnover in this business sector of 870 mio DM in the year 1993 (Varta Geschäftsbericht 1993, p.10). As can be seen from figure 2.4 above, a large proportion of consumed batteries is imported. This suggestion is confirmed by the fact that all large international producers have affiliated companies in Germany (Duracell, Ralston, Rayovac, Philips, Panasonic).

As for actual manufacturing of batteries in Italy, the national production is limited and the total market share of the Italian producers is only 10-15% according to ANIE (Italian Association of Electrical Industries). Market leader is Duracell which controls about 70% of the alkaline battery segment and 61 % of the total market with the "Duracell", "Superpila" and "Suprema" trademarks. Other trademarks are "Energizer", "Sony", "Philips" and the domestic "Volta" and "Pilazeta".

2.3.2 Future developments in the area of battery powered appliances

The battery market is strongly influenced by the latest and future developments in the area of battery powered appliances. The most interesting, and for the development of the battery market most important, trend is that towards an increasing use of cordless appliances which is embedded in a more general trend of growing mobility. From an environmental point of view this trend gains attention since the battery systems used in these appliances are mostly nickel-cadmium accumulators which are chiefly responsible for the cadmium load which stems from batteries and which is discarded into the environment through various channels (see section 2.4).

This "emancipation from the wall socket" (Österreichisches Ökologie Institut 1991, p.19) has exerted considerable influence especially on the use and development of secondary, rechargeable accumulators, namely the nickel-cadmium and nickel-hydrid accumulators. Cloke (1992, p.86) from VARTA Ltd., United Kingdom, states that nickel-cadmium batteries will be used mainly for portable power tools, low cost communications and computers, whereas the nickel-hydrid cell "will be specified for those applications which demand extra capacity, and/or minimum volume and where a price premium can be achieved". Based on this prognosis, Cloke expects the market for nickel-cadmium batteries to continue to grow until 1995, at which point the growth will be taken by nickel-hydrid cells. However, for the time being, the use of nickel-cadmium batteries is still increasing; the main application areas being camcorders, portable phones and computers.

Mobile telephones are expected to have enormous growth owing to increased miniaturisation and the freeing of previously restricted frequency spectra (Cloke 1992, p.85). For Germany, for example, growth rates are reported of up to 350 % (ZEIT, 27.5.94). As one consequence, the key requirements will be to develop smaller and lighter nickel-cadmium cells, capable of fast reachargeability (Delon, 1992, p.93f.).

In Italy, a strong market expansion has recently been recorded for portable computers and cordless communication systems. Mobile phones, for example, according to the Public Relation office of SIP (Italian Telephone Company), have been growing as follows:

December 1993:	1,230,000 units
March 1994:	1,380,807 units
December 1994:	2,000,000 units (expected projection).

Even if a correct forecast of future growth is hard to make, this rate of growth should further increase during the next years as SIP will lose its monopolistic position.The resulting competition should drive the price of cellular phone operation down and increase the number of new users. There is no official estimation available, but talking with experts revealed a

number from 6 to 9 million units as possible value. As for portable computers, IBM estimates its number in Italy around 1 million. However, even in this area, the personal computer note book and multimedia portable devices are expected to be the fastest growing segments and 10 million devices of this kind are expected to be sold in Italy in the near future.

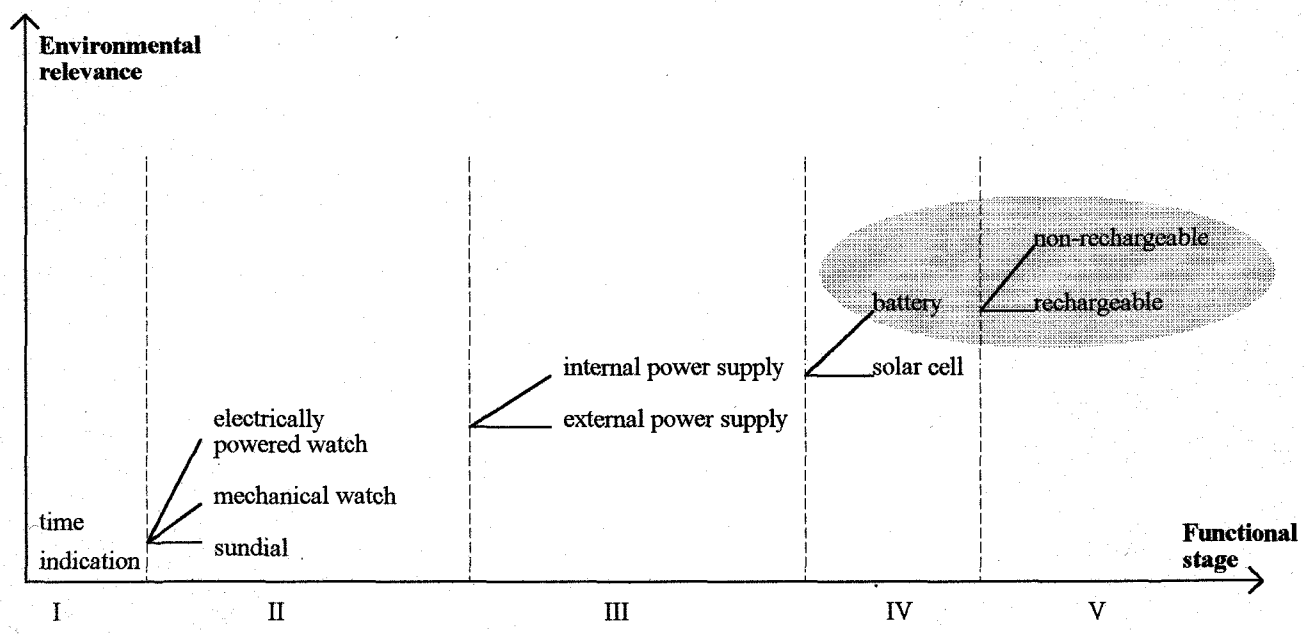
The manufacturer's aim to maximise functionality and portability in the field of portable computers (notebooks and laptops) results in the following demands which have to be met by the battery system (Phillips, 1992, p.95):

* maximising energy content,
* small weight and optimal form for maximum portability,
* safety,
* minimum charge time,
* low costs.

2.4 Environmental aspects

If one tries to take stock of the environmental relevance of batteries, their locus within the "functional chain" has to be considered. This chain describes a basic need that has to be met, i.e. a service that has to be fulfilled, and the following different alternatives to do so. The environmental relevance along this chain, (i.e. the environmental relevance of the functional alternatives) sometimes varies considerably. The following figure depicts an exemplary functional chain for the case of the service "time indication".

Figure 2.5: Functional chain for the service "time indication" (own draft)



At the successive functional stages I-V one can choose between several alternatives to fulfil the function that belongs to the preceding stage. Stage I describes the service "time indication". Time can be indicated by either a sundial, a mechanical watch or an electrically powered watch (stage II). The environmental relevance of an electrically powered watch, in comparison to the sundial, would be a bigger one because the material and energy intensity of the production process is relatively high. If one would choose the electric powered watch, the alternatives "internal" versus "external power supply" can be offered (stage III)[11]. For internal power supply, an appropriate source would be needed which has to be produced first. It is assumed here that the production process of the internal energy source, including resources for the development, would consume relatively more energy, materials and substances compared to a

[11] This example is a bit "artificial" because an additional service to be fulfilled could be "mobilitiy". In this case, a watch that is dependent on an external power supply will not be an appropriate alternative. The same holds true for the preceding alternative "sundial". These aspects are neglected for the sake of simplicity.

situation where an external power supply is made available. If internal power is chosen at this stage, it can either be supplied by a battery or a solar cell (stage IV). If the battery is chosen, then, one can use either a rechargeable or non-rechargeable battery (stage V). It is assumed at this fifth stage that the environmental relevance - in terms of the material and energy intensity during the production process - of a rechargeable battery is less severe than that of a non-rechargeable battery[12]. Despite its highly simplifying character[13], the figure shows that this case study with its main focus on the environmental relevance emerging from the different battery systems (*grey coloured ellipse in figure 2.5*) inevitably excludes those environmental aspects that appear at earlier stages of the functional chain. In other words, some degrees of freedom have already been lost and a certain "level" of environmental relevance has already been reached with the choice to use batteries instead of, for example, solar cells.

Along this "functional chain" the environmental relevance of batteries can be distinguished into a more general relevance and a more specific relevance.

General relevance

The general relevance regards early stages of the functional chain (stages II-IV) and encompasses environmental impacts that are connected with the decision to use a battery as the source of power supply instead of other alternatives. With this choice a certain environmentally relevant energy relation is already fixed. Namely: The production of a battery consumes 50 times the energy it supplies during its life span (Warmer Bulletin 35/92, p.10). In this sense batteries can be regarded as a kind of "energy filter". And owing to the small energy efficiency they are sometimes called the most expensive electric energy in the world.[14]

The main interest of this study is to evaluate the instruments which aim at reducing the (negative) environmental impacts emanating from batteries (given a certain demand for batteries or battery power), so that the assessment of this general relevance plays a minor role. However, it may gain importance in the context of measures which follow the objective of reducing battery use.

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[12] One could come to the opposite assessment in terms of dangerous substances included: The reachargeable accumulator is often of the nickel-cadmium type, whereas most non-rechargeable batteries contain only very small quantities of cadmium and mercury.

[13] This is an example based on an ad-hoc assessment of the environmental relevance of the different alternatives rather than on LCA based information.

[14] One kWh for a battery powered watch costs approximately DM 20,000 whereas the same amount of solar based energy supply costs only DM 5 to 100 (Fachinformationszentrum Karlsruhe 1992).

Specific relevance

The specific relevance includes those environmental impacts that are emerging along the life cycle of a battery. There are two aspects that are of major concern:

* What are the most important substances contained in batteries from an environmental point of view? (section 2.4.1)
* What are the most important stages of the life cycle from an environmental point of view? (section 2.4.2)

2.4.1 Environmental relevance of the applied substances

The different available battery systems and accumulators consist of more than 200 different chemical substances. Some of them are basic for the composition and functioning of a battery, e.g. cadmium in a nickel-cadmium-accumulator cannot be replaced. For others which are added to improve the performance and properties of the battery, there might be substitutes. Many of these substances have been proven to have a hazardous impact on health and the ecosystem. For other substances, the examination as to their possible impact has not yet been carried out. In general, it turns out that the assesssment of a substance according to its dangerous properties is difficult and therefore an unambiguous definition hardly possible. In view of this assessment problem, the following explanations are necessarily restricted to the brief description of the main and generally accepted hazardous substances.

Most of the metals contained in batteries are *heavy* metals. They can be parted into *essential* (heavy) metals (in batteries: zinc, iron, manganese, copper, etc.) which the human body needs up to a certain amount, and toxic (heavy) metals (in batteries: cadmium Cd, mercury Hg, lead Pb, nickel Ni,...) which are toxic, carcinogenic, or even mutagenic and accumulate in the food chain. For both the essential and the toxic (heavy) metals there are standards indicated by the World Health Organisation (WHO) regarding the concentrations in air, soil, water, and food.

Batteries made of **lithium** are considered to be relatively harmless for the environment. In fact, very little information can be found about the impacts of lithium on health or the environment. The fact that lithium reacts very strongly with water and that too high a concentration in the incineration processes might lead to explosions, should give cause for deeper research.

Zinc-air batteries which are to substitute mercury-oxide batteries in hearing aids are also considered environmentally sound. However, they are not free from hazardous substances and should therefore be subject to selective disposal (Fachinformationszentrum Karlsruhe 1992).

In Germany there is intensive research on the environmental relevance of **cadmium**. On behalf of the German commission of enquiry on the "Protection of Men and Biosphere" a material

flow analysis has been carried out which inventorises all cadmium flows within the German economy and subsequently evaluates these flows against the background of a.o. ecological criteria. However, the final assessment has not yet been completed. (Enquête-Kommission "Schutz des Menschen und der Umwelt" 1993, p.106-136).

Annex II provides a list of the most important hazardous battery components with some possible reaction products including an estimation of their impact, based upon German and international classifications of hazardous substances.

Quantified data concerning the heavy metal load from batteries into the environment is often quite incomplete and contradictionary. One reason may be that the figures for the consumption of heavy metals in batteries is mixed up with figures for the amount of these battery substances in the waste. In the latter case, the estimates have to assume recovery and recycling quotas for the different battery systems which might often be very difficult to judge.

Figures on the **mercury** emissions from all batteries and so called "general purpose" batteries which encompass the cylindrical zinc-carbon and alkali-manganese batteries for the whole of Europe are provided by the European Portable Battery Association (EPBA). Corresponding figures for Germany are published by the German Association of battery producers (ZVEI).

Table 2.12: Tonnes of mercury from batteries in waste (EPBA 1991, 1992, ZVEI 1989)

Year	Europe (EPBA)		Germany (ZVEI)	
	general purpose[a)]	all batteries	alkali-manganese	zinc-carbon
1985	205.0	267	45	1
1986	119.9	180	n.a.	n.a
1987	137.1	190	20	n.a
1988	103.0	170	5	0.6
1989	30.0	88	(2.5)	(0.1)
1990	26.1	77	0	(0)
1991	14.6	65	n.a.	n.a.
1992	(9.8)[b)]	(60)	n.a.	n.a.
1993	(3.8)	(40)	n.a.	n.a.

a) "General purpose batteries"= cylindrical zinc-carbon and alkali-manganese batteries

b) Figures in brackets represent estimates.

The figures for mercury emissions from mercury oxide button cells can - for the whole of Europe - be derived from the difference between "all" and "general purpose" batteries, that is, for example, 57 tonnes in 1989 (EPBA 1991, p.3). For Germany alone, the respective figure is assessed at about 10 tonnes per year (ZVEI 1989).

The main findings are:

* mercury emissions from batteries have reduced over recent years,
* this trend is mainly due to the reduction of mercury in alkali-manganese and zinc-carbon batteries,

* the mercury load from mercury oxide button cells is still on a high level due to the fact that in this battery system, there is no substitute because the material is used for one of the electrodes.

One has to consider in this context, that the above figures focus on the annual flows of mercury and thereby neglect the problem of mercury stocks, i.e. the increasing mercury accumulation in the environment.

For **cadmium** an opposite trend can be observed. Cadmium consumption has strongly increased over recent decades, the main reason being the rising sales figures of nickel-cadmium accumulators. For Germany, the use of cadmium in this application area has almost tripled between 1975 and 1989 (Balzer 1991). It amounts to approximately 50% of the entire cadmium consumption in 1989 as can be seen from the following table.

Table 2.13: German domestic consumption of cadmium in 1989 (Bätcher et.al. 1992)

Application area	Absolute [t]	Relative [%]
Nickel-cadmium accumulators	427	48.2
Pigments	282	31.8
Stabilisers	94	10.6
Galvanisation	35	4.0
Glass-industry	26	2.9
Alloys	21	2.4
Others	1	0.1
Σ	886	100

Considering the expected sales figures for this battery system (see section 2.3) the trend of an increasing cadmium consumption in the application area nickel-cadmium accumulator is likely to continue for the next years.

If the relative environmental relevance of batteries is assessed, it is necessary to compare the heavy metal content of batteries with the heavy metal quantities in domestic waste. The following table provides the respective figures for Germany. Not merely mercury and cadmium are regarded, but lead, nickel, manganese and zinc also. The metal content of the waste relates to the year 1987 and the metal content of equipment batteries relates to the year 1990.[15]

[15] This explains that in the column "cadmium" the figure "Metal content in equipment batteries" exceeds the figure of "Metal content in waste".

Table 2.14: Comparison of the metal content of household waste with the metal content of batteries (Bätcher et.al. 1992, p.181)

Metal	**Cadmium**	**Nickel**	**Lead**	**Mercury**	**Manganese**	**Zinc**
Metal content in waste [t]	300	2,800	13,500	125	n.a.	56,000
Metal content in equipment batteries [t]	327	400	60[a)]	14	4,200	2,700

a) Lead used in starter batteries is not taken into account here, because only equipment batteries are considered.

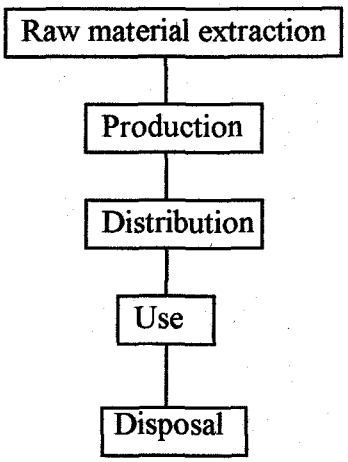
The table provides the following findings:

* batteries, mainly nickel-cadmium accumulators, are the most important single cadmium source in household waste,
* the mercury load into household waste from batteries is relatively small,
* the metal content of household waste is hardly influenced by lead and zinc from batteries.

2.4.2 Environmental relevance along the life cycle of a battery

The following figure shows the stages of the battery life cycle that can be distinguished in general. This life cycle is not complete, because transport and storage of used batteries have been ommitted.[16]

Figure 2.6: Life cycle of a battery



Our enquiry of available literature has shown that an LCA (life cycle assessment) of batteries has not yet been carried out. The main focus of the studies so far is on the after-use-management of batteries, which means that the environmental impacts of the different disposal paths - landfilling, incineration and recycling - are investigated. An interview with experts (Baumann et.al. 1994) has confirmed this special focus on the disposal stage because the manufacturing processes are regulated rather intensively and the use stage exerts hardly any negative impacts. Even a German battery producer follows this opinion attaching low importance to the production and use of batteries, but medium and even high importance to the disposal alternatives for batteries with regard to their (negative) impacts on the environment.[17] However, this isolated way of looking at single stages of the life cycle results in a fading out of trade-offs between environmental gains and losses that can occur between the different stages. Box 2.2 provides some examples.

Box 2.2: Trade offs along the battery life-cycle

- Hofstetter/Hähne (1990, p.13) mention that the reduction of mercury in **alkali-manganese** batteries has been achieved through the application of extremely pure battery components (e.g. zinc) which have to be produced, however, relatively energy and waste intensively.

[16] However, even Hofstetter/Hähne (1990, p. 18 ff.), who state that these stages have not yet gained enough attention, exclude them from their study because they are either controllable (in the case of storage) or negligible (in the case of transport) compared to the environmental importance of other stages.

[17] His opinion has been revealed by means of a questionnaire within a survey carried out by IÖW for this study.

Hence, the reduction of the environmental impact at the disposal stage has caused an increased impact at the production stage.

- Compared to non-rechargeable batteries **nickel-cadmium accumulators** exhibit a positive energy balance after ten times of recharging (BUWAL-Bulletin 1/90, p.19). If one supposes that nickel-cadmium accumulators can be recharged up to 500 times, it is obvious that from an energy point of view they come off better than non-rechargeable primary cells. However, since these systems include the highly toxic heavy metal cadmium, the balance of hazardous substances might come off even worse than that of a non-rechargeable battery[18], which is low in hazardous substances (RSU 1990, p.230). This trade-off between the reduced amounts of energy and material consumed at the production stage (since they are rechargeable, lower quantities of nickel-cadmium accumulators supply the same electric energy as higher quantities of non-rechargeable batteries) and the bigger amounts of hazardous substances at the disposal stage is even stressed by the fact that, on average, the recharging rates of nickel-cadmium batteries do not reach their maximum (BUWAL Bulletin 1/90, p.13). Estimates that may help to quantify this trade off assume that only one nickel-cadmium battery in ten replaces general-purpose primary batteries (International Management April 1994, p.53).

Although it seems important not to neglect these trade-offs along the entire life cycle, this study, owing to financial and time restrictions, has also to restrict itself to the environmental problems that may arise during the disposal of used batteries (see chapter 2.4.3) and will try to evaluate the instruments that are intended to reduce potential negative effects at this stage (see chapter 4). However, the need to strengthen research activities on the environmental impacts emerging along the entire battery life cycle has become obvious and therefore a short overview of the environmental relevance of the other stages of the life cycle shall be given in the following paragraphs.

Raw material extraction

The considered literature says only a few words about the raw materials needed for battery manufacture. Studies on the environmental impacts of these processes are not known.

Cadmium is a by-product of zinc extraction (Katalyse-Umweltgruppe 1985, p.95, Enquête Kommission 1993, p.106 ff.). Therefore, the processing of zinc ores will always give rise to considerable amounts of cadmium which have to be dealt with in some way. Mercury, nickel and lead seldom occur in pure form. Usually they are contained in certain ores.

[18] Depending on the way the battery is being disposed of.

Production

The manufacturing of primary batteries is either a dry or mechanical process. The working of dry powders (manganese dioxide, silver oxide, mercury oxide and zinc) causes dust emissions, which have to be extracted. When mercury oxide or zinc powder is processed, the floors are damply cleaned afterwards. The waste water emerging then has also to be cleaned before discharge. (Hiller et.al. 1990)

Distribution

A study of available literature has revealed that environmental impact caused by the distribution of batteries and battery powered appliances (mainly through external effects of transports) has not yet been focused upon. Therefore, we cannot offer any assessment of this stage of the battery life cycle. However, it might be assumed that distribution, in comparison to the other stages, is of less importance from an environmental perspective. (Cp. footnote 16)

Use

The proper use of a battery causes hardly any noise emissions or emissions of hazardous substances. Only the improper use, for example exposing batteries to open fire or opening the battery case by force, can result in health risks for the users. Two examples are to be mentioned: When a nickel-cadmium pack is short-circuited it may exhibit a fire hazard. When swallowed, button cells may cause poisoning. (Hiller et. al. 1990)

Disposal

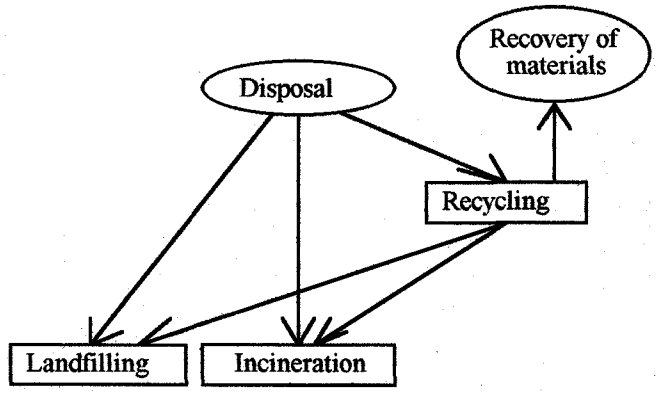
Most of the studies dealing with the battery issue focus on environmental problems that (can) arise with the disposal of used batteries, leaching the chemical substances contained into the environmental compartments air, water and soil.

In principle, the after use management of batteries can follow three different paths, namely

* landfilling,
* incineration,
* recycling,

as it is shown in figure 2.7 below.

Figure 2.7: Alternative ways of disposal



In the following section 2.4.3 the environmental impact of these alternatives is briefly described.

2.4.3 Environmental relevance of alternative ways of disposal

Landfilling

From an ecological perspective the discarding of used batteries along with the household waste gains importance because of the heavy metal load that is dispersed into the environment. Under landfill conditions batteries will undergo degradation which could lead to the leaching out of the chemical substances contained. The Institute for Risk Research (1992, p.iv) mentions some variables that influence this degradation process and thereby the probability for a battery to leach out:

* battery system,
* state of charge,
* physical conditions at the landfill site.

The authors state that "under ideal landfill conditions, metals will not leach rapidly through landfills and soils into ground water"(p.iv). At the same time, they have to admit that "metals do not decompose or degrade, and thus have the potential of leaching into aquifers over long periods of time" (p.iv).

Empirical studies have provided some evidence. A study by Kerndorff (n.y.), for example, examines the ground water in the area of dump sites. It has shown that the concentrations of the considered metals can vary considerably and in some cases even surpasses the corresponding EC standards for 1980. Owing to this high variance in the heavy metal concentration of the observed samples and also due to the different estimates regarding the contribution from

batteries to the heavy metal load[19], the actual contribution of batteries to the leachate is difficult to assess. The reason for the comparatively low mercury-contaminations of the ground water according to Kerndorff (n.y.) is probably the high volatility of mercury. This would result, however, in a higher air contamination if mercury is set free from the cells.

Concerning the environmental relevance of the disposal of batteries along with the household waste, two recent studies provide different findings. The Institute for Risk Research (1992) claims that "most household batteries (*alkaline and zinc-carbon batteries are meant, GS*) may be safely disposed of in municipal landfills ..."(p. iv), whereas Baumann et.al. (1993, p.118) are of the opinion that in principle, no battery system should be disposed of in landfills along with the normal household waste. However, exemptions from this general ban could be allowed, when the disposal site has "stabilised" in the sense that its reactive potential has ceased or when the used batteries are disposed of in landfills for hazardous waste.

Incineration

Incineration represents the second alternative for the disposal of batteries. It has gained attention because of the environmentally relevant emissions that are obtained in the different residues of the incineration process or that leave the site through the chimney. The amount of emissions is dependent on the incineration technology, the composition of the waste and the applied flue gas scrubber.

The majority of todays incineration plants contains an electric filter and a flue gas scrubber, both following the incineration unit. During the incineration process certain residues are obtained, namely clean-off gas, slag, filter dust and gas scrub residues. The distribution of the metals in these four incineration residues differs due to their different chemical and physical properties, as it is shown in table 2.15 below. Mercury and cadmium are volatile and therefore highly concentrated in unfiltered gas. Mercury is held back in the gas scrub process only insufficiently, and up to 14% can be found in the pure gas. Cadmium is adsorbed by the dust particles when it cools down (which is the reason for the high cadmium content of 75% in the filter dust).

[19] The estimate of the contribution from batteries to the heavy metal load from households is dependent on the underlying estimate of the respective return rates for the used batteries.

Table 2.15: Distribution of heavy metals in incineration residues in % (Figures for Germany)

Metal	Clean off-gas[a)]	Slag [b)]	Filter dust[b)]	Residues of gas scrub [b)]
Cadmium	0,3-3	23	75	2
Mercury	4,75-14,2	1	12	87
Manganese	0,001-0,1	n.a.	n.a.	n.a.
Nickel	0,33-4,2	93	7	0,1
Zinc	0,19-3,0	61	37	2

a) According to Baumann et.al. 1993.

b) According to Deutscher Bundestag Drucksache 12/6987.

The absolute amount of residues obtained is dependent on the level of the applied emission standards. The incineration residues containing large quantities of toxic substances have to be disposed of properly in order to avoid any negative impact on the environment. The slag is usually disposed of in capped landfills or reused in road construction. If the latter alternative is chosen, the washing out of heavy metals may exert a negative impact on the environment. The filter dust is either obtained separately or together with the residues from the flue gas scrubber. Due to the high concentration of soluble heavy metals these residuals have to be disposed of in capped landfills. Meanwhile processes are examined which treat the dust in a way to make it reusable. (RSU 1990, p. 420 ff)

For Germany, some figures are available which describe the contribution of batteries to the heavy metal load to be incinerated, as it is shown in table 2.16. The total amount of heavy metals in incinerated domestic waste varies from 30 t for mercury to 20,000 t for zinc for the year 1990. The figures with regard to the battery percentage are estimated based on the return rates from Baumann et.al. and ZVEI.

Table 2.16: Estimated contribution from batteries to the heavy metal load from incinerated domestic waste (Baumann et.al., p.126)

Metal	Total amount in incinerated domestic waste [t]	Contribution from batteries [%]	
		underlying recycling quota: Baumann et.al.	underlying recycling quota: ZVEI
Cadmium	171,5	16,9	7,7
Mercury	32,1	7,5	4,2
Manganese	5841	15,9	15,9
Nickel	865	3,4	1,5
Zinc	20632	4,8	4,8

The table shows that in the case of manganese, and, if the recycling quota of Baumann et.al. is assumed, also in the case of cadmium, the contribution of batteries to the heavy metal load for incineration accounts for a considerable percentage. Whereas, nickel, zinc and mercury represent a medium contribution to the incineration input. The extent to which the incineration of used batteries may exert some negative influence on the environment, according to the

different possibilities described above, cannot be assessed quantitatively, although it has become obvious that their potential contribution may not be neglected.

Recycling

The third possible alternative for the after use management of batteries is their recycling, i.e. the reuse of some of the materials contained. Recycling processes for the following battery systems are available:

* battery mixes,
* alkali-manganese and zinc-carbon,
* mercury- and silver-oxide,
* nickel-cadmium accumulators.

Only 5 recycling plants are operating in Europe at the moment, two of which are located in Switzerland. Many pilot projects have been run in several countries and had to be shut down because of technical problems or lack of profitability. The following table provides a short summary of the existing and examined processes, their possible inputs and their stage of development.

Table 2.17: Overview of recycling processes for household batteries (own elaboration)

Organization (country)	**Input**	**Process**	**Stage of development, capacity**
Batrec (CH)	battery mix	thermal	commercial operation; 2 000 t/a
ETH (CH)	zinc-carbon; alkali-manganese	thermal/ electrolysis	pilot project closed
Recytec (CH)	battery mix; no button cells	pyrolysis/ electrolysis	commercial operation; 1,500-4,500 t/a
Elwenn & Frankenbach (D)	mercury and silver oxide button cells	thermal	closed in 1987
Lurgi (D)	battery mix	thermal	pilot project closed
NQR (D)	mercury oxide button cells	thermal	commercial operation
Tersa (E)	mercury and silver oxide button cells	thermal/ electrolytic	commercial operation
SNAM/ SAVAM (F)	nickel-cadmium batteries	thermal	commercial operation approx. 2,000t/a
Clean Japan Center (J)	batteries containing mercury	thermal	closed in 1987
TNO (NL)	battery mix	chemical	unknown
MRT (S)	mercury and silver oxide button cells	thermal	closed in 1988: mercury concentrations too high; capacity too low
SAB-NIFE (S)	nickel-cadmium batteries	thermal	commercial operation

One main problem during the recycling process is the **sorting** out of battery systems which might disturb the recycling process. There are different suggestions to solve this problem.

TEM (University of Lund, Sweden) has introduced a sorting concept which combines a manual sorting, sieving, weighing, with the measuring of the electric resistance (Lindhqvist 1989). A process which uses sieving together with a magnetic distinction is presented by Trimag Titalyse SA, Switzerland (Wiaux 1992). TNO has tried to separate the batteries by X-ray pattern recognition (Deelen 1989). INFU has developed an invisible marking system for batteries which is based on ultraviolet bar code recognition. The bar codes will be able to give information not only about the substances contained in the batteries, but also about the producer. This might provide the possibility to charge the producer for the disposal of every single battery.

With regard to the possible environmental impact that may emerge from the recycling of used batteries it has to be stated that an environmental impact assessment has not been carried out so far (Deutscher Bundestag 1994, p.7). However, it is obvious that the residues from the recycling process have to be treated somehow when they are not recovered for reuse. The off-gas is being filtered and scrubbed, and the excess water has to be treated before it is disposed of to the municipal sewage plant. The slag can be disposed of in landfillings. Mercury that is emitted to the air and manganese that is reaching the soil might be of environmental importance. The concrete ecological risk, however, is dependent on the dispersed quantities then.

2.4.4 Conclusions

In this sub-section we want to summarise the main environmental aspects of batteries based on the insights we gained from the preceding sub-sections.

* We have distinguished a "general" and a "specific" environmental relevance of batteries. The general relevance pertains to the "energy filter" aspect of batteries, the specific relevance mainly to the hazardous substances included (heavy metals such as lead, mercury and cadmium).
* The environmental discussion about batteries usually focuses on their specific relevance.
* Mercury emissions from batteries have been largely reduced during recent years, except for the emissions from mercury-oxide button cells.
* Cadmium emissions through batteries are still large and even growing. Today, batteries are the most important single cadmium source in household waste.
* The safe disposal of batteries in hazardous waste landfills appears to be possible.
* The actual contribution of batteries to the leachate of sanitary landfills cannot be clearly assessed.

* Incineration shifts the environmental burden caused by emissions (via slag, filter dust, residues of gas scrub) mainly to the environmental compartment soil. Hazardous waste landfilling of the residues is necessary.
* In the case of manganese and cadmium the contribution of batteries to the incineration input accounts for a considerable percentage.
* Recycling plants for battery systems exist (for battery mixes, nickel-cadmium batteries, mercury and silver-oxide button cells). Their capacities still appear to be restricted. Their environmental relevance (environmental impact assessment) has not yet been studied.
* LCAs for batteries are still lacking.

2.5 Relevant actors

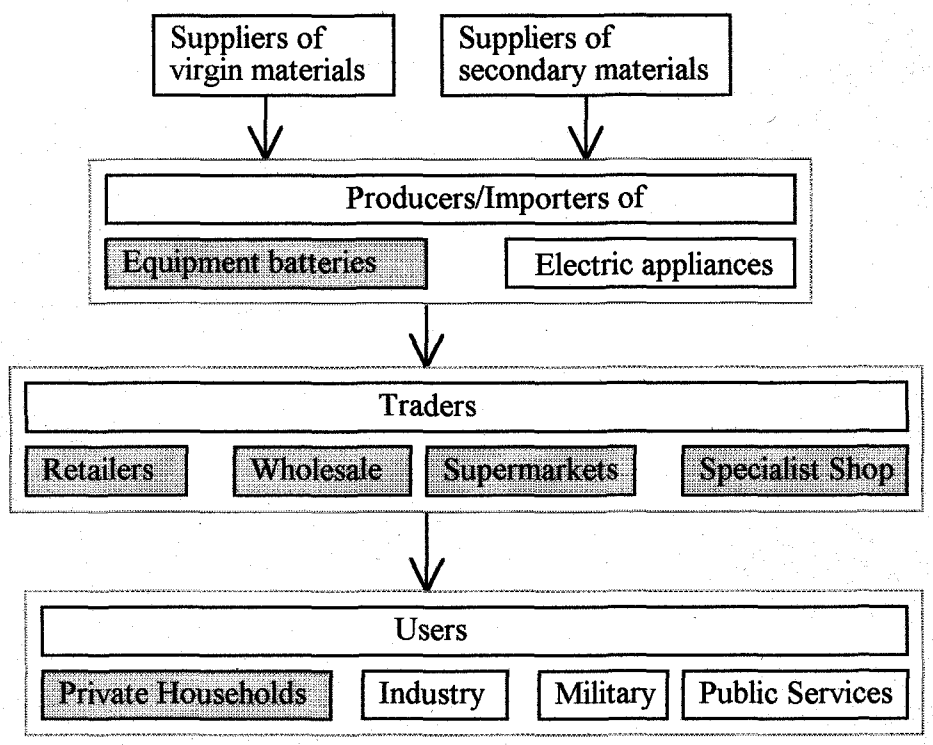
Apart from technical, economic and environmental aspects of the battery issue it is necessary to study the network of involved actors. This network can be described from two different perspectives:

* orientation towards the material flow connected with a battery,
* orientation towards the process of environmental policy making.

The latter perspective is of importance when the policy design and the implementation of certain instruments is studied, whereas the first perspective focuses on the actors which are especially involved in the application and functioning of the instruments.

The figure below depicts the most important actors from the more material flow oriented perspective, taking into account solely the stages production, distribution and use of equipment batteries.

Figure 2.8: Actors along the life cycle of equipment batteries



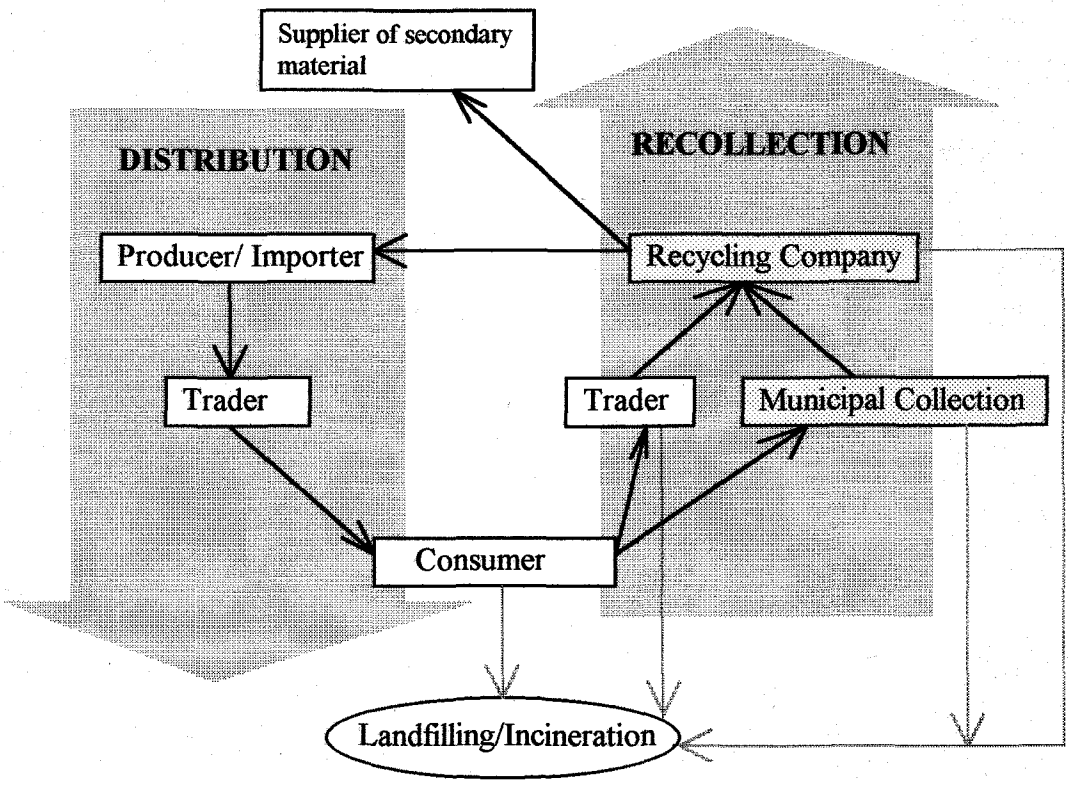
Suppliers of raw or secondary materials deliver the input for the manufacturing firms. At this stage the production of equipment batteries as such and the production of the electric devices has to be distinguished. Additionally, importers of batteries and appliances are located at this production stage. The products are distributed through different channels, namely wholesale,

retailers, supermarkets and specialist shops. Finally they reach the consumers who can basically be distinguished into private households, industry and military uses and public services.

The main focus of this case study will be on the producers and importers of batteries, on all actors involved in the trading of batteries and on the private households as the main user (*grey boxes*)[20].

The disposal stage is not yet taken into account. If we do so and assume recollection schemes for used equipment batteries, municipal collectors and recycling companies as additional actors enter the stage. The figure below shows these two actors as part of the recollection stream. If consumers do not discard the used batteries along with the normal household waste they are offered two alternatives: they can bring them back to the trader (retailer, supermarket, specialist shop etc.) or to the hazardous waste collection sites of the municipalities.[21]

Figure 2.9: Actors involved in the distribution and recollection of batteries

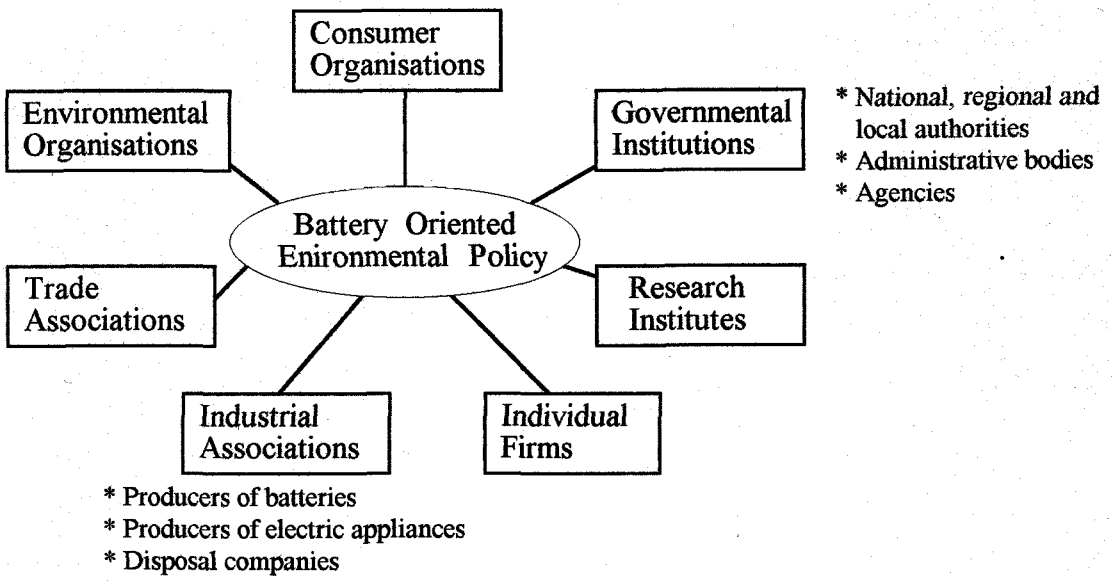


[20] The restriction to private households is appropriate because there is hardly any quantified data available concerning the military and industrial use and the use in public services.

[21] The black coloured arrows describe the distribution of new batteries and their after use "retro"-distribution in the case of recollection. The grey coloured arrows describe the "final" disposal paths for used batteries respectively residues of the battery recycling.

The following figure shows the actors from the more policy oriented perspective.

Figure 2.10: Actors involved in the policy making process



There is a correspondence between the material and political perspective. Those actors described in the two figures above are represented in this figure by their respective association which is responsible for the lobbying - organisation and formulation of interests - in the political area. Moreover, research institutes enter the stage influencing bargaining processes with scientific expertise and also environmental organisations which represent the "interests" of the natural environment.

2.6 Objectives of battery-oriented environmental policy

In general there are four main objectives of battery oriented environmental policy which can be put down to their environmental characteristics, their technological features and their economic performance. The following summary of these objectives is not to imply any priorities among them.

1. **Reduction of hazardous substances contained in case where the respective substance is not necessary for the principal functioning of the battery system.**

This goal mainly addresses alkali-manganese and zinc-carbon batteries. The mercury included in these systems can be reduced by technological innovations, e.g. the application of purer materials.

2. **Substitution of hazardous substances contained in case where the respective substance is necessary for the principal functioning of the battery system. (Substitution of battery systems)**

This objective is directed to batteries such as nickel-cadmium accumulators or mercury oxide button cells. The dangerous substances used in these systems (mercury, cadmium) cannot simply be reduced without influencing the proper functioning of the battery, so that the environmental impact emanating from them can only be regulated by developing and promoting alternative battery systems for the same application area. Exemplary substitutes which are low in hazardous substances are the nickel-hydrid battery and the zinc-air button cell. These two substitution processes are of special concern because of still increasing sales figures for the nickel-cadmium accumulator, leaving this battery system as the major single source of the cadmium consumption, and because of the mercury oxide battery representing in the meantime, after the widespread introduction of low mercury batteries, the most important application field for mercury in batteries. Furthermore, we subsume the promotion of cadmium- and mercury-free lithium cells under this objective because they can serve as substitutes for several battery systems.[22]

3. **Recollection and selective treatment (recycling) of batteries which still contain dangerous substances.**

If a battery system is high in hazardous substances, its recollection and environmentally proper treatment must be ensured. This prerequisite mainly relates to nickel cadmium accumulators and mercury oxide button cells. It is also directed to alkali-manganese and zinc-carbon batteries as far as their mercury content has not been reduced. Recovery rates and recycling facilities must be improved for these systems. However, the problem of all the other

[22] Cp. table 2.5 for possible substitutions among batteries.

"dangerous components" (according to EC Directive 91/689/EEC on dangerous waste) and their proper after use treatment is pending, as well.

4. Overall reduction of the battery use.

This objective is often formulated by environmental and consumer organisations. It is based on the fact that the input-output-balance for energy and materials comes off rather bad for batteries. Their energy supply is therefore relatively expensive and resource-intensive.

The substitution of non-rechargeable batteries by rechargeable batteries, mainly nickel-cadmium accumulators, can also be subsumed under this objective because by means of this substitution the use of mercury is avoided and the material consumption reduced. However, one must consider here that the substitution can only be beneficial in environmental terms when the recovery of the used cadmium is ensured.

3 Description of the environmental policy regarding batteries

3.1 Introduction

In this section, we describe the battery-oriented environmental policies that have been formulated within the European Union. At first, the initiatives that have been taken by the European Union itself are summarised (section 3.2). Here, the directives that are relevant for the battery discussion will be mentioned. Subsequently, the policies in Germany (section 3.3) and Italy (section 3.4) are depicted in sub-sections "Policy context", "Instruments" and "Conclusions". Finally, the interesting measures on batteries as they are introduced in other countries are briefly summarised (section 3.5). For this purpose we have chosen three EU Member States (Denmark, Belgium, The Netherlands) and one non-EU country, namely Switzerland. The selection encompasses instructive examples for unique environmental policies on batteries. In the last section 3.6, the findings of the preceding sections are compared.

3.2 The policy at the Union level

The first measures on batteries taken at the level of the European Community go back to a Danish proposal from the mid eighties concerning the harmonisation of the marking of batteries and accumulators. Up to that time several directives have been passed which aim at regulating the environmental impacts that might emerge from the heavy metals mercury, cadmium and lead.[23] Mercury, cadmium and their compounds are on the "black list" in the Annex to the Council Directives 76/464/EEC on pollution caused by certain dangerous substances discharged into the aquatic environment and 80/68/EEC on the protection of ground water against pollution caused by certain dangerous substances. The directives prescribe certain maximum emission levels of the substances or prohibit any emission. Lead is on the "grey list". This requires the Member States to conduct a prior investigation on all plans to discharge lead into ground water. (L'Hermite 1988, p.9)

At the same time, measures against environmental pollution through cadmium and cadmium products had been initiated. In 1987, the Commission prepared an action programme which contained an overview of the environmental impact and sources of this kind of pollution followed by a strategy for controlling cadmium in products and in waste. One proposed measure calls on the Community to provide incentives for the recycling of cadmium containing

[23] In the year 1989 there were 20 directives containing prescripitions on cadmium and mercury. (Baschab 1989, p.2)

products. By the end of the same year the Council adopted a corresponding resolution. (L'Hermite 1988, p.9)

The motives for the proposal of a directive on batteries were twofold:

* smooth running of the internal market,
* optimal protection of the environment.

The free circulation of goods is one major objective of the single market. By the end of the year 1992 technical barriers to trade, such as different norms and labelling prescriptions, should have been abolished. In order to avoid negative influences on free trade, that might emanate from unilateral measures taken on batteries, it was necessary to harmonise the legal prescriptions among the Member States. (Baschab 1989, p.3)

Within the Fourth Community Action Programme on the Environment from 1987 a proposal for a directive on batteries and accumulators containing dangerous substances as part of the Community Waste Management Programme was announced. (L'Hermite 1988, p.6). This proposal was designed to help protect the environment following the basic guidelines: preserving, protecting and improving environmental quality and ensuring a rational utilisation of natural resources. Moreover, one has to note that the battery directive is a specific directive of the framework directive on waste which has been passed 15th July 1975 (75/442/EEC) and adapted to technical progress by Directive 91/156/EEC on waste.

The directive on batteries and accumulators containing dangerous substances was issued by the 18th of March in 1991 (91/157/EEC). In the same year the Directive 91/689/EEC, related to dangerous wastes, was passed. It states that wastes issued from all non-rechargeable and rechargeable batteries are considered as "dangerous waste" and it lays down prescriptions as to the collection, transport and storage of dangerous wastes.[24] Directive 91/157/EEC has recently been amended by Directive 93/86/EEC which prescribes a Union wide labelling scheme. The Member States had to comply with the first directive before September, 18th 1992 and with its amendment before December, 31st 1993. The following table depicts the main aspects of the directive.

[24] Annex III provides a list of substances that fall under the Directive 91/689/EEC and that are of interest in the case of batteries.

Table 3.1: EC Directive on batteries and accumulators containing dangerous substances.

EC Directive on batteries and accumulators containing dangerous substances (91/157/EEC)	
* Product modification and innovation	* General objectives to be pursued: - Reduction of the heavy metal content in batteries and accumulators. - Promotion of batteries containing no or less dangerous substances. - Promotion of research on environmentally sound battery systems. * As from 1 January 1993 the Member States must prohibit the placing on the market of special purpose alkali-manganese batteries containing more than 0.05% of mercury by weight and of all other alkali-manganese batteries containing more than 0.025% of mercury by weight. Alkali-manganese button cells are excluded from this ban. * As from 1 January 1994, batteries are allowed to be built-in in electric appliances only in cases where the battery can be easily replaced after the battery is used up.
* Labelling	* Batteries must be labelled that have been placed on the market after 18 September 1992 and that contain more than 25 mg of mercury per cell, except for alkali-manganese, more than 0.025% of cadmium by weight, more than 0.4% of lead by weight, and alkali-manganese batteries that contain more than 0.025% of mercury by weight. * The label must indicate: separate collection, recycling, content of heavy metals. * Equipment with incorporated batteries must be labelled.
* Recollection/ disposal	* The Member States have to take measures providing for selective collection and separate disposal of the labelled batteries. * The Member States are called on to implement an effective and selective recollection system. This may be supported by the introduction of an obligatory deposit-refund scheme.
* Recycling/ reuse	* Promotion of research on recycling processes.
* Information	* The Member States have to take measures for the promotion of consumer information campaigns.

The EC Directive 93/86/EEC provides detailed prescriptions regarding the labelling of the batteries to which 91/157/EEC applies. The following table summarises the main aspects.

Table 3.2: EC Directive 93/86/EEC for the amendment of Directive 91/157/EEC to the technical progress

Directive 93/86/EEC	
* Labelling	* Separate collection is to be indicated by a label which consists of a crossed out dustbin.[25] * The content of heavy metals is to be indicated by the chemical symbol of the respective substance. * The producer of batteries, or the institution in charge of the placing on the market, is responsible for labelling.

[25] See Annex IV.

The Commission is assisted by the Waste Management Committee (according to Art. 18 of the Directive 91/156/EEC) and the Advisory Committee for adaptation to scientific and technical progress and it will assess the progress made and the need for any further Community measures.

In order to assess the possible effectiveness of the Directive, there are two aspects that need further attention:

* scope of the directive,
* prescriptions regarding built-in batteries.

The Directive does not apply to all kinds of equipment batteries, but only to those which have to be labelled, i.e. those that exceed certain maximum values of included heavy metals (cadmium, mercury and lead). If the content of heavy metals as reported in Annex I is taken as the benchmark for the application there are the following systems to which the EC Directive applies:

* zinc-mercury-oxide button cells,
* zinc-silver-oxide button cell,
* zinc-air button cells[26],
* nickel-cadmium cylindrical and button cells,
* small lead batteries,
* alkali-manganese button cells,
* alkali-manganese prismatic cells.

In the case of permanently built-in batteries, the Directive prescribes that equipment which contains batteries that fall under the scope of the Directive must be labelled in the same way as the respective batteries have to be (Art.4(2)). Moreover, the Directive states that, as from 1 January 1994, batteries are allowed to be built-in merely in cases where the battery can be "effortlessly" replaced after use (Art.5). There are a few exceptions permitted, when the permanent incorporation of a battery is necessary for functional and safety reasons. Among others, in the case of medical appliances when uninterrupted functioning is necessary (for example heart pace makers), of some devices in industrial use and in cases where the replacement of the battery by non-professional personnel may exhibit a danger for the user. However, the user instructions enclosed with these appliances have to contain information on environmentally harmful content and proper disposal of the device.

[26] The EC Battery Directive does not apply to all zinc-air button cells. Some of them have a mercury content below 25 mg.

The description of the EU policy regarding spent batteries and accumulators can be summarised in the following way:

* The most important legislative act is the Directive on batteries and accumulators containing dangerous substances (91/157/EEC).
* This directive identifies those battery systems which contain hazardous amounts of certain substances.
* For the identified battery systems concrete labelling prescriptions are formulated (93/86/EEC).
* Selective collection systems for the labelled systems have to be introduced and their separate disposal has to be ensured.
* The same prescriptions are valid for appliances with permanently built-in batteries.
* Moreover, the directive contains some "soft" measures, among others the promotion of environmentally benign battery systems and appropriate recycling schemes and the introduction of consumer information campaigns.[27]

With respect to the objectives of a battery-related environmental policy as the have been mentioned in section 2.6 one realises that the EC Directive is mainly directed towards the recollection and selective treatment of batteries which contain hazardous substances and furthermore towards the reduction of theses substances in the batteries.

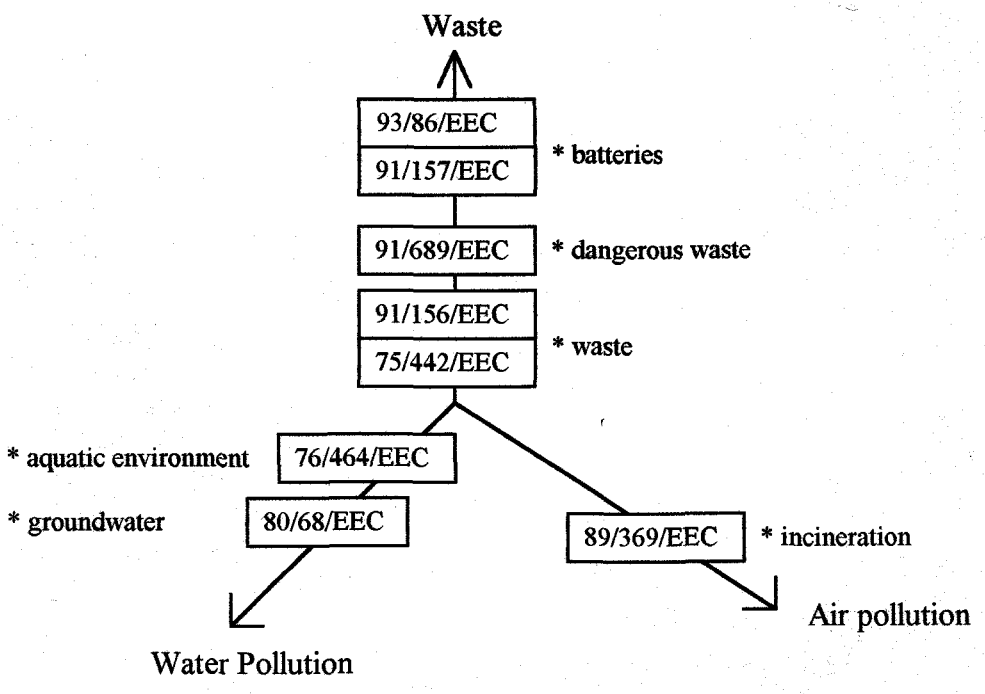
Apart from the fact that a directive only gives a framework for the setting-up and implementing of regulatory measures in the single Member States (according to Art. 189 EC treaty), one must note that the Directive on batteries and accumulators containing dangerous substances does *not* lay down any prescriptions concerning:

* the introduction of extended producer responsibility by means of a take back obligation imposed on the producer of certain battery systems,
* the consideration of the trade as the "gate-keeper" in the distribution and re-distribution chain (information of consumers, point of sale and recollection etc.),
* the necessary conditions for an efficient and environmentally benign recycling of spent batteries,
* the distribution of additional costs caused by the separate collection and proper disposal,
* discouraging the use of batteries.

[27] The ban on certain battery systems can also be regarded as a "soft" measure because it is oriented towards the technical feasibility (Baschab 1989, p.3).

The following figure tries to summarise all the environmental regulation (usually directives) which is of importance in the case of batteries. The three dimensions are distinguished according to the environmental compartment they address (air, water, soil) respectively environmental problem (waste) they are intended to cope with.

Figure 3.1: Dimensions current environmental regulation of the EC (own draft)



Recently, the EU has adopted an a **eco-labelling scheme** for several product groups, one of them being **batteries**. So called "lead countries" are responsible for the elaboration of the labelling criteria. In the case of batteries, France is the leading country. But to date, the working group which has been set up at AFNOR, the French institute for standardisation, has made no progress: the process is at its beginning, a catalogue of criteria does not yet exist. Only an "Overview of the primary and rechargeable batteries consumption in Europe" (ADEME 1993) has been prepared so far.

3.3 Germany

3.3.1 Policy context

In Germany the discussion about the environmental aspects of batteries started in the year 1978 when the Federal Environmental Agency realised the ecological problems emerging from mercury oxide button cells that used to be discarded along with the household waste. In order to reduce the heavy metal load of domestic waste the government and the producers and importers of batteries agreed upon the voluntary collection of these cells starting in the year 1980. At the same time, battery collection facilities were installed in public buildings, enterprises, shops and municipalities in order to recollect all types of household batteries on a voluntary basis. (Genest 1988, p.2) In the year 1981 the first eco-label (Blue Angel) for batteries was available, namely for the mercury free zinc-air system which was to replace the mercury-oxide cell in its main application area hearing aids. (RAL 1993, p.47)

The year 1986 represents a caesura. The fourth amendment of the German Waste Act was passed then which places greater emphasis on the prevention principle[28] by introducing the "hierarchy": prevention, recycling, disposal. This act provides for the possibility for government to lay down regulations pertaining to product-oriented labelling duties, separate collection, restrictions on composition and use of certain products, recycling and disposal of certain products, take-back obligations and obligatory deposits. In particular, Art. 14 on labelling, separate collection, take-back and bring back obligation is aimed at the prevention or reduction of hazardous substances in the waste and at the environmentally proper disposal of products containing dangerous substances.

In 1987, the criteria for the eco-label on mercury and cadmium free lithium batteries and on solar powered products and mechanical watches were passed. The latter should help in reducing the use of batteries in general.

In the following year, a voluntary self-commitment concerning the disposal of spent batteries between the organisation of battery producers and importers (Fachverband Batterien im Zentralverband Elektrotechnik- und Elektroindustrie e.V. "ZVEI")[29] and the trade organisation (Hauptgemeinschaft des deutschen Einzelhandels "HDE") was agreed. This initiative has certainly been influenced on the one hand by the changed priorities and new regulatory possibilities which had been offered by the modified waste legislation and on the other hand by the increased sensitivity of the public towards the waste problems, not least because of the inten-

[28] The first German environmental policy programme from 1970 formulates as its major principles: prevention principle, polluter-pays principle and cooperation principle.

[29] All important battery suppliers for the German market - Varta, Daimon-Duracell, Ralston, Philips, Panasonic - are members of this association.

sive information work of environmental and consumer organisations. Another impetus to this agreement was given by the decision of the battery producers of Europe, Northern-America and Japan on the gradual elimination of mercury from alkali-manganese batteries (Hiller et.al. 1992, p.15). The covenant between industry and trade is described in more detail in chapter 3.3.2.

This voluntary commitment was followed by the EC Directive on batteries and accumulators containing dangerous substances (91/157/EEC)[30] which should have been enacted into national legislation not later than September, 18th 1992. At the same time it emerged that the covenant between industry and trade was not as effective as it was expected (lacking information of consumers and traders and also insufficient cooperation of the latter were two of the main problems).[31] Against the background of these two developments - legislative action of the EC and lacking effectiveness of the voluntary self-commitment - the German minister for the environment decided to pass a decree on spent batteries based on Art. 14 of the Waste Act. The decree deals with the identification of environmentally harmful battery systems, with labelling obligations and with prescriptions pertaining to proper after-use-management. It is depicted in more detail in section 3.3.2.

The decree on batteries has been prepared together with several other decrees, all of which are aimed at implementing the principle of extended producer responsibility, formulated in Art. 14 of the Waste Act. These are, among others, the Waste Car Decree, Waste Printing Decree and Electronic Waste Decree. The latter may be of importance for the scope of this case study when batteries are permanently built-in in electric appliances. The draft version of the Electronic Waste Decree mainly pursues two objectives (Wieczorek 1993, p.203):

* reduction of the amount of domestic waste (quantitative),
* reduction of hazardous substances discarded along with domestic waste (qualitative).

These objectives are to be achieved by the introduction of take-back obligations and recycling duties for electric appliances which address traders and producers.

At the time of writing (July 1994) the legal basis of the battery decree is changing. The recent Waste Management and Product Recycling Act (Kreislaufwirtschafts- und Abfallgesetz, KrWAbfG) is going to take the place of the Waste Act from 1986. It aims at the further development of the former Waste Act and at the promotion of an environmentally benign "Kreislaufwirtschaft" (closed-loop economy). Its coming into force is planned for the year 1996. As a consequence, the draft regulation on spent batteries is going to be modified once again making any assessment of its final realisation impossible.

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[30] See chapter 3.2.

[31] For a more detailed evaluation of the effectiveness of the voluntary self-commitment see chapter 4.

The realisation of the Waste Act objectives is explained in more detail in the so called "Verwaltungsvorschriften" (administrative regulations), which address administrative bodies (Bilitewski et.al. 1993, p.9). In the case of used batteries there are two administrative regulations of importance:

* "Technische Anleitung Abfall", TA Abfall (technical direction on waste);
* "Technische Anleitung Siedlungsabfall", TA Siedlungsabfall (technical direction on domestic waste).

The TA Abfall applies to waste that needs to be supervised, i.e. hazardous waste. It contains regulations with regard to technical and organisational prerequisites on storage, chemical, physical and biological treatment, incineration and final disposal of dangerous waste. The TA Siedlungsabfall is directed to waste caused by private households and it formulates general demands on product recycling and the reduction of hazardous substances. It contains statements pertaining to the separate collection and deals, among others, with the following objectives (Bilitewski et.al. 1993, p.11 ff.) :

* reducing the contents of dangerous substances in waste to a minimum,
* recycling of unavoidable waste as far as possible,
* environmentally sound treatment and final disposal of non-recyclable waste.

These technical directions do not have a statutory character. However, non-compliance may lead to monetary sanctions and punishment according to legislation on environmental liability. Moreover, disposal companies may have their licence withdrawn. It is not known wether the latter has ever happened.

Both TA's contain prescriptions that are directed to batteries and materials used in batteries and to their appropriate disposal. Table 3.3 below provides a synopsis of the regulation. It reveals that all used equipment batteries must not be disposed of in domestic waste landfills according to the administrative regulation.

Table 3.3: Batteries and battery substances that are regulated by the "TA Abfall" and "TA Siedlungsabfall" (Baumann et.al. 1993, p.7)

Battery (substance)	Preferred Disposal
Nickel cadmium accumulator	Sub-soil dumping site
Batteries containing mercury (independent on percentage of mercury)	Sub-soil dumping site
Dry batteries[a)]	Hazardous waste landfill
"Braunstein", manganese oxide	Hazardous waste landfill
Zinc-oxide, zinc-hydroxide	Hazardous waste landfill
Ammoniumchloride	Sub-soil dumping site
Acid from accumulators	Chemical/physical or biological treatment

a) "Dry batteries" encompass: zinc-carbon, alkali-manganese, silver-oxide, mercury-oxide, nickel-cadmium.

3.3.2 Instruments

In chapter 3.3.1 the context of the battery oriented environmental policy in Germany has been described. It has been mentioned that there are mainly two initiatives which aim at mitigating the environmental impact emanating from spent battery handling procedures. The first major step has been the covenant between battery producers, importers and the trade organisation from 1988. It has been followed by the Council Directive on batteries and accumulators containing dangerous substances which is going to be enacted into national law by the battery decree for which a first draft has been prepared. Apart from these legally binding and not-binding arrangements, some additional activities can be observed in the field of voluntary information instruments (product tests and eco-labelling) and environmental and consumer advisory services.

At first the **voluntary self-commitment** and the draft version of the **battery decree** are described (tables 3.4 and 3.5). Afterwards, the measures that have been taken on a voluntary basis and which aim at satisfying information needs are summarised. In this context a voluntary initiative for the recollection of built-in batteries is briefly depicted.

Table 3.4: Main aspects of German self-commitment on used batteries between industry and trade (1988)

Voluntary self-commitment on the disposal of spent batteries (1988)	
* Product modification and innovation	* Production and development of batteries containing less or no dangerous substances. * Development of substitutes for environmentally harmful battery systems, especially mercury oxide cells. * Reduction of the mercury content of alkali-manganese batteries (0.15% of mercury by weight in 1988, 0.10% in 1990 and less than 0.10% in 1993).
* Labelling	* Labelling with the ISO recycling symbol 7000-Reg.No. 1135 of the following systems: sealed nickel-cadmium accumulators, starter batteries, button cells containing mercury and alkali-manganese batteries containing 0.1% or more of mercury.[32]
* Recollection/ disposal	* The retailers and producers commit themselves to take back the *labelled* batteries.
* Recycling/ reuse	* The producers have to build up facilities that ensure the recycling of the hazardous substances in the batteries.
* Information	* Traders and producers/ importers are responsible for informing consumers. * Annually the minister for the environment is to be informed about the actual status of the realisation of the commitment.
* Period of validity	* The self-commitment is valid until the government lays down a regulation on batteries, i.e. a battery decree.

[32] Cp. Annex V for the ISO symbol.

The following table summarises the essential topics of the draft version of the German battery decree dated June, 10th 1992.

Table 3.5: Main aspects of the German draft regulation on used batteries

Decree concerning the recycling and disposal of used batteries and accumulators - draft version of June, 10th 1992 -	
* Product modification and innovation	* Further reduction of the heavy metal content. * As from 1 January 1993 the placing on the market of special purpose alkali-manganese batteries containing more than 0.05% of mercury by weight and of all other alkali-manganese batteries containing more than 0.025% of mercury by weight is prohibited. Alkali-manganese button cells are excluded from this ban. * As from 1 January 1994, batteries are allowed to be built-in only in cases where the battery can be easily replaced after the appliance is used up.[33]
* Labelling	* Batteries that have been placed on the market after 18 September 1992 and that contain more than 25 mg of mercury per cell, except for alkali-manganese, more than 0.025% of cadmium by weight, more than 0.4% of lead by weight, and alkali-manganese batteries, that contain more than 0.025% of mercury by weight, have to be labelled. * Equipment with incorporated batteries must be labelled.
* Recollection/ disposal	* Producers and traders are obliged to take back *all* used batteries. * Traders have to keep the labelled batteries separate from the non-labelled batteries. * Non-recyclable batteries have to be disposed of according to the prescriptions of the waste legislation.
* Recycling/ reuse	* As a matter of priority spent batteries and battery materials are to be recycled/ reused.

The battery decree is to transpose the EC Directive on batteries and accumulators containing dangerous substances. However, if the Directive is compared with the draft version of the decree there are two striking differences concerning the following aspects:

* scope of application,
* introduction of a deposit refund scheme.

The take-back obligation, as formulated in the German draft version of the battery decree, is not confined to the labelled batteries, but also encompasses non-marked batteries. This general take-back obligation is justified by the need to avoid "misthrows": if the take-back duty only covers the labelled ones, there is a risk that the consumer discards not only batteries low in hazardous substances (non-labelled) along with the domestic waste, but batteries containing a large percentage of dangerous substances (labelled) as well. (BMU 1992, p.8) However, the general take back obligation does not imply a general recycling duty for all collected batteries. Hence, there is a fraction of used batteries low in dangerous substances which can either be

[33] There are the same exceptions from this prescription as they are formulated in the Council Directive 91/157/EEC.

disposed of in landfills or incinerated according to the respective prescriptions of the waste legislation.

In contrast to the EC Directive the German battery decree does not explicitly mention the possibility of introduction of an obligatory deposit refund system in order to increase the recovery rates of spent batteries. Two main arguments are quoted for this omission (BMU 1992, p.5):

* a national initiative would result in additional costs for domestic producers and traders and moreover cause competition problems with other EU countries,
* an effective deposit must be high and would therefore bind considerable quantities of financial resources during the life span of a battery.

Besides the voluntary self commitment between industry and trade on spent batteries and the draft version of the battery decree there are other measures which fall under a battery oriented environmental policy, which mainly follow an informative approach. Among them are the product tests of certain magazines, the eco-label "Blue Angel" and the advisory services of environmental and consumer organisations. Moreover, the German Federal Environmental Agency has published a "Handbook on environmentally friendly procurement" which provides information for public purchasers on the environmental features of certain products, among others batteries, and gives advice with regard to "green" procurement.

Two German magazines deal with the **testing of selected products** against the background of certain criteria, which more or less cover ecological aspects. Namely, the Foundation "Warentest" with its monthly publication "test" and the monthly journal "Ökotest". The following table lists the product tests which either study batteries as such or battery powered appliances. The column "environmental aspects" summarises the environmental issues connected with the respective product which are discussed in the text but do not serve as a criterion for the assessment. If environment related criteria are explicitly relevant for the product assessment they appear in the column "applied criterion". Proposals that have been made in the context of the product test and that are directed to environmental policy makers are listed in the last column "proposals".

Table 3.6: Product tests in the field of batteries and battery powered appliances

Product	Magazine[a)]	Environmental aspects	Applied criterion	Proposals
Cordless tools	test, 12/88	Environmental impact of the disposal of built-in nickel-cadmium accumulators.	none	Improved labelling, deposit refund.
Zinc-carbon, alkali-manganese, nickel-cadmium batteries	ökotest, 7/89	Disposal of mercury and cadmium containing products	Mercury and cadmium content	Application of non-rechargeable and rechargeable batteries only when necessary. Recollection of all batteries
Flash lights	test, 11/89	Disposal of spent batteries.	none	Warning symbols
Chargers	test, 1/90	Environmental advantage of rechargeables compared to non-rechargeables with regard to the mercury content.	none	Deposit refund on nickel-cadmium accumulators.
Battery powered screw driver	test, 9/90	Replaceability of the accumulator. Disposal of built-in nickel-cadmium accumulator. Existing disposal instructions and return premia.	Notes for the user on the disposal.	
Electric shavers	test, 1/91	User instructions on the disposal of built-in nickel-cadmium accumulators. Comparison with the functional alternative "wet shaving".	Notes for the user on the disposal.	
Laptops	test, 10/91	User instructions for the disposal of built-in nickel-cadmium accumulators.	Notes for the user on disposal	
Nickel-cadmium accumulators	test, 1/92	Environmental advantage of rechargeables compared to non-rechargeables with regard to the mercury content. Disposal of nickel-cadmium accumulators.	Existing notes for the user on the disposal and information on the possible impact of the included heavy metals.	Deposit refund

a) "test" is the monthly magazine of the Foundation "Warentest". "Ökotest" is an independent monthly published magazine.

Some conclusions can be drawn from this brief overview:

* Product tests dealing with batteries started in the late eighties.
* Batteries as such have been tested only twice.
* Among the battery powered appliances some of those with relative high growth figures can be found (laptops, cordless tools).
* The environmental aspects mentioned mainly cover disposal problems in connection with the included heavy metals.
* The environmental testing criteria are restricted to notes for the user concerning the proper disposal of the battery.
* The instrument which is proposed the most often is a deposit refund scheme.

Environmental and consumer advisory centres have the function of supplying the interested public with information on the quality and environmental features of certain products. In this context they are, among others, dealing with batteries. The following table summarises programmes of selected organisations.

Table 3.7: Battery "policy" of environmental and consumer organisations

Organisation	Environmental aspect	Proposals
Bundesverband für Umweltberatung (BfUb)	Heavy metal load in domestic waste. Wide range of battery applications.	Priority use of mains operated appliances. Prohibition of devices with permanently built-in batteries. Separate collection of all batteries. Take-back obligation and obligatory deposit for environmentally harmful batteries . Improved labelling prescriptions.
Verbraucherzentrale	Heavy metal load in domestic waste. Batteries are generally regarded as hazardous waste.	Avoiding and reducing the use of batteries as far as possible. Preference for mercury free battery systems. Recollection of all batteries.

The programmes are characterised by a more far reaching scope compared to other measures. On the one hand they doubt the usefulness of some battery applications and prefer the use of mains operated appliances as far as possible. On the other hand, they call for a general take-back obligation for all battery systems and for the introduction of obligatory deposits for those battery systems which are high in hazardous substances.

As already mentioned in chapter 3.3.1 there are **eco-labels** available for zinc-air batteries, lithium batteries, solar-powered products and mechanical watches. Table 3.8 below summarises the main criteria for the application of the labels.[34]

Table 3.8: The German eco-label "Blue Angel" (RAL 1993)

Labelled product	Year	Main criterion	Other requirements
Zinc-air batteries	1981	"Small mercury content"	Other dangerous substances contained may not exceed maximum values. Information for consumers on the taking-back of used batteries by the trade is recommended. The battery must meet usual quality requirements.
Lithium batteries	1987	"Mercury and cadmium free"	Other dangerous substances contained may not exceed maximum values. Notes for the user on the proper disposal are recommended. The battery must meet usual quality requirements.
Solar powered products (watches, calculators), mechanical watches	1987	"Without battery"	Certain performance standards for the solar cells. No cadmium containing compounds allowed. Used capacitors must not contain halogen compounds (e.g. PCB).

One interesting aspect of this synopsis is the labelling of products that do not run on batteries. In this case a more general reduction of the amount of used batteries is supported whereas the

[34] Cp. Annex VI for the eco-labels.

labelling of lithium and zinc-air batteries only pursues the substitution of environmentally harmful battery systems by less harmful alternatives.

The "Handbook of environmentally friendly procurement" which is published by the Federal Environmental Agency formulates concrete guidelines for an environment oriented **public procurement** (UBA 1993b). However, it does not merely address public purchasers but all other kinds of purchasers in the industry and society. The chapter on batteries informs about the environmental burden connected with the disposal of environmentally harmful battery systems and also about the measures taken so far in order to reduce the potential negative impact on the environment. Finally, it provides some advice concerning the procurement of batteries:

* Preferred use of zinc-air and lithium batteries.
* Preferred use of solar powered appliances.
* Separate collection of mercury containing batteries.
* Use of rechargeable nickel-cadmium accumulators when separate disposal is ensured.

It is obvious that the proposed guidelines are oriented towards those measures that are promoted by the official eco-label. This is due to the fact that the "author" in both cases is the Federal Environmental Agency.

The measures which have been mentioned so far are mainly directed towards single batteries. But as already said in section 3.2, the EC Directive on batteries and accumulators containing dangerous substances (91/157/EEC), which is to be transposed by the German battery decree, also includes prescriptions for permanently **built-in batteries**: as from 1 January 1994, they are allowed to be built-in merely in cases where the battery can be replaced "effortlessly" after use. Otherwise, the appliances have to be marked in accordance with the labelling prescriptions. However, apart from these permanently installed batteries there are also batteries of the "cassette type" or so called "power packs" available which consist of several single accumulators in one case. The power pack is easily replaceable, but the single batteries are not. Usually, these power packs include nickel-cadmium accumulators. Accordingly, the recollection of these battery systems is more complicated than that of a single battery. The box below provides an instructive example of a voluntary take-back scheme for electrical hand tools which normally use power packs for their energy supply. This system must be regarded in the context of the draft version of the German Electronic Waste Decree (see section 3.3.1) which foresees take-back duties for several kinds of electric waste (e.g. household appliances, audio and video equipment, electric tools etc.).

Box 3.1: Voluntary recollection scheme for "power-packs"

In Germany 14 producers of electrical hand tools have recently introduced a voluntary take-back system for their products. This pilot project represents an anticipation of the planned Electronic Waste Decree (cp. section 3.3.1).

Until April 1992 the producers paid a rebate of 10% on new appliances to clients who brought back the used tools including the power pack. Since the costs for landfilling of the spent tools rose for every producer, they decided - based on a cost-benefit analysis - to install a voluntary take-back and recycling system at the beginning of 1993 as a less expensive alternative to landfilling. Boxes for recollection were put up at those retailers which participated in the system. The full boxes are being stored temporarily at a central collection site where the electronic waste is dismantled and the power packs separated. Subsequently the spent power packs are sent to a recycling plant in France. The ensuing costs are assigned to every producer in correspondence to the weight of his collected tools. The costs will be shifted to the consumer resulting in higher sales prices for the electrical hand tools. According to information from a leading producer of electrical hand tools in Germany this system has realised very modest single digit recovery rates so far.

3.3.3 Conclusions

In this section we summarise the measures of battery-oriented environmental policy in Germany. They can be viewed according to the categories we have introduced for the first project step of "Product policy in support of environmental policy".[35] The table below provides an overview of the instruments and their actual status and also of the main objectives being pursued by the respective instrument. Moreover, it gives a hint of the stage of the battery life-cycle to which the instrument is mainly directed and of the relevant actors. The column "actors" is subdivided into the "actors implementation" encompassing the major interest groups which are engaged in the formulation of the regulation and the "actors application" listing those actors which are in charge of the proper "functioning" of the respective measure.

[35] Cp. Annex VII.

Table 3.9: Overview of battery-oriented environmental policy instruments in Germany I

	Instrument	Status	Main objectives	Life-cycle approach	Actors implementation	Actors application
I.	**Direct regulative instruments**					
I-1-1	Prohibition	planned	Reducing mercury content. Improving replaceability of batteries.	production stage, disposal stage	BMU, BMWi, UBA, all lobbying parties	producers
I-5-1	Product standards	planned	Reduction of mercury content.	production stage	BMU, BMWi, UBA, all lobbying parties	producers
I-7-1	Obligation to take-back	in force, on a voluntary basis	Recollection of spent batteries.	disposal stage	industrial association and trade organisation	consumers, traders, producers
I-7-2	Obligation to take-back	planned, on an obligatory basis	Recollection of spent batteries.	disposal stage	BMU, BMWi, UBA, all lobbying parties	consumers, traders, producers
II.	**Economic instruments**					
II-5-1	Deposit -refund	discussed	Increasing recollection rates.	disposal stage	environmental and consumer organisations	consumers, traders, producers
III.	**Compulsory information instruments**					
III-1-1	Compulsory labelling	planned	Separate collection.	disposal stage	BMU, BMWi, UBA, all lobbying parties	consumers

Table 3.10: Overview of battery-oriented environmental policy instruments in Germany II

	Instrument	Status	Main objectives	Life-cycle approach	Actors implementation	Actors application
IV.	**Voluntary information instruments**					
IV-1	Test reports	in force	Separate collection and selective treatment of spent batteries.	disposal stage	Foundation "Warentest"	consumers
IV-2	Eco-label	in force	Promoting batteries low in hazardous substances. Promoting a general reduction of battery use.	disposal stage. use stage.	UBA, industry, environmental and consumer organisations, representatives from churches and Länder	consumers
IV-3-1	Other voluntary labelling	in force	separate collection	disposal stage	industrial association and trade organisation	consumers
IV-8-1	Recommendations	in force	Promoting batteries low in hazardous substances. Promoting a general reduction of battery use.	disposal stage, use stage	UBA	consumers (public purchasers)
V.	**Voluntary agreements**					
V-2	Self-commitments	in force	Take-back of batteries high in hazardous substances. Further reduction of heavy metal content.	disposal stage	industrial association and trade organisation	producers, traders, consumers
VI.	**Consumer policy**					
VI-2	Consumer advice	in force	Reduction of battery use. Separate collection and selective treatment of spent batteries.	use stage, disposal stage	environmental and consumer organisations	consumers

Some conclusions can be drawn from this abridged overview:

* In Germany, the (planned) environmental policy regarding batteries consists of several different instruments from several different categories. However, since direct-regulatory instruments have not yet been introduced, voluntary information instruments predominate so far. Economic instruments are merely discussed at the moment. A voluntary take back scheme for spent batteries has been in force for a couple of years.

* It becomes obvious that the main focus of battery-oriented environmental policy in Germany is on the recollection of spent batteries and therefore on the disposal stage of the life-cycle. Besides that, the development of environmentally more sound battery systems at the production stage is promoted.

3.4 Italy

3.4.1 Policy context and applied instruments

The Italian legislation on batteries started with the D.P.R. (Decreto Presidente della Republica) n.915/82. This law has been issued to comply with the European Directives CEE n.75/442, 76/403 and 78/319 on "Dangerous and Toxic Wastes".

In the DPR 915/82 mercury and cadmium are listed as dangerous substances; batteries indicated as dangerous waste are subjected to a separated collection from the solid urban waste.

The law becomes effective only by the issue of the "decreti applicativi" (application directives) (Interministerial Committee directives n 52/84 and 441/87). In Italy there are specific directions as to how a law must be applied. Only from April 27, 1988 are local authorities obliged to organise the separate collection of spent batteries.

According to the Italian legislation, batteries are dangerous waste because of the presence of mercury and other heavy metals. The local municipalities (Comuni) must collect them and discard them separately from other domestic solid wastes. The collection is made by special containers in the street; usually located close to electrical material dealers, in electrical appliances retailers and in big shopping centres.

According to the legislation, the spent batteries must be neutralised in a concrete block and disposed of in special landfills or processed in authorised plants for recycling or recovering heavy metals. In Italy, there are only a few landfills which can take only part of the spent batteries volume. Hence, batteries are stored in temporary deposits or given to private companies which take them abroad to special recycling units. There is one stock centre in Paderno Dugnano - Milan which got the Regione Lombardia approval for stocking maximally 1,500 t of spent batteries.

The EC Battery Directive has not yet been implemented by the Italian Parliament and because of the recent change of the Italian Government nothing can be said concerning its future policy.

At this time (July 94) the parliamentary minority has presented a draft version of a law based on the EC Battery Directive 91/157/ EEC which forbids the commercialisation of alkali-manganese or of any other battery system with a mercury plus cadmium content greater than 0.025 % of the total weight. Button cells and accumulators are excluded, but it will be mandatory to put a label indicating the danger for the environment of the product.

A deposit refund of 500 lire for button cells and 1,000 lire for accumulators (cylindrical, i.e. not lead batteries for cars) is also foreseen. The deposit is given back to the buyer when the

spent battery is given to any point. The proposal also indicates the manufacturers and importers of the batteries as those responsible for the proper after-use-management.

For accumulators which are built into electric and electronic equipment like computers, telecommunication systems, and portable tools, there are no regulations for disposal proposed so far, except for a recently approved law (art n. 39 of the February 22.94 Law n.146/94 - Disposition to comply with the obligations of the EC Directive 259/93). This states that devices made from thermoplastic and thermosetting resins can be discarded as urban solid waste, so that cordless devices do not require special disposal measures.

The problem is limited nowadays as cordless technology is in its infancy and the second hand market is still absorbing large quantities of appliances. However, the problem will appear in the near future, when the market will reach a maturity and some of the old models will definitely go out of the market.

The box below describes an example of a voluntary measure of recovery in this area, namely that of IBM-SEMEA.

Box 3.2: Recovery of spent computers in Italy

IBM SEMEA started to offer a service for the disposal of used computers. The service is extended to computers of IBM competitors. It started in 1993 and was recycling 22,000 machines for a total of 4,500 t. Devices including batteries and accumulators, as personal computers or computers with an continuously operating internal clock account for about 10 % of the total number of devices (2,500 pieces). The collection service is operated by the IBM sales network. The recycling site is located in Busnago-Milan. It employs 50 people and has a credit balance.

IBM offers a discount on the new system if the customer gives the old one back. After the dissembling of the old system only 10% of the weight is destroyed at a cost of 300-400 L/kg. IBM's target is to increase the rate of recovered material to 95%.

The electronic materials are recycled to less sophisticated applications such as video games for example. Heavy and precious metals are sold or reprocessed within IBM. Some spare parts of the systems which are no longer produced by IBM are given to the Technical Service for the maintenance of old models still operating in the marketplace.

3.4.2 Conclusions

In this section, we summarise the battery-oriented environmental policy measures in Italy. We follow once again the categorisation of policy instruments as it has been introduced for the entire project (see section 3.3.3). The overview turns out to be less detailed than that for the German situation. This is due, on the one hand, to a less detailed information base and on the other hand to the fact that the Italian activities in this area are at their very beginning and so far cannot represent a comprehensive set of battery-related environmental policy measures. Therefore the column "actors implementation" which lists those actors participating in the formulation of the respective programmes has been omitted.

Table 3.11: Overview of battery-oriented environmental policy instruments in Italy

	Instrument	Status	Main objectives	Life-cycle approach	Actors application
I.	**Direct regulative instruments**				
I-1-1	Prohibition	proposed	Reduction of mercury content	production stage	producers
I-7-1	Obligation to take-back	in force	Separation of dangerous waste from domestic solid waste.	disposal stage	local communities, consumers
II.	**Economic instruments**				
II-5-1	Deposit -refund	proposed	Increasing recovery rates of button cells and accumulators.	disposal stage	consumers, retailers
III.	**Compulsory information instruments**				
III-1-1	Compulsory labelling	proposed	Indicating danger for the environment.	disposal stage	consumers
IV.	**Voluntary information instruments**				
V.	**Voluntary agreements**				
VI.	**Consumer policy**				

The overview reveals that:

* actually the recollection of spent batteries is mainly the task of municipalities who are in charge of separating used batteries from other household waste,
* the "official" proposals, (i.e. those proposals which have been made on a parliamentary level), focus on those prescriptions which are also included in the EC Battery Directive and furthermore explicitly mention deposits as a means to improve the recollection of used batteries,
* instruments such as voluntary information instruments, voluntary agreements and consumer advice are not yet being used nor proposed.

3.5 Battery policies in other countries

In this section we give a brief overview of battery-oriented environmental policy in some countries. This overview is not intended to be complete; but to present some instructive examples instead.

3.5.1 Denmark

Policy context

Denmark imports almost all batteries it consumes. Domestic production facilities are available only for special batteries which are used for military or scientific purposes. In the early eighties the contribution from batteries to the mercury and lead pollution was considerable. In 1982 the mercury consumption due to the use of batteries in comparison to the entire mercury consumption accounted for 28%, the respective percentage for lead accounted for 45%. However, during recent years, batteries' contribution (especially to mercury consumption) has been reduced (1.5% of mercury consumption was caused by batteries in 1990).[36] For cadmium, however, an opposite trend was observable. The relative cadmium consumption due to the use of batteries and accumulators amounted to 6% in 1978 and to 70% in 1994 leaving batteries as the largest single source of the cadmium load into the environment. (Ministry of the Environment 1991, 1992, 1994)

The first environmental policy measures on batteries were implemented in the mid eighties and aiming at reducing the mercury content of alkali-manganese and zinc-carbon batteries by financing national research and development. These actions were followed by an agreement between the government and the battery importers in Denmark in 1988, under which the import of high mercury battery systems (alkali-manganese and zinc-carbon) were to be phased down to a certain level before the year 1992. One year later, Statutory Order No. 804 on Collection of Oil and Chemical Waste was passed, laying down rules for local authorities with regard to the setting up of collection schemes for batteries containing heavy metals. After surveys of sale and consumption of nickel-cadmium accumulators in the late eighties, an agreement between the Danish Minister for the Environment and the Danish Association for Collection of Rechargeable Batteries, which consists of retailers and importers of batteries and appliances, was settled in 1991 on the collection of these battery systems and also on equipment with incorporated batteries. The parties involved committed themselves to collect 75% of spent batteries a year. This voluntary agreement has been supplemented by Statutory Order No. 15 of January 3, 1992 which obliged parties which had not joined the covenant to fulfil the same requirements. In the same year, a disposal charge was introduced on nickel-cadmium

[36] For lead from batteries and accumulators the percentage still amounted to 31% in 1990.

accumulators (Statutory Order No. 10 of January 3, 1992). This charge is to cover the cost of collection and reprocessing and also the costs caused by information campaigns (TV information features, library folders, advertising in newspapers etc.). The charge amounts to 2 DKK per cell and to 8 DKK per permanently incorporated battery in electronic appliances. Moreover, the Ministry has issued Circular No. 2 of January 3, 1992 on Collection of Rechargeable Nickel-cadmium Batteries and Appliances with Built-in Nickel-cadmium Batteries from Public Institutions and Offices.

The Government Cleaner Technology Action Plan 1993-1997 contains, as a general objective, the gradual phase out of cadmium in all application areas, among others in batteries. This framework programme reserves funds for the implementation of projects to substitute cadmium. (Ministry for the Environment 1994)

The action to be taken for the next few years will largely consist of monitoring and adjustment of ongoing measures. Moreover, measures will be taken to encourage the use and marketing of environmentally sound battery systems. (Ministry of the Environment 1992)

Transposition of the EC Battery Directive

The EC Directive on batteries and accumulators containing dangerous substances was transposed into national legislation in the year 1993 (Statutory Order No. 966 of December 13, 1993). The regulations laid down in Statutory Order No. 966 generally coincide with the prescripitions formulated in the battery Directive except for one aspect relating to permanently built-in batteries. The Directive is more stringent. Batteries are allowed to be built-in merely in cases where the battery can be easily replaced after the battery is used up (cp. section 3.2). The Danish Executive Order says that import and marketing is "only permitted if consumers are informed of the method of removing them (*the permanently incorporated batteries, GS*) before disposing of the appliance". Apart from this small deviation, the Statutory Order lays down that the Danish Environmental Protection Agency is in charge of supervising and controlling the rules. The EC Directive makes no concrete statement on this issue.

Instruments

The following table provides a brief synopsis of the measures taken in Denmark. It excludes those measures which are based on the implementation of the EC Directive on Batteries and Accumulators Containing Dangerous Substances.[37]

[37] Cp. section 3.2 for this Directive.

Table 3.12: Overview of battery-oriented environmental policy instruments in Denmark[a)]

	Instrument	Status	Main objectives	Life-cycle approach	Actors
I	**Direct regulative instruments**				
I-7-1	Obligation to take-back	in force	Recollection of spent batteries.	disposal stage	local authorities
I-7-2	Obligation to take-back	in force	Recollection of spent batteries.	disposal stage	public institutions and offices
II	**Economic instruments**				
II-2-1	National product charges	in force	Financing collection and processing of spent nickel-cadmium batteries.	disposal stage	
II-4-1	Financial assistances	in force	Reducing mercury content. Substitution of cadmium in products.	production stage	importers, producers
III	**Compulsory information instruments**				
IV	**Voluntary information instruments**				
V	**Voluntary agreements**				
V-2-1	Self-commitments	in force	Reducing mercury load from batteries. Recollection of spent nickel-cadmium batteries.	production stage disposal stage	producers/importers consumers, retailers, producers/importers
VI	**Consumer policy**				

a) Instruments which are based on the implementation of the EC Directive on Batteries and Accumulators Containing Dangerous Substances are excluded from this table.

Two main findings concerning battery oriented environmental policy in Denmark are provided by this overview:

* the scope of the applied instruments also encompasses economic instruments,
* there is a special focus on environmental problems caused by the heavy metal cadmium which is contained in the nickel-cadmium accumulator.

3.5.2 Belgium

Belgium has not yet transposed the EC Battery Directive into national legislation. However, in the framework of a nation-wide waste management policy, it has been decided to introduce an eco tax, among others, on batteries. It was to be introduced by 1st January 1994, but the implementation suffered from several time delays.[38] A bill has been adopted to introduce the tax on batteries at the latest by 1st January 1995.

The scheme foresees a tax of 20 BFR on every single battery independently of the amount of heavy metals it contains.[39] However, batteries can be exempted from the tax if the producers and importers succeed in the installation of a deposit refund scheme which furthermore ensures the proper after-use treatment of the spent batteries, e.g. their recycling. The deposit has to amount to at least 10 BFR.

3.5.3 The Netherlands

The Netherlands have transposed the EC Battery Directive into national legislation. Moreover, a legislative draft is being prepared at the moment which foresees an obligatory deposit-refund if the Dutch Association of Battery Manufacturers (NEFIBAT) does not accomplish the formulated objectives for the recollection of spent batteries: a recovery rate of 80 % as from 1 January 1996 and of 90 % as from 1 January 1998. The level of the deposit is not yet laid down, the idea is to impose a deposit of 0,50 NFL on non-rechargeable batteries and a deposit of 2,50 NFL on rechargeable nickel-cadmium accumulators.

[38] For more detailed information on the Belgian eco taxation scheme see Leek et.al. (1993): Product policy in support of environmental policy. Case study Belgium.

[39] Permanently built-in batteries are excluded from the eco tax.

3.5.4 Switzerland

The Swiss experience with the environmentally proper treatment of spent batteries is reviewed briefly because it seems to be the only country that succeeded in setting up a voluntary take-back and recycling system funded by a kind of disposal charge. (cp. Jordi 1994)

Due to regulation on the separate disposal of dangerous waste, used batteries were collected by municipalities and retailers until 1990. The recovered batteries were exported and finally disposed of at a landfill in East Germany. These exports were prohibited in 1990. Subsequently, the costs for the domestic disposal of spent batteries increased and the local communities were no longer willing to bear the additional financial burden. This was the impetus for Swiss battery-producers and -importers and major retailers to found an organisation for the disposal of spent batteries[40] ("Batterieentsorgungs - Selbsthilfeorganisation", BESO). The BESO concluded treaties with two battery recycling companies in Switzerland responsible for the recycling of the collected battery mixes (BATREC and RECYTEC, cp. section 2.4.3).

Since 1st January 1992, the after-use management (collection and recycling) is financed by an advanced voluntary disposal fee ("vorgezogene Entsorgungsgebühr", VEG) which is levied on the producer or importer of a battery who delivers the fee to the BESO, in charge of managing the disposal fund. The fee is shifted from the producers/importers to the final consumers via retailers. The basis for the calculation of the fee is the weight of sold batteries, reported monthly to the BESO.[41]

The BESO works closely together with local collection facilities (municipalities, retailers and special shops). The recovery rates realised during recent months are estimated between 55 to 60%. These estimates exceed the average figures for other European countries.

[40] This organisation deals solely with the disposal of spent household batteries and small accumulators.

[41] The fee is independent of the amount of hazardous substances contained in the sold batteries.

3.6 Comparison and conclusions

The description of the environmental policy dealing with batteries practised or planned in different countries has revealed differences and similarities among them. There is no uniform approach and the regulatory intensity of the adopted measures sometimes varies considerably. However, it has also been shown that the applied instrumental set may be similar, at least in parts, among the different countries. This fact can certainly be put down to the EC Directive on batteries and accumulators containing dangerous substances, passed in 1991. Although it has been transposed into national legislation only in two member states so far, (namely Denmark and the Netherlands), it certainly represents a guideline for the actual and planned environmental policies on batteries in other countries.

The **similarities** between the approaches of the different countries are the following:

* The main focus of the battery-related environmental policy is on environmentally proper disposal of used batteries.
* Recollection schemes have been installed in every country. The major motive is the separation of dangerous substances (e.g. toxic heavy metals) from solid household waste.
* In this sense, it is mainly the consumer who is in charge of bringing back the used battery either to a public (e.g. municipality) or private (e.g. retailer) collection site.
* An overall reduction of battery use in order to avoid hazardous waste appears to be an objective of minor importance in all countries.

The **differences** of the country-specific environmental policies dealing with batteries encompass the following aspects:

* The comprehensiveness of the instrumental set varies considerably among the countries, i.e. the development of environmental policy dealing with batteries differs.
* The responsible actors for the recollection of spent batteries are in some countries public actors (i.e. municipalities in Italy), in other countries non-public actors, such as retailers and battery producers (as in Germany).
* The funding of collection and treatment of batteries differs: Some countries have introduced voluntary or obligatory disposal charges.
* The operationalisation of the objective "Recollection of spent batteries" differs. In the Netherlands, for example, concrete recovery rates to be achieved within a certain period of time have been formulated.
* The main scope of battery policy is not always the same: Whereas in Italy the policy focus is not yet concentrated on certain battery systems, it appears to especially deal with nickel-cadmium accumulators in Denmark, for example.

4 Assessment and Evaluation

4.1 Introduction

In connection with the assessment and evaluation of the product policy directed to the product group of batteries, one has to distinguish between two different discussion levels:

* discussion on **environmental goals** in the case of batteries,
* discussion on the appropriate **instruments** to achieve these goals.

Usually, environmental goals are the result of an intensive bargaining process among the different relevant actors in society and therefore represent a mixture of environmental quality objectives, economic and social objectives (Schwanhold 1994). In this case study several objectives of a battery related environmental policy have already been mentioned (see section 2.6).

The instruments or the mix of instruments chosen are also the result of a bargaining process. They are selected according to several criteria, a.o. their ecological effectiveness, their economic efficiency and their acceptance. The criteria do not only serve the ex-ante function of instrumental selection, but they also serve the ex-post function of policy evaluation which is going to be the main focus of this chapter. However, our reasoning might also address the formulated environmental objectives, so far as they can be regarded as an important obstacle to the success of product-oriented environmental policy.

The main criteria we have chosen for the evaluation of the instruments are listed in table 4.1. Each criterion is briefly explained and subdivided into several sub-criteria when necessary. These criteria are to serve as a general guideline for the evaluation. They cannot always be addressed explicitly due to lacking operationalisability. Accordingly the statements based on these criteria have a more qualitative character.

Even where the chief criteria have been detailed by sub-criteria, it can still be difficult to operationalise and quantify them. In this sense the economic criteria, which can be quantified more easily, may be regarded as the "hard" ones and the other criteria, especially acceptability, as "soft". It will be the task of this chapter to identify apt - qualitative and quantitative - indicators for the evaluation (sub-) criteria.

Table 4.1: Evaluation criteria

Main-criteria	Explanation	Sub-criteria
* Environmental effectiveness	Reduction of negative environmental impacts	** degree of goal accomplishment ** rate of goal accomplishment
		** change in acceptance of the environmentally preferable alternative ** change in consumer consciousness/behaviour ** change in producer consciousness/behaviour
* Economic efficiency	Relation between the degree of the realisation of environmental goals and the ensuing costs	** information costs ** implementation costs ** administrative costs
* Acceptance	Attitude of major economic and social groups towards the instrument	
* Flexibility	Extent to which an instrument can be adjusted to new circumstances	
* Side-effects on competing and/or alternative product groups	Influence the respective measure exerts on other products than the one it is directly intended to deal with	

This chapter is organised as follows: The evaluation of the German (4.2) and Italian (4.3) situation is subdivided along the battery policy objectives. For each objective the applied (and discussed) instruments are being assessed against the above mentioned criteria. Subsequently, main barriers for the "functioning" of the applied instrumental set will be summarised (4.4). Finally, the findings for Germany and Italy are being compared and some country-specific conclusions are drawn.

4.2 Germany

Section 2.6 summarises the major objectives of battery oriented environmental policy in general. As it is described in section 3.3 these objectives can also be found in the German policy on batteries and in the discussion about appropriate instruments. They are either part of "official" policy programmes or part of proposals from involved actors. The overall goal of reducing the emissions of hazardous substances into the environmental compartments air, water and soil can correspondingly be subdivided into the following objectives (see section 2.6):

1. Reduction of hazardous substances contained in cases where the respective substance is not necessary for the principal functioning of the battery system. (section 4.2.1 "Reduction of substances")

2. Substitution of hazardous substances contained in cases where the respective substance is necessary for principal functioning of the battery system. (section 4.2.2 "Substitution of battery systems")
3. Recollection and selective treatment (recycling) of batteries which still contain dangerous substances. (section 4.2.3 "Collection and recycling")
4. Overall reduction of battery use. (section 4.2.4 "Reduction of battery use")

The table below provides a mapping of the objectives and the instruments used or discussed in Germany, which are meant to realise these objectives. However, there is no statement made with respect to the weighing or obligation of the objectives mentioned.

Table 4.2: Mapping of objectives and instruments for German battery policy

Instrument	Objectives			
	reduction of substances	substitution of battery systems	collection and recycling	reduction of battery use
Direct regulatory instruments				
Prohibition	(x)			
Standards	(x)			
Obligation to take-back			x	
Economic instruments				
Deposit-refund			(x)	
Compulsory information instruments				
Compulsory labelling			x	
Voluntary information instruments				
Test reports			x	
Eco-label	x	x		x
Other voluntary labelling			x	
Recommendations[a)]		x		x
Voluntary agreements				
Self-commitments	x		x	
Consumer policy				
Consumer advice			x	x

[x] Instrument serves the objective.

[(...)] Objectives which are pursued by instruments that are not yet applied are put in brackets.

a) "Handbook of environmentally friendly public procurement"

In the following sections we will study the goal accomplishment along the four general objectives. The accomplishment is assessed by selected indicators which represent the criteria we have chosen for the evaluation (see section 4.1).

4.2.1 Reduction of substances

The reduction of hazardous substances in batteries in cases where the respective substance is not necessary for the principal functioning of the battery system represents a qualitative and technological objective which has to be pursued mainly by the battery producers. It mainly addresses the elimination of mercury from zinc-carbon and alkali-manganese batteries. Considerable progress has been made in this area. The following table provides an overview of the achievements according to different information sources.

Table 4.3: Mercury reduction in batteries

Battery system	European market [a)]	Germany I[b)]	Germany II[c)]
Alkali-manganese	1985: 1%[d)] 1986: 0.5% 1988: 0.3% 1990: <0.025%	1989: <0.1% 1992: 0%	1989: 0.011-0.25%
Zinc-carbon	1985: 0.01% 1990: 0-0.01%	1988: 0.008% 1990: 0%	1989: 0-0.006%

a) According to European Portable Battery Association, EPBA 1992 (former EUROPILE)
b) According to ZVEI, German association of battery producers.
c) According to "Ökotest" 7/89, German test magazine. 13 zinc-carbon batteries and 15 alkali-manganese which are available in Germany have been tested.
d) All figures in percentages by weight.

Despite some variance among the figures provided by the different sources a general trend can be observed, namely the

* almost complete elimination of mercury from alkali-manganese and zinc-carbon batteries.

These findings are confirmed by a study carried out in 1990 (Balzer 1991) which states that all tested alkali-manganese batteries exhibit a mercury content below 0.025% by weight and all tested zinc-carbon batteries are practically mercury free.

If one compares the realised reduction of the heavy metal content with the reduction targets formulated in the EC Battery Directive (ban on alkaline batteries containing more than 0.025% of mercury by weight as from 1993) and in the voluntary self-commitment in Germany (0.15% in 1988, 0.10% in 1990 and less than 0.1% in 1993) it becomes obvious that the agreed objectives have been achieved even faster than planned. This implies that the ecological effectiveness, i.e. the degree and the rate of goal accomplishment, is rather high with respect to the reduction of the mercury content in these battery systems. However, this fact might also suggest that the formulated objectives have been influenced by the battery manufacturers - at least in the case of the voluntary self-commitment - in such a way making them relatively easy to comply with.

The **instrument mix** applied to pursue the objective of a reduction of hazardous substances in the battery system consists mainly of three instruments:

* voluntary *self-commitment* which formulates concrete reduction targets,
* official *eco-label* which can be awarded to batteries that are low in hazardous substances and
* the planned *ban* on alkali-manganese batteries containing more than 0.025% of mercury by weight which is laid down in the draft version of the battery decree.[42]

Apart from these measures, there are other variables which may influence the reduction process and which are not due to government or industrial association initiatives. These variables may hamper or support the reduction of hazardous substances. In a survey carried out by IÖW in the framework of this case study, two battery manufacturers have stated that apart from the negative impacts on the environment caused by batteries, which is the main impetus of the initiatives listed above, the competition with other manufacturers and a change in the areas of application are main motives for the development of innovative battery systems. However, they also mention barriers such as high sales price of the innovative product and high development costs. In the following we will not assess the influence of these "unofficial" parameters but rather the contribution of the different "official" instruments to the goal accomplishment, taking also into account selected evaluation criteria such as efficiency, acceptability and flexibility.

In the case of German **voluntary self-commitment,** the high rate of goal-accomplishment suggests that the fixed targets (see section 3.3.2) have been easy to achieve. They have been surpassed by approximately three years. This implies that the innovation incentive of the covenant has been rather modest. This assessment is confirmed by our survey among different actors who similarly attach a minor importance to voluntary self-commitments with respect to their incentive function.

The agreement between industry and trade from 1988 has to be studied in connection with the modification of the German waste legislation in 1986, This has implemented the concept of extended producer responsibility by laying down the possibility of take-back obligations for certain products.[43] This modified legal basis has increased the "threatening potential" of the government, which is regarded a.o. as one of the success elements of voluntary self commitments (Hansjürgens 1994, p.38). Anticipating the possible consequences for their products, the

[42] This ban can also interpreted as a *product standard,* because it prescribes a certain composition of the battery.

[43] The German waste legislation has recently been changed again (see section 3.3.1). As from the year 1996 the Waste Management and Recycling Act is going to take the place of the 1986 Waste Act. It also contains the principle of extended producer responsibility.

battery manufacturers might have taken the initiative in order to avoid a more stringent obligatory regulation.

The battery manufacturers estimate that total costs caused by the self-commitment amount to DM 180 millions for the whole of Europe (ZVEI 1989)[44]. We are not able to assess the level or the distribution of these costs[45]. However, because of the fact that the producers have taken the initiative and because of the voluntary character of the agreement one can suggest that this instrument is relatively cost-efficient.

Voluntary self-commitments can be regarded as a more "soft" instrument compared to direct regulatory instruments such as prohibitions or standards. Hence, their acceptance should be quite high. However, the opinions towards this instrument vary. We carried out a survey among different actors (BMU, EPBA, AgV, BUND, BMWi, INFU)[46] asking for their acceptance of the instrument. In it we found that environmental and consumer organisations are more critical of this instrument (low to medium acceptance), whereas government and industry are more in favour of it (medium to high acceptance).

In case of the **eco-label** for low-mercury zinc-air batteries and for mercury- and cadmium-free lithium batteries the impact on the reduction target, which aims at reducing hazardous substances in batteries, can hardly be separated from the impact on the substitution target, which aims at substituting batteries containing hazardous substances by alternative battery systems. It is assumed here that eco-labelling, apart from its information function which is directed towards the consumers, represents an incentive for product innovation for the producers. This objective is contained, among others, in the German Blue Angel Programme which includes "acceleration of technological change" as one of its goals (UBA 1990, p. 4f).

However, it is not clear in how far the labelling of environmentally benign product alternatives actually realises this goal. Our survey among different interest groups has shown that the innovation incentive of the eco-label is assessed low to medium. This finding is confirmed by the statement of two battery manufacturers who also attach a medium innovation incentive to eco-labelling. Moreover, one has to take into account that the eco-label awards products which are already available. In this sense it cannot exert a direct incentive for the original innovators, i.e. those who have developed the product alternative, but only an indirect incentive for the imitators, i.e. those who adopt the technological novelty.

We will evaluate the German eco-label for the two battery systems (zinc-air and lithium) in greater detail in the following section 4.2.2 "Substitution of battery systems".

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[44] This figure does not only relate to the costs of product innovation, but also to the costs for the recollection and environmentally friendly treatment of collected batteries.

[45] One can assume that the producers will try to shift additional costs to the consumers by means of higher sales prices.

[46] The abbreviations are explained in the appendices.

The announced **prohibition** of alkali-manganese batteries which exceed a certain percentage of mercury content can be regarded as part of a governmental "threat and control"-policy. As already mentioned above, the anticipation of environmental policy measures might have been one major reason for agreeing upon the voluntary self-commitment on batteries. If this suggestion is true, the announcement of a ban on products which do not meet certain objectives can be regarded as rather effective. Since for Germany the target has been realised by means of a voluntary agreement it can also be regarded as relatively cost efficient. The acceptance of such a prohibition is dependent on the perceived urgency of the environmental problem and on the efforts necessary to be in keeping with the formulated goals. Our survey among relevant actors has shown that the degree of acceptability is high in case of environmental and consumer organisations and low in the case of industry. The former might favour the first perspective - urgency of the environmental problem - whereas the latter might favour the second perspective - necessary efforts.

Conclusions:

- The reduction of hazardous substances in batteries represents a product innovation. Product innovations are influenced by several instrumental and structural variables. The structural variables encompass supporting and impeding factors. Supporting factors are a.o. market competition and consumer behaviour (increased environmental consciousness), impeding factors are the higher sales price or the development costs.
- With "instrumental variables", the applied mix of product-policy instruments is meant. In this case it consists of the voluntary self-commitment, the eco-label and the announced prohibition on certain battery systems. Due to the existence of the structural parameters, their influence on the innovation process is difficult to separate.
- With respect to the reduction of the mercury content in zinc-carbon and alkali-manganese batteries the voluntary self-commitment has been successful. Meanwhile, these two battery systems are mercury-free. However, the high rate of goal accomplishment suggests that the formulated objectives were not very stringent.
- The contribution to the development of "green" batteries that comes from the eco-label, awarded to low mercury zinc-air batteries and mercury- and cadmium-free lithium batteries, appears to be quite modest.
- The announcement of restrictive product standards as they are contained in the draft version of the battery decree seems to be quite effective. It might be suggested that the anticipation of the ban contributed to the establishment of the self-commitment.
- The actors' assessment of the different instruments varies. Environmental and consumer organisations are more sceptical of voluntary measures, which are preferred by the industry. The acceptance of direct-regulatory instruments is higher with the former group.

4.2.2 Substitution of battery systems

The substitution of hazardous substances in batteries in cases where the respective substance is necessary for the principal functioning of the battery system also represents a qualitative and technological objective which is to be pursued by the manufacturers. In section 2.6 it is said that this objective encompasses:

* the substitution of nickel-cadmium batteries by cadmium-free nickel-hydrid batteries,
* the substitution of mercury-oxide cells by zinc-air cells,
* the promotion of cadmium- and mercury-free lithium cells.

As table 4.2 shows there are only two measures implemented which explicitly follow this objective, namely

* the *eco-label* for zinc-air and lithium batteries and
* the *recommendations* contained in the "Handbook of environmentally friendly public procurement".

In the following we will evaluate these instruments against the background of our evaluation criteria (cp. table 4.1).

The **German eco-label** "Blue Angel" is awarded to the low mercury zinc-air (since 1981) and to the mercury- and cadmium-free lithium batteries (since 1987). The market segment of these two battery systems is a small one. For the year 1993, their relative percentage as to the estimated amount of sales accounts for approximately 1%. However, these two battery systems show considerable growth rates varying between 14 % (for 1993) and 40% (for 1992). Wether these increasing sales figures can be put down to the eco-labelling of some of the products is difficult to ascertain. In the case of the zinc-air batteries it is known that they are sold at a high price, which may serve as an obstacle to increasing consumption.

Two aspects may provide some hints as to the effectiveness of the instrument eco-labelling. The first aspect relates to the **number of labelled products** and the second aspect to the **labelling criteria**.

Today the label for zinc-air batteries is applied to three products of three firms, the label for lithium batteries is applied to two products of two firms (RAL 1993). In 1988 the legal basis of awarding the label for zinc-air batteries, not the criteria themselves, has been changed, so that the applicators had to complete new treaties. At that time most of the applicators were suppliers of hearing aids.[47] Today the batteries, which are awarded with the eco-label, are

[47] Zinc-air batteries are not sold directly in the consumer market, but purchased by major applicators such as producers of hearing aids.

supplied by three battery manufacturers (Amperell, Rayovac, Varta). The number of applicators and the number of labelled products are summarised in table 4.4 below.

Table 4.4: Applicators and products for the German eco-label on batteries

Year[a)]	Zinc-air batteries		Lithium batteries	
	Number of applicators	Number of labelled products	Number of applicators	Number of labelled products
1988	29	32	1	1
1991	3	3	1	1
1993	3	3	2	2

a) Figures for the years before 1988 are not available.

The eco-label for **zinc-air** batteries is to promote the substitution of mercury oxide cells in the application area of hearing aids (RAL 1993, p.47). However, this substitution process has not been very succesful so far: the market share of zinc-air batteries accounts for 27% and that of mercury oxide cells for 73%.

Eight years after the introduction of the eco-label, a market survey has been conducted investigating the impact of the label on the use of zinc-air compared to mercury-oxide batteries for hearing-aids (G&I 1989). Based on a sample of 201 users of hearing-aids the study asked which battery system is being used and what the reasons have been for the application of the battery system. The study reveals that

* the majority of the applied battery systems belonged to the mercury-oxide type,
* the users of zinc-air batteries have mainly been informed by the vendors in the shops about the characteristics of this battery system,
* the reasons for applying a zinc-air instead of a mercury-oxide battery were partly based on environmental considerations (one fourth answered "environmentally friendly", about twenty percent "recommendation by the shop" and another twenty percent answered "longer life span").

The results of the study do not clearly assess the effect of the eco-label on the application of zinc-air batteries for hearing-aids. At least there might be some evidence that environmental aspects are being considered by the users. However, the advice given in the shops might be the most significant determining factor for their purchasing decision. Finally, one can suggest that the eco-label positively contributes to the level of environmental information supplied by vendors in shops.

The labelling of the non-rechargeable **lithium** battery is to promote substitution for mercury-oxide and alkali-manganese batteries in certain application areas. The labelling of the rechargeable version of this battery system is to promote the substitution of nickel-cadmium accumula-

tors in certain application areas (RAL 1993, p.97).[48] To date the market penetration of lithium batteries is very small. This might be due to several reasons, one of them certainly being the relatively high price (cp. section 2.3.1). How far labelling can counteract this development cannot be assessed. However, the fact that the "Blue Angel" for this battery system has been available for six years with only two products labelled to date, suggests that the impact of the eco-label is very modest. Correspondingly the innovation incentive might be quite low.[49]

The **labelling criteria** for zinc-air and lithium batteries have not been changed since adoption. The following table 4.5 gives an overview of the criteria and tries to assess their relationship to requirements that have been formulated in more or less "official" policy programmes (EC Battery Directive or voluntary self-commitment from 1988) or that correspond to usual quality standards. This assessment is to serve as an indicator for the stringency of the formulated criteria.

The table shows that:

* with regard to technological aspects, the labelled batteries have to represent a real product innovation in the sense that the percentage of hazardous substances is strongly reduced,
* with regard to the after-use-management, labelled lithium batteries have to be in keeping with "official" regulations, whereas labelled zinc-air batteries are subject to more stringent conditions.

[48] The possible application areas are restricted by the battery type: the non-rechargeable lithium battery is available in button and cylindrical type, the rechargeable version only in button type. Therefore it is usually not a suitable substitute for nickel-cadmium accumulators. Cp. section 2.2.1.

[49] According to information from Federal Environmental Agency, manufacturers' interest in the eco-label for lithium cells is small and even decreasing. It is suggested that more producers could apply for the label because their products would meet the criteria.

Table 4.5: Assessment of eco-labelling criteria for batteries

Criteria	Zinc-air	Lithium	Assessment
Mercury content < 60mg/Ah[a)]	x		+[b)]
Cadmium and mercury free		x	o [c)]
Other substances only up to a maximum of 50% of the maximum level formulated in Hazardous Substances Decree	x	x	+
Note for the user informing about separate recollection if the respective regulation (decree or voluntary agreement) has been passed	x	x	o
Treatment of the spent zinc-air battery in compliance with the regulation on recollection and recycling for mercury oxide cells.	x		+[d)]
Usual quality requirements	x	x	o

Explanation:

[x] Criterion is relevant for the respective battery system.

[+] Criterion is more stringent than "official" regulation.

[o] Criterion is in concordance with "official" regulation.

a) Assuming a maximum capacity of 0,25 Ah for zinc-air batteries the maximum admissible mercury content of this battery amounts to 15 mg in absolute terms.

b) The labelling prescriptions for batteries containing more than 25 mg of mercury and more than 0.025% of cadmium as it is laid down in the EC battery Directive are to serve as a benchmark. The compulsory labelling is to indicate the need for a separate collection and treatment.

c) Criterion is automatically fulfilled due to the battery construction.

d) The only "official" regulation available is the voluntary self-commitment. It does not lay down any rules for zinc-air batteries, because they are regarded as free from hazardous substances. It only formulates goals for batteries high in hazardous substances such as for the mercury oxide battery (voluntary take-back, recycling of the hazardous substances).

The flexibility of the instrument "eco-label" seems to be quite restricted in this case. Although the Federal Environmental Agency claims that the criteria are adapted to technical progress, the actual adoption might take place with at least some time lag. In the case of batteries, it is said that a label for the mercury- and cadmium-free nickel-hydrid battery has not been discussed so far, indicating that technological innovations are not anticipated.

Another important aspect which might limit the contribution of the eco-label on lithium batteries to the pursued substitution process, is the fact that rechargeable lithium batteries can only be used within narrow application areas; for example in computer memory back-ups .

Within our survey we asked relevant actors (AgV, BUND, BMWi, INFU) of the battery discussion in Germany for their acceptance of eco-labels. The variance among the answers was moderate. On average, the acceptance was medium to high. This assessment is confirmed by another survey which investigated the status and future necessities of product-oriented instruments, among others of the German eco-label (Rubik 1993, p.123). All actors considered in this survey (BDI, BfUb, BMU, BUND, DGB, UBA, VI) stated that the use of the eco-label should be intensified, herewith providing an additional hint on the relatively high acceptance of eco-labelling.

As already mentioned in section 3.3.2, the "Handbook of environmentally friendly public procurement", (of which about 10,000 copies are sold), provides some advice with regard to the **procurement of batteries**, including the preferred use of zinc-air and lithium batteries which can be awarded with the official eco-label.

In assessing the effectiveness of this measure, a study on behalf of the Federal Environmental Agency (UBA-Jahresbericht 1993, p.129 ff.) on environmentally sound public procurement of communities might be of interest. This report states that:

* office material, to which batteries may belong, is one of the most important sectors of "green" public procurement,
* if measures are taken, they are due to the individual initiatives of motivated personnel,
* initiatives of the Ministry of the Environment and the Federal Environmental Agency ("Handbook of environmentally friendly public procurement", "Blue Angel") are taken into account and have proven to be major information sources in the process of public purchase.

These findings suggest that, in general, the "Handbook of environmentally friendly public procurement" might be rather effective with regard to its information function. However, in the context of substituting environmentally harmful battery systems by less harmful alternatives, the ecological effectiveness is supposed to be quite restricted: On the one hand the significance of the subjective factor (individual motivation of purchasers) can hardly be evaluated; on the other hand, the assignment of batteries to the main item "office materials" may not be clear-cut. Despite these two confining aspects, the cost efficiency and acceptance of this instrument seems to be quite high.[50]

Conclusions:

- The goal of substituting environmentally harmful battery systems (nickel-cadmium, mercury-oxide) by their less harmful alternatives (nickel-hydrid, zinc-air and lithium) is far from being accomplished. The market share of the "greener" batteries is still very small.
- Only a few instruments have been introduced, exclusively belonging to the category of voluntary information instruments (eco-label and recommendations). Their acceptance among involved actors is medium to high.
- The eco-label for zinc-air and for lithium batteries is not wide spread among manufacturers; although these labels have been available for a couple of years. However, the

[50] A more detailed analysis of the instrument of public procurement is conducted by IVM in the framework of our project "Product policy in support of environmental policy". Cp. van der Grijp 1995.

application area of the labelled battery systems is sometimes restricted by their construction and can therefore necessarily not raise large substitution processes.

- From a technological point-of-view, the adopted labelling-criteria are relatively stringent compared to more or less "official" environmental policy requirements. However, it has not become clear how difficult it is for battery producers to comply with the criteria.
- The recommendations listed in the "Handbook of environmentally friendly public procurement" might be effective with respect to their information function. But, apart from its limited dissemination, it cannot be ascertained in how far they actually influence the purchasing behaviour.

4.2.3 Collection and recycling

The recollection and selective treatment (recycling) of spent batteries represents one of the major objectives of battery-oriented environmental policy occurring in Germany at present. Table 4.2 reveals that the applied instrument set is the most comprehensive, when compared with the measures taken for other goals. It encompasses the following instruments:

* *obligation to take-back* (laid down in the voluntary self-commitment and in the draft version of the battery decree),
* *deposit-refund schemes* (only discussed so far)
* *compulsory labelling* (as it is laid down in EC Directive 93/86/EEC, indicating separation of certain spent batteries from domestic waste)
* *test reports* (providing recommendations on separate collection),
* other *voluntary labelling* (ISO recycling symbol used in the voluntary self-commitment),
* *self-commitment* by battery manufacturers/importers and retailers,
* *consumer advice* (provided by environmental and consumer organisations).

Before studying the instrumental set in greater detail we will briefly discuss necessary conditions for a recycling of spent batteries (see the box 4.1 below).[51]

Box 4.1: Recycling of spent batteries

Recycling cannot be made obligatory for the after-use-management of batteries. There are several different aspects that influence the effectiveness and efficiency of the recycling processes and that make it a useful alternative to landfilling and incineration. The most important are the following (Österreichisches Ökologie Institut 1991, p.38):

* sufficient amount of recyclable batteries,
* high content of recyclable materials contained,
* availability of a recollection scheme and realisation of high recovery rates,
* availability of a recycling technology,
* re-usability and sufficient market-price of recycled secondary materials,
* economic efficiency of the recycling process,
* energy consumption of the recycling process.

[51] The environmental relevance of recycling and the different recycling processes have already been depicted in section 2.4.3.

The first condition is dependent on the consumption of batteries and on the functioning of the recollection scheme. The second condition is fulfilled for those battery systems to which the recollection is mainly directed, namely nickel-cadmium accumulators and mercury-oxide button cells. By means of the voluntary self-commitment between producers and traders, a recollection scheme has been installed. High recovery rates are to be ensured - on a voluntary basis - by information of retailers and consumers and by specific labelling prescriptions. Recycling technologies are available for mercury oxide button cells (NQR in Lübeck) and for nickel-cadmium accumulators (the German recycling company NIREC[52], Rodgau, in collaboration with the company SNAM/SAVAM in France). In Switzerland there are recycling plants for battery mixes. The materials which can be recycled are basically silver, mercury, iron and zinc. The price for secondary silver is quite high, the prices for recycled mercury and zinc are decreasing and the price for iron unchanged. According to information from NIREC, all other materials included in nickel-cadmium batteries are also recycled. Available data on cost aspects and energy consumption of battery recycling is already mentioned in section 2.4.3.

The German Waste Act places special emphasis on the economic aspects of recycling (Art. 3 (2) AbfG). It says that waste recycling has priority to other alternative ways of disposal, when

* recycling is technically possible,
* ensuing costs are not unreasonable compared to the costs of alternative ways of disposal,
* markets for the secondary materials exist.[53]

We will first evaluate the actual measures which are taken (see section 4.2.3.1)- mainly the voluntary self-commitment - and then summarise the discussion about other instruments which are not yet applied, especially deposit-refund schemes (see section 4.2.3.2). Finally, we will draw some conclusions from the findings of the two preceding sections (see section 4.2.3.3).

4.2.3.1 Applied instruments for recollection

First, this section summarises the major findings of the studies which have investigated the collection of used batteries in Germany ("Recollection of spent batteries"). Then it focuses on instruments to support the collection scheme, such as labelling prescriptions (sub-section b)) and consumer advice (sub-section c)).

[52] NIREC is an authorized collection company for spent nickel-cadmium accumulators. The actual recycling, however, takes place at SNAM/SAVAM.

[53] These conditions are also included in the recent amendment of the Waste Act, namely in the Art. 5 (4) KrW-/AbfG.

a) Recollection of spent batteries

Besides the promotion of a more general reduction of hazardous substances in batteries and the gradual substitution of environmentally harmful battery systems by less harmful alternatives the **voluntary self-commitment** by industry and trade formulates targets as to the recollection and recycling of certain spent batteries. The targets are the following[54]:

* retailers and producers commit themselves to take back the labelled batteries[55],
* the producers have to take care of the recycling of hazardous substances,
* traders and producers are responsible for informing the consumers on these issues.

In Germany, several studies have been conducted which attempt to assess the effectiveness of the agreement (Verbraucherzentrale Hamburg 1989, test 7/90, Balzer 1991, Baumann et.al. 1993). Another study from 1993 aims at describing the disposal of spent equipment batteries in Germany in quantitative terms (LfU 1994). The studies will be briefly summarised in the following paragraphs.

The "Verbraucherzentrale" (consumer advisory centre) in Hamburg carried out the first inquiry on this subject in 1989; one year after the establishment of the self-commitment (Verbraucherzentrale Hamburg 1989). They made a written survey by means of questionnaires among 36 retailers and a market inquiry at 29 retail shops. The following results are provided:

* not all retailers have taken back spent batteries,
* only six of 29 shops pointed to the possibility of taking-back used batteries in their shops,
* most batteries were not labelled with the recycling symbol,
* a separation of spent batteries according to the substances contained was obviously carried out only in two of 29 shops.

The findings reveal that the trade is one of the major bottlenecks within the recollection chain. Moreover, approximately one year after the voluntary self-commitment the battery manufacturers have not succeeded in realising the agreed labelling prescriptions sufficiently.

The Foundation "Warentest" conducted a similar survey (test 7/90). Their sample consisted of 152 retail shops in Berlin which have been visited. Unfortunately the magazine reports no quantitative results, but some hints as to the problems with recollection are provided:

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[54] Cp. section 3.3.2.

[55] Nickel-cadmium accumulators, starter batteries, mercuric button cells, alkali-manganese batteries with more than 0.1% of mercury by weight.

* The sellers were insufficiently informed (about what to do with the batteries after having collected them).
* Special containers for the collection were rarely observed.
* If collection took place, then it was in a rather undifferentiated way.
* Purchased batteries were either not labelled at all or the label was too small and not clearly visible. References to the content of hazardous substances and to the potential environmental dangers were not made.

These indicate once again that traders lacking information is one major obstacle to an effective recollection, together with an insufficient labelling compared to the arrangements which have been laid down in the self-commitment.

The most extensive study on the recollection of spent batteries carried out in 1990, two years after the self-commitment (Balzer 1991). 1,879 shops were visited and shopkeepers interviewed in all the Länder of West Germany. The sample consisted of, among others, shops for electronic and electric equipment, for photographic equipment, for toys, do-it-yourselfer markets and drugstores. The main findings can be summarised in the following way:

* The *actual knowledge* about the obligation to take-back amounts to only 60%, whereas
* the *willingness* to take back used batteries accounts for 88%.
* Informing customers in the shops is passive, rather than active (only when being asked, do the sellers supply the respective information).
* Collection of spent batteries at the retailers happens in an undifferentiated way. A sorting according to battery types does not take place.
* Retail trade estimates the recovery rates at 25%, on average.
* Kind and scope of battery labelling is insufficient.

This study also confirms that the trade is one of the major bottlenecks of an effective after-use-management of batteries. Despite a relatively high willingness to take spent batteries back, the actual recollection at the point of sale hardly works, due to insufficient information and lacking efforts in sorting.

However, consumers are in charge of bringing back the batteries and obviously, considering the moderate recovery rates, they are either unwilling or unable to take this responsibility. The inability might be rendered even more difficult by the fact that the labelling of the batteries with the ISO recycling symbol turns out to be either non existent or not sufficient.

Recently, a research project on behalf of the Federal Environmental Agency has studied the recovery rates for nickel-cadmium accumulators and mercury oxide button cells. It is being

published by the ZVEI, the German association of battery manufacturers and importers. (Baumann et.al. 1993)

In the case of **nickel-cadmium accumulators** the figures are essentially influenced by the following assumptions:

* are accumulators which are built-in included or excluded,
* which life span is assumed.

In 1983, 400 t of sealed nickel-cadmium accumulators were sold, 30% of them (120 t) permanently built-in. Excluding this 120 t and assuming a life span of seven years, the ZVEI calculates a recovery rate of 50% for the year 1990. If the built-in accumulators are taken into account and a life span of five years[56] is assumed, the recovery rate drops to 24%.

Recovery rates for the **mercury-oxide button cell** amount to 70% for the year 1990 according to the ZVEI. Baumann et.al. report that recollected button cells are usually not separated into mercury-oxide and other non-rechargeable button cells and, moreover, they are mixed with rechargeable button cells. Accordingly, they calculate a more realistic estimate which amounts to approximately 36%.

In addition, the analysis of recollected button cells by Baumann et.al. provides figures as to the recovery of **other button cells** which also contain small amounts of mercury. These figures must be considered very carefully, because they are not based on a representative sample. In the year 1990, approximately 15% of zinc-silver oxide, 22% of alkali-manganese and 30% of zinc-air button cells were collected. The ZVEI provides no data with respect to these three battery systems.

This means that the figures with respect to the collection of spent batteries, which are being published from the producers' side, obviously overestimate the actual rates, which on average, do not exceed 30%.

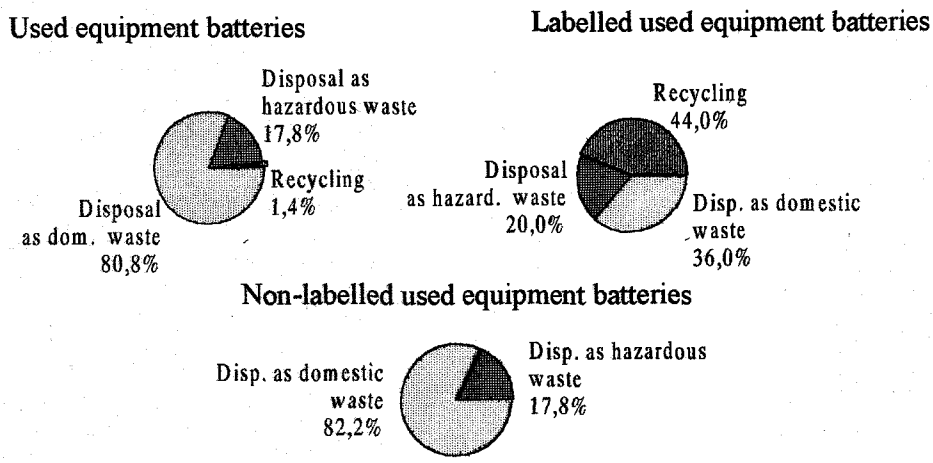
Another study tries to describe the disposal of spent batteries in Germany in quantitative terms (LfU 1994). The figures offered here must be regarded as rough estimates because their calculation is based on several more or less robust assumptions. However, the findings (see below) also reveal that the proper after-use-management of batteries is not yet working effectively.

The figure 4.1 below provides an overview of the relative percentages of the different alternative ways of disposal, namely either recycling or disposal as hazardous waste or disposal along with domestic waste. The authors of the study subdivide the group of all used equipment

[56] Baumann et.al. say that this is even a very conservative estimate. Usually the life span might amount only to three to four years.(Baumann et.al. 1993, p.84)

batteries into the two subgroups "labelled" and "non-labelled batteries".[57] Moreover, they assume that used batteries are recollected via trade or central/decentral/mobile collection. Solely in the case of non-labelled batteries it is assumed that the facilities for recollection are confined to central/decentral/mobile collection.[58]

Figure 4.1: Breakdown of used batteries according to their disposal for the year 1992 (LfU 1994)



With regard to the arrangements which have been laid down in the voluntary self-commitment by the battery industry and the trade in Germany the sub-group "labelled used equipment batteries" is the most interesting one. The two actors have committed themselves to organise the recollection of these batteries only. It seems then that, according to this study,

* still more than one third of *labelled* batteries are not collected separately, but discarded along with domestic waste instead, i.e. that this part is actually not covered by the voluntary take-back system.

In general, the studies investigating the recollection of used batteries have revealed that the take-back system which is introduced for certain battery systems by means of the voluntary self commitment by industry and trade does not realise high recovery rates. Maximum figures vary from 20 to 30 % for the different systems, excluding silver-oxide button cells (recovery rate 80%). In this regard the covenant must be considered as a failure. Its ecological effectiveness and also its economic efficiency must be doubted. One main reason for the insufficient effectiveness of the covenant is obviously information deficit - both at the level of the traders and consumers.

[57] Labelling in accordance with the prescriptions contained in the voluntary self-agreement, see section 3.3.2.

[58] In the category of "non-labelled batteries" the authors also include a mix of labelled and non-labelled used batteries. Therefore the subdivision must be regarded as a more theoretical one.

Moreover, the findings seem to justify the more critical attitude of environmental and consumer organisations (cp. section 4.2.1) towards the self-commitment as a tool to ensure an extended producer responsibility.

b) Labelling of batteries

The consumers are to be informed about the take-back obligation of traders and manufacturers by means of a label on the battery case and/or packaging of the battery. The label consists of the ISO recycling symbol 7000-Reg. N. 1135.[59] It represents a "positive" label indicating that the respective battery can/should be recycled. The Foundation "Warentest" criticises this symbol with the following arguments (test 12/88, p.68):

* the symbol is meaningless and misleading because a complete recycling of batteries and the materials included is not yet possible in Germany,
* hints as to the content of heavy metals are missing.

Moreover, the actual marking with this symbol turns out to be quite ineffective because the symbols are too small and hardly visible. (Baumann et.al. 1993, p. 98; test 7/90, p.48)

The first aspect - misleading information - is also included in another report (RSU 1991, p.234). This states that the misleading interpretation of the ISO recycling symbol might even curb the credibility of official eco-labels.

In contrast to the more positive connotations of the ISO recycling symbol, the symbol which is proposed in the EC Battery Directive (crossed-out dustbin[60]) more clearly suggests that the labelled battery must not be disposed of along with the household waste, but be separated from it. This label indicates in a more negative way that labelled battery systems are harmful to the environment when they end up in landfills for domestic waste or in incineration plants.

The proposal to mark batteries in different colours according to the heavy metals they contain (cadmium or mercury) might be difficult to implement because some colours are already used for marketing purposes (e.g. "*Green* line") and because button cells are too small to be coloured in a visible way. (Baumann et.al. 1993, p.98) The last aspect implies a more general problem: in those cases where the battery is too small to wear any visible symbols they have to be placed on the packaging. However, usually the packaging will not be available anymore when the battery is spent.

Despite these actual problems of voluntary/obligatory labelling in the context of the battery issue, the assessment of the instrument "labelling" according to involved actors is rather good. Our survey among relevant actors (BMU, EPBA, AgV, BUND, BMWi, INFU) has shown that

[59] Cp. Annex V.
[60] Cp. Annex IV.

the economic efficiency - the relationship between the benefits and the costs - is assessed medium to high. Also the acceptance of this instrument turns out to be medium to high. The discrepancy between the assessments stated in the survey and the practical problems connected with the labelling of batteries indicate that the evaluation of this instrument strongly depends on the specific realisation of the labelling prescriptions, such as design and size of the symbol, connotations etc..[61]

c) Other information instruments

Apart from voluntary self-commitment with a take-back obligation and labelling prescriptions for certain battery systems, there are additional measures in the context of battery recollection and recycling which aim to inform about on need to separately collect and properly recycle spent batteries, namely

* the *product tests* of the Foundation "Warentest" and
* the *consumer advisory centres*.

Table 3.6 in section 3.3.2 provides an overview of **product tests** dealing either with batteries as such or with battery powered appliances. The potential negative impacts of disposal of certain battery systems are mentioned in each of them. However, the availability of notes for the user on the proper after-use-management of spent batteries explicitly becomes a criterion for the product assessment only from the year 1990. Since the Foundation "Warentest" is well known and each month more than 740,000 magazines are sold, its effectiveness with regard to an improvement of consumer information is assessed quite high. Its relatively wide dissemination causes direct effects on the market as several empirical studies have proved (Lösenbeck/Reiter 1992, Raffée/Fritz 1985, Hilger et.al. 1984). Fritz et.al. (1984, p.91) report that in the case of non-durable goods between 7 and 17 % of the consumers use the test reports for their purchasing decision, in the case of durable goods the respective figure is between 20 and 41 %. Moreover, the study shows (Fritz et.al. 1984, p.61) that the test results influence the turnover of the tested products. If the product is assessed relatively positive sales can increase up to 23 % for a period of six months, whereas in case of a negative result they can decrease by 35 % for a period of seven months. However, one must mention that these figures have not been broken down to the product group of batteries, so that they merely describe possible market reactions. Nevertheless, the information and recommendations provided by the Foundation "Warentest" might at least influence the behaviour of some of the consumers.

Consumer advisory centres also inform their clients about the proper treatment of spent batteries by means of leaflets and consumer exhibitions (see section 3.3.2, table 3.7). They are

[61] In the survey we asked for the assessment of the instrument "obligatory labelling" as such and made no specifications as to the design of the label.

in favour of a general take-back obligation covering *all* used batteries in order to make the collection easier for the consumers who do not have to distinguish anymore between "good" used batteries, i.e. those which can be discarded along with the household waste, and "bad" batteries, i.e. those which have to be collected separately. In addition, the consumer advisory centres serve as a multiplicator for the findings of the product tests because these are available at the centres. In this sense, they can strengthen the influence of the product tests on the purchasing behaviour.

The acceptance of product tests and consumer advisory centres varies considerably between the actors included in our survey. Environmental and consumer organisations attach a high acceptance to both instruments, whereas the battery industry is more sceptical, especially in the case of product tests. The economic efficiency of the instruments is assessed differently. For advisory centres it is medium in most cases and for product tests it varies from very good to very bad.

4.2.3.2 Discussed instruments for recollection

At first the assessment of the relevant actors with respect to an obligatory take-back system, which is based on an official decree instead of a voluntary agreement, is summarised. Then the idea of a deposit-refund system for improving the recovery rates of used batteries is depicted briefly. Finally other proposals for economic instruments are described which are not explicitly discussed in Germany but might be of importance for future discussion.

a) Obligatory take-back system

The voluntary self-commitment between battery manufacturers and importers and the trade lays down a voluntary take-back system[62], whereas the planned battery decree intends to install an obligatory system which would oblige every producer or importer of certain batteries to take back the batteries after use.[63] The actual organisation of the take-back system would be quite similar. However, the first draft version in 1992 covered *all* kinds of equipment batteries, not only those high in hazardous substances.

In our survey among relevant actors we asked for their assessment of such an obligatory take-back system.[64] The innovation incentive emanating from such an obligatory system is assessed relatively high on average, as well as its economic efficiency. However, acceptance varies

[62] This voluntary system contains a take back *obligation,* but not a legal one.

[63] The German battery decree is to transpose the EC Battery Directive 91/157/EEC in combination with its amendment 93/86/EEC into national legislation (see sections 3.2 and 3.3). The Member States had to comply with the Directive before December, 31st 1993. Germany has not done so so far.

[64] We did not specify the question with regard to the scope of batteries the take-back system is to encompass, i.e. it was not distinguished between a system covering *all* kinds of equipment batteries and a system covering only the environmentally harmful ones.

strongly: trade and industry reject an obligatory system, whereas environmental and consumer organisations and governmental authorities support it.

The discussion held in Germany about the introduction of an obligatory take-back system for used batteries mainly focuses on the scope of batteries which should be covered by the system. The more environment-oriented interest parties favour a solution covering all kinds of batteries; whereas industry wants to distinguish between harmful and non-harmful battery systems. From their point-of-view, only the first group should be recollected. The other group should be allowed to be discarded along with the domestic solid waste. These opposite standpoints, among other problems, have resulted in the great time delay in the transposition of the EC battery Directive into national legislation in Germany.

b) Deposit refund scheme

The most often discussed instrument in the context of battery recollection is that of deposit-refunds. In Germany, they are frequently promoted especially by consumer and environmental organisations (BUND 1989, AgV 1992, AgV 1993). These organisations claim that only a real economic incentive; namely a deposit on certain batteries - at least on nickel-cadmium accumulators and mercury oxide button cells -, will succeed in increasing recovery rates sufficiently. They call for a graded deposit related to the chemical substances contained and the life span of the battery and support a Europe wide deposit-refund scheme. When discussing this instrument for battery recollection in greater detail, the following aspects are of importance:

* scope and level of the deposit,
* organisation of the deposit-refund scheme,
* cost aspects,
* main criticism,
* assessment of relevant actors.

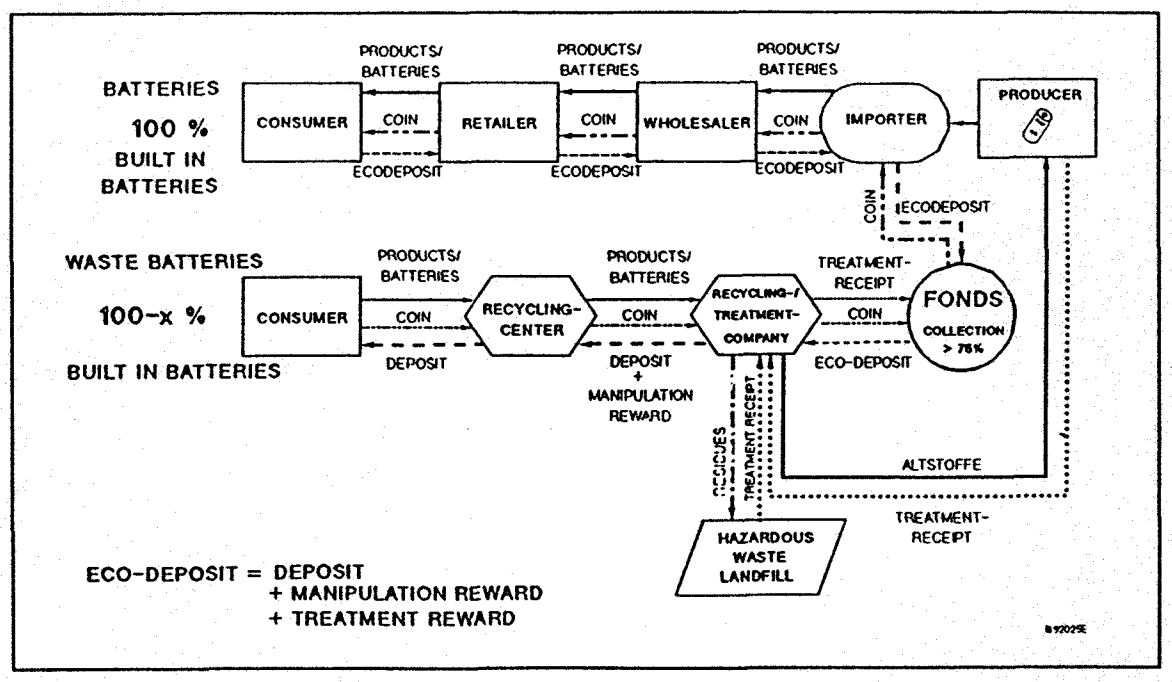
Deposit refund schemes are preponderantly proposed for batteries which are high in hazardous substances such as nickel-cadmium accumulators and mercury-oxide button cells. The level of the deposit is one decisive determinant of its effectiveness. A deposit which is too low represents no incentive for bringing back the used battery. A deposit which is too high could cause deceit (producing and bringing back battery "dummies") and - in the case of an imposition on nickel-cadmium accumulators only - could promote a substitution of rechargeable by non-rechargeable batteries. The following table summarises the proposals for the level of the deposit in Germany.

Table 4.6: Proposals for a deposit on batteries

Source	Proposal
RSU 1990	DM 5,- on batteries containing cadmium, DM 10,- on mercury-oxide button cells
Bätcher et.al. 1992	Solely on nickel-cadmium accumulators: DM 1,- to DM 5,- for batteries <150g and DM 5,- to DM 10,- for batteries >150g
BUND 1989	20% to 50% of the selling price. Priority battery systems: nickel-cadmium and lead accumulators, mercury-oxide button cells.

A concrete organisational scheme for realisation of a deposit-refund scheme is not explained very often. The most elaborate model is that of the Austrian Federal Environmental Agency which is shown in the figure below. It encompasses single batteries and built-in batteries as well. The actual amount of the deposit which is paid out to the consumer is supplemented by an additional amount which is to cover the costs of the trading companies ("manipulation") and another additional amount for the treatment of the waste batteries ("treatment"). In this sense, the "eco-deposit" model can be regarded as a deposit-refund scheme including an additional disposal charge.

Figure 4.2: The "eco deposit" model (Mayr 1989)



Bätcher et.al. (1992, p.165) have elaborated a similar model. The manufacturer/importer of batteries imposes a deposit on his client, i.e. wholesaler or producer of electric appliances. This deposit is passed on to a central institution ("Fonds") which runs several collecting enterprises. The wholesaler/producer of electric appliances shifts the deposit to his client, i.e. the retail trade who again shifts the deposit to the consumer. When the used battery is delivered to any retailer the consumer will receive a refund. The retailer gives the used battery to one of the collection enterprises and is refunded by the fund. This fund sells the battery scrap to a recycling company.

Such a system raises costs for those who participate. The point of recollection, i.e. usually the retailer, has to spend time taking back the used batteries and sending them to the collection enterprise, which has to sort and count the batteries. Moreover, costs result from the calculation of the amount of the deposit between the "Fonds" and the manufacturers/importers. The battery consumer is the ultimate deposit payer and has to bear the costs for the tying up of financial capital during the life span of the battery.

The criticism which has been formulated with regard to the introduction of a deposit-refund scheme on batteries can be summarised as follows:

* A deposit will not lead to the collection of the batteries which are already in circulation (Jorgensen 1989, p.34).
* A deposit should not be introduced on a national level because countries are strongly linked by import and export of batteries. Moreover, a nation wide deposit could be an incentive for people from neighbouring countries to bring back their used batteries in this country and thereby receiving a deposit they have not funded before (Hiller et.al. 1992, p.35).
* A high deposit could be an incentive for deceit by producing and bringing back battery "dummies" (Hiller et.al. 1992, p.36).
* The pre-financing of the deposit ties up financial capital in the long term which is not at the disposal for consumption during this period of time (Deutscher Bundestag 1994, p.11).

There is no experience with a deposit on batteries. Our investigation has shown that no EU Member State has introduced such a scheme. An experiment on the Danish island Bornholm (TEM 1990), which was based on a simulation of a deposit system, has revealed a general preparedness among consumers and shopkeepers to accept a deposit and moreover, that for the administration in the shops some compensation is necessary in order to guarantee committed participation.

The assessment of the actors who participated in our survey (BMU, UBA, EPBA, AgV, BUND, BMWi, INFU) of the instrument "obligatory deposit refund" vary. The European Portable Battery Association attaches a very low innovation incentive and very low economic efficiency to this instrument, although two battery manufacturers who answered our questionnaires, saw at least a high innovation incentive emerging from it. This positive judgement is supported by environmental and consumer organisations and by representatives from the Environmental Ministry and Federal Environmental Agency. The acceptability of deposit refund schemes is assessed controversially as well. Industry rejects this instrument, whereas environmental and consumer organisations are in favour of it.

c) Other economic incentives for recollection

The proposals listed below are entirely directed to the collection of nickel-cadmium accumulators. However, one could imagine applying these instruments to other battery systems as well.

Jorgensen (1989) proposes a **rebate scheme** combined with a **disposal charge**: the consumer obtains a rebate when buying a new nickel-cadmium battery, provided that he delivers the used battery at the same time. The scheme is to be financed by charges collected in connection with the sale of these batteries.

The Swedish Environmental Protection Agency (1991) similarly calls for the introduction of a **return bounty** by which the state should repurchase used batteries. It would be payable even on a battery on which the purchaser has not paid any charge at all. The system is to be funded by a charge on newly sold nickel-cadmium accumulators. The authors assume that the total of the charges exceeds the total of the paid return bounties.

The effects of a return premium on used batteries were experienced in the small Swedish town of Östhammar during the year 1985 (TEM 1990). The shopkeepers involved stated that the inconvenience with this system was only marginally greater than with the voluntary take-back scheme. The problem of incoming batteries from other municipalities has been mitigated by laying down that large numbers of returned batteries should be referred to municipal authorities. The achieved recovery rates were relatively high, namely 100 % for alkali-manganese batteries and 50 % for zinc-carbon batteries.

Macauley et.al. (1992) have elaborated a **modified deposit refund scheme**. A charge is imposed on the manufacturers of batteries and the revenues from these charges are paid out to collection enterprises in dependence on the number of batteries collected and on a verification of their appropriate disposal. The collection enterprises would decide then how best to ensure the return of the used nickel-cadmium batteries, e.g. compensate retail stores or municipal collectors. The profit motive should drive the search for the least-cost means of collection.

4.2.3.3 Conclusions

The following conclusions summarise the main findings of the preceding sections.

- The recollection and selective treatment (recycling) of spent batteries can either cover all kinds of batteries or can be confined to certain battery systems which are high in hazardous substances, i.e. nickel-cadmium and lead accumulators, mercury-oxide button cells, alkali-manganese batteries with more than 0.1 % of mercury by weight. In Germany the voluntary self-commitment between producers and trade favours the latter alternative, whereas the draft version of the battery decree from 1992 prefers the first alternative.

- Different studies have proven that realised recovery rates in Germany do not exceed 30 % on average. In this sense, goal-accomplishment must be regarded as far from being realised.
- The instrumental set that is in force in Germany consists mainly of the "self-obliging" voluntary take-back system installed on the basis of the self-commitment in 1988 and included labelling prescriptions which are to inform the consumers about the recollection and recycling. Additionally, there are information instruments such as product tests and consumer advisory centres. An obligatory take-back system has not yet been introduced.
- One of the major bottlenecks within the redistribution chain for spent batteries is obviously the trade. Retailers who have committed themselves to take back used batteries are insufficiently informed and do not support the recollection at the point-of-sale.
- However, consumers also contribute to the moderate recovery rates because they are the ones to bring back the used batteries. Apparently, they are not sufficiently informed. Moreover, it might be suggested that the incentive for recollection is too low.
- Information instruments, such as labels indicating the recycling of the collected batteries or recommendations provided by product tests and consumer advisory centres, enjoy a relative high acceptance, but obviously are not yet effective enough. In the case of labelling the effectiveness might strongly depend on the actual design and size of the label.
- Economic instruments which serve either the creation of an incentive for bringing back used batteries (e.g. deposit-refund schemes or return premiums) or the financing of a more environmentally benign after-use management (e.g. disposal charges) are not a part of battery-oriented environmental policy in Germany. In particular deposit-refund systems are very controversial.

4.2.4 Reduction of the battery use

This section is subdivided into two parts. The first part discusses the substitution of non-rechargeable by rechargeable batteries which aims at the reduction of the total amount of non-rechargeables. The second part assesses other measures which aim at reducing the overall use of batteries.

The substitution of non-rechargeable primary batteries by rechargeable secondary batteries is to avoid the use of mercury batteries and to reduce the overall material consumption[65]. However, one must consider that this substitution can only be beneficial for the environment when the recovery of the used cadmium is ensured (Enquête-Kommission 1993, p.130).

[65] Depending on its life span, a rechageable battery can substitute 500 to 1,000 non-rechargeable batteries.

The only "instrument" explicitly serving this purpose is the recommendation included in the **"Handbook of environmentally friendly public procurement"**. It says that the use of rechargeable nickel-cadmium accumulators should be preferred when their separate disposal is ensured. The suggested effectiveness of this measure has already been discussed in section 4.2.2, the main finding being the effectiveness with regard to its information function. However, other variables such as the small dissemination of the handbook and "personal factors" within public procurement seem to dominate this positive aspect.

Quantified "substitution quotas" which could provide a hint as to the effectiveness of this strategy can rarely be found. Figures, that can only serve as a rough estimate, assume that only one nickel-cadmium battery in ten replaces a general-purpose non-rechargeable battery (International Management April 1994, p.53). If this is true, one can conclude that the reduction of the overall (non-rechargeable) battery use is only marginally encouraged by a substitution by rechargeables.

The reduction of the overall use of batteries is explicitly supported by three measures (see table 4.2):

* *recommendation* included in the "Handbook of environmentally friendly public procurement",
* German *eco-label* on solar powered and mechanical appliances,
* *consumer advice* offered by environmental and consumer organisations.

Since the recommendations contained in the "Handbook of environmentally friendly public procurement" are closely connected with the German "Blue Angel" scheme, and since the effectiveness of the manual has already been discussed (see section 4.4.2), we will confine ourselves to the assessment of the last two instruments.

The **German eco label "Blue Angel"** which is awarded to solar powered appliances (watches and calculators) and to mechanical watches has been described in section 3.3.2. The decisive criterion for the award of the label is the fact that these appliances are "without batteries". The criteria have not been changed since they have been passed in the year 1987. The table 4.7 below provides an overview of the number of applicators of the label and the number of labelled products.

Table 4.7: Applicators and products for the German eco-label on solar-powered products and mechanical watches (RAL 1988, 1991, 1993)

	Solar-powered products and mechanical watches	
Year	Number of applicators	Number of labelled products
1988	3	10
1991	6	17
1993	8	29

The table reveals that both the number of applicators and the number of labelled products has strongly increased over the last couple of years. This development suggests a high acceptance of the label among applicators.

According to information from a producer of scientific calculators, (who has applied the label since 1988), the eco-label is to promote the turnover of the respective product, although its direct contribution to the development of the sales figures cannot be assigned. It is said that the innovation incentive with respect to the development of solar powered calculators is very modest. This would be confirmed by the fact that the main competitor in the same market segment supplies solar powered calculators without the eco-label. A producer of mechanical watches, whose products are wearing the eco-label, stresses the marketing effect of the labelling which might have contributed to rising sales figures of the labelled product.

However, the effectiveness of the eco-label for solar-powered calculators and mechanical watches with regard to sales promotion might be impeded by the fact that these products are on average more expensive than their battery powered alternative. The price differential for mechanical watches, for example, amounts to 20 % of the sales price (Fachinformationszentrum Karlsruhe 1992).[66]

The consulting of **consumer and environmental advisory centres** contains statements as to the reduction of the overall use of batteries (see section 3.3.2, table 3.7). They call for the preferable use of mains-operated appliances instead, where possible. The product tests of the Foundation "Warentest", available at the consumer advisory centres, contain one example where the possible alternative to an electrical shaver is wet shaving. This proposal represents an example of a substitute for a battery powered product which completely avoids electric power.

However, the effectiveness of these information measures must be regarded as very modest.

[66] However, the price differential is compensated by the fact that batteries do not have to purchased during the life span of the product.

Conclusions:

- The reduction of the overall battery use in order to diminish the amount of hazardous substances, especially toxic heavy metals, entering the "technosphere" obviously represents only a peripheral objective of battery-related environmental policy in Germany. The only hint as to the "official" character of this goal is the availability of an eco-label for solar-powered appliances and mechanical watches.
- The objective consists of two "sub-objectives": substitution of non-rechargeable batteries by rechargeables and the substitution of battery powered appliances by mains operated alternatives or even by products which do not need electrical power at all. The usefulness of the first sub-objective requires an effective recollection and recycling system for the rechargeable batteries, mostly nickel-cadmium accumulators.
- The objective "reduction of the overall battery use" is very far from being realised. Reasons might be: it is of minor or almost no importance in "official" policy programmes, the recollection and recycling system for rechargeables is not yet feasible and the applied instrumental set contains only a few "soft" information instruments (eco-label, consumer advice).
- The applicability of the eco-label is confined to small product groups. Therefore considerable changes in the volume of sold batteries cannot be expected.

4.3 Italy

4.3.1 Reduction and substitution of substances

The reduction and substitution of hazardous substances in batteries obviously represents solely a peripheral objective of battery-oriented environmental policy in Italy. However, one can suggest that the Italian waste legislation which classifies spent batteries as dangerous waste (see section 3.4.1) exerts some influence on the application of heavy metals in the battery manufacturing.

One example might be, that industry has introduced the "mercury cadmium free" batteries in the major segment of the market. Manufacturers and importers are strongly pushing these products and are lobbying for treating the "mercury-cadmium free" batteries as standard urban solid wastes.

4.3.2 Collection and recycling

In Italy, the collection of spent batteries seems to be the major objective of environmental policy dealing with the after-use-management of batteries. As mentioned in section 3.4.1 batteries are stored in temporary deposits or given to private companies who take them abroad to special recycling plants. In Italy there are no possibilities for recycling of used equipment batteries.

The last official report of the Minister for the environment in 1992 states that only some Italian Regions (Lombardia, Veneto, Friuli Venezia Giulia, Emilia Romagna and Toscana) offer the service of separate recollection with a limited effectiveness. In the most active towns the separate collection amounted to 50-80 g per inhabitant which equals 20-30 % of the total consumption for the year 1989.

An independent study carried out by "Cooperativa Ecologia" included in a more comprehensive report on the Urban Solid Waste Disposal ("Piano Smaltimento dei Rifiuti Solidi Urbani") for the "Provincia di Milano" reveals that in 1992 all the municipalities of the Province of Milan were collecting about 20 % of the consumed quantity.

Even if the official statistical data is quite old, it can be estimated that in 1993 only 30 % of local municipalities in Italy have activated the separate collection of spent batteries.

One can conclude from data that the existing take-back obligation is not effective, due to lack of enforcement.

4.3.3 Reduction of the battery use

In Italy there is neither any environmental policy measure in force nor being discussed which deals with the objective of reducing the overall use of batteries. It has only been reported that environmental organisations in Italy are in favour of the application of rechargeable batteries instead of non-rechargeable batteries. However, this "semi-official" recommendation cannot be expected to contribute to a decreasing consumption of non-rechargeable batteries.

4.3.4 Assessment of involved actors

Since battery-oriented environmental policy is not yet based on a comprehensive set of instruments in Italy, we had to focus, besides the evaluation of existing measures, on an assessment by relevant actors of possible product policy instruments. In the following we will describe their assessment in greater detail.

a) Industry

In Italy there is one domestic producer of batteries. It is a small but very old and reputed company with 60 employees and a turnover of about 6 billion lira (2.5 of which sold in the national market). It produces only cylindrical and prismatic zinc-air and zinc-carbon batteries.

According to a representative of this company, measures to be taken for an effective recycling system are a mandatory deposit refund system included in the sales price, a ban on highly harmful substances in batteries, eco taxes and an obligation to recover the materials from used batteries.

Limited information is seen as one of the causes of the poor effectiveness of the present system. Therefore, a proper environmental labelling of the product is said to be a suitable tool for supporting the recovery.

The Italian market leader for batteries, an international company, is very active in meeting the aim of finding agreement upon the compatibility of cadmium and mercury free batteries with urban waste by means of specialised media and sponsoring environmental campaigns.

From its point of view, an obligatory deposit system, a ban on battery systems with a high content of harmful substances, a disposal charge, an eco tax, a take back obligation and an obligation to bring used batteries back are regarded as effective instruments of environmental policy, with a high incentive for technological innovation and good balance between the benefits and the ensuing costs. Environmental labelling exhibits a medium degree of acceptance with a balanced relation between costs and benefits and a low innovation incentive.

A representative of another internationally operating firm in Italy said that the best way to limit damages to the environment from the disposal of used batteries does not lie in legislation but in the increase of general knowledge and education. Measures for the achievement of these objectives are thought to be the mandatory labelling of the product, the prohibition of harmful and dangerous substances, and the obligation to recollect spent batteries. On its mind, the best tools for accomplishing environmental policy objectives are the ones which are mostly accepted by all involved actors. The list includes eco-labelling and consumer advice.

b) Retailers

The "Confesercenti" (Italian Retailers Association) thinks that the introduction of a deposit refund on batteries will create an unbearable administrative and bureaucratic problem for the recollectors, i.e. the retailers in this case, by forcing them to use an input/output book distinguishing all the different trademarks.

They prefer the creation of a consortium of producers and importers of batteries to which to assign the problem of recovery and proper disposal of the batteries.

c) Consumer organisations

As can be concluded from studying the major focus of the advertising of battery manufacturers the most important expectation of consumers concerns the life-span of a battery, then its price. Even if the average Italian consumer is not very sensitive about the environmental issue, the problem of mercury pollution is known, whilst less known is cadmium and other heavy metal pollution. Hence, the elimination of these substances from batteries is seen as a sacrifice as far as it should cause a worsening of the battery performance.

The only consumer association which participated in our survey was "Movimento dei Consumatori" (The Consumer Movement). One of its representatives said that an ideal mix of instruments for minimising the environmental impact from batteries could be represented by an eco label, an increase of information at the consumer level, an obligatory deposit system and the education of personnel of local administrations. According to the interviewee the problem of the harmful composition of batteries has been partially solved by the new battery systems which are low in hazardous substances, whilst the recovery system is ineffective and the following step of recovering the heavy metals from the collected batteries is totally inefficient.

d) Environmental organisations

The Italian environmental organisations conducted a long campaign calling for mercury reduction in batteries and also for the full application of the law stipulating the separate collection of batteries. Moreover, they support a total ban on hazardous substances and the introduction of new battery systems which are low in harmful substances.

An improved information policy at retailers and final users level is seen as one instrument to increase the effectiveness of environmental policy.

Proper product labelling clearly indicating environmental harmful substances, and the need for separate collection and disposal are seen as the most effective tools for this information policy. The introduction of the ecolabel could speed up the introduction of less harmful batteries.

The introduction of a deposit refund is seen as a reinforcing measure, indicating the need for recollection and recycling on the consumer side and as a way to increase the involvement of producers and importers in the disposal of spent batteries.

In addition, the environmental organisations favour an increased application of rechargeable batteries.

The following table 4.8 summarises the main results of this survey. It shows the instrumental mix regarded as the most appropriate by each respective actor.

Table 4.8: Proposed product policy instruments in Italy

	Instrument	**Industry**			**Retail-organisation**	**Consumer-organisation**	**WWF[d)]**	**Legambiente[e)]**
		Domestic producer	International firm I	International firm II				
I	*Direct regulatory instruments*							
I-1	Prohibition[a)]	x	x	x		x	x	x
I-7	Obligation to take back	x	x	x	x[f)]	x	x	x
II	*Economic instruments*							
II-1	National product taxes[b)]	x	x					
II-2	National product charges [c)]		x					
II-5	Deposit-refund	x	x			x		x
III	*Compulsory information instruments*							
III-1	Compulsory labelling	x					x	x
IV	*Voluntary information instruments*							
IV-2	Eco label		x	x		x		x
V	*Voluntary agreements*				x			
V-1	Voluntary self commitment							
VI	*Consumer policy*							
VI-1	Consumer advice			x		x	x	

[x] This instrument is part of the proposed instrumental mix which is regarded as appropriate in the context of battery-oriented environmental policy by the respective actor.

a) Prohibition of battery systems which are high in hazardous substances.

b) National taxation in form of an "eco tax".

c) National product charge in form of a disposal charge.

d) World Wildlife Fund For Nature in Italy.

e) Italian environmental organisation.

f) Take-back system without charge for the consumers.

This table reveals that:

* the assessment of the instruments by the actors "industry" and "environmental organisations", does not differ very much. With two exceptions, they even agree upon deposit-refunds as an appropriate instrument for battery-related environmental policy.
* Moreover, the majority of the interviewed representatives of battery manufacturers in Italy are obviously in favour of eco-taxes.
* "Soft" information instruments, such as eco-labels and consumer advice seem to be the less controversial ones. They achieve a relatively high degree of acceptance at almost all interest parties.
* The robustness of these quite surprising results is not very clear. Since battery-related environmental policy is not very developed in Italy, the actors' opinion might, at least in some cases, equal a kind of ad-hoc assessment. However, it might also be that the interviewed actors, who are not yet engaged in an intensive battery discussion in Italy, might be "free" to give their honest views on these issues.

The survey carried out in Italy among the different actors can be summarised against the background of the evaluation criteria "innovation incentive", "economic efficiency" and "suitability".

* The battery manufacturers agree that obligatory deposit systems and a ban on systems high in harmful substances create high to very high innovation incentives. They think that a take back obligation, and obligatory labelling work from medium to very high. The other actors attach a high to very high innovation incentive to a ban on systems high in harmful substances, to take back obligations and obligatory labelling.
* With respect to the relationship between costs and benefits, the battery companies assess take back obligations, test reports, bans on systems high in harmful substances and advisory service as from balanced to very good. The other interviewed actors, especially consumer and environmental organisations, assign a very good balance also to environmental labelling.
* There is agreement among battery manufacturers on the suitability of bans on systems high in harmful substances for promoting the development of environmentally friendly battery systems. On eco taxes and bans for increasing the market share of environmentally friendly battery systems. And, on take back obligations and obligatory deposit systems for increasing the return quota and supporting the recycling of collected batteries.

4.4 Barrier analysis

In this section we will summarise the main obstacles to an effective environmental policy for equipment batteries.

In this context it might be helpful to distinguish several kinds of barriers:

* *awareness* barriers,
* *information* barriers,
* *economic* barriers,
* *organisational* barriers,
* *technical* barriers,
* *other* barriers.

The assessment of barriers and opportunities includes the evaluation of both the Italian and German situations. However, since the German environmental policy on batteries benefitsfrom far more experience than the Italian policy, the following sub-sections might preponderantly take the findings for Germany into account.

Awareness barriers

* A lack of knowledge on environmental impacts caused by batteries can be observed both in Italy and Germany. However, the environmental consciousness with respect to the mercury and cadmium problems might be far more developed in Germany than in Italy.
* If there is knowledge about the environmental relevance of batteries, it is mostly confined to their specific relevance (disposal problems) and neglects general aspects of the battery use ("energy filter").

Information barriers:

* If the eco-label for certain types of environmentally benign batteries actually exerts an influence on innovation and market penetration processes, this has not been proven empirically. It seems as if it's effect is very modest. One reason might be that the label for zinc-air and lithium batteries is not widely known and, due to the small size of the battery and its packaging, can hardly be perceived by the consumer.
* According to information from an applicator of the label for zinc-air batteries the different labelling activities ("Blue Angel", "Green dot", ISO recycling symbol) which are going on in Germany at the moment might cause confusion among consumers. This could prevent the manufacturers from applying for the eco-label.

* An important structural parameter which influences the effectiveness of battery recollection is the information of retailers and consumers. It has become obvious from our evaluation that traders and consumers are insufficiently informed about the need and the possibility to collect spent batteries.

* In this context, the distinction between "good" and "bad" batteries, i.e. those batteries which should be allowed to be disposed of along with the household waste and those which should be collected and disposed of or recycled separately, might constitute a crucial point. One can suggest that this distinction has confused consumers and might thereby be responsible for the large quantities of spent batteries high in hazardous substances that still end up in landfills.

* The voluntary self-commitment by industry and trade in Germany appears to contain inappropriate labelling prescriptions (the label - ISO recycling symbol - is misleading and not clearly visible) and therefore can hardly contribute to an improved information basis of the consumers.

* The objective of reducing the overall use of batteries (following the strategy of waste avoidance) either by substitution of non-rechargeable batteries by rechargeables or by a reduction of the use of battery powered appliances is perceived as a peripheral goal of environmental policy so far. The instruments are confined to a few recommendations provided by consumer organisations.

Economic barriers:

* One structural parameter that probably impedes the development of batteries low in hazardous substances is development cost. However,this cost ensues with any product innovation. Compensationcomes later by the competitive advantage the producer gains from supplying the innovation in the market. Since, meanwhile, the alkali-manganese and zinc-carbon batteries are practically mercury free, one can suggest that the market competition between the different manufacturers as a supporting factor for the innovation process is of more importance than development costs.

* Especially in the case of lithium batteries which are cadmium- and mercury-free, the relatively high sales price has turned out to be an obstacle to a sufficient market penetration.

* For the major actors in the recollection chain, retailers and consumers, the after-use-management of batteries takes additional time and causes costs.

Organisational barriers:

* Another important structural parameter, besides available information, which influences the effectiveness of battery recollection is lack of existing incentives to bring back used batteries. Our evaluation has revealed that neither traders nor consumers face a strong incentive to participate in the redistribution of spent batteries.

Technical barriers:

* It has become clear that the creation of an eco-label for an environmentally benign product (e.g. nickel-hydrid accumulators) suffers from a certain time-lag. Eco-labelling only comes within environmental policy when the eligible product has already been introduced into the market.

* A stronger promotion of a substitution of non-rechargeable batteries by rechargeable nickel-cadmium accumulators has to be based on the assumption that there is a recollection system and a recycling technology available for the spent accumulators.

* The substitution of environmentally harmful battery systems by their less harmful alternatives is to some extent determined by the field of application. For example, solar cells can serve as a suitable substitute only in case of low power devices, such as watches or scientific calculators.

Other barriers:

* The assessment of the environmental relevance of, for example, mercury-free batteries is different among the different actors. Industry argues they can be disposed of with normal household waste, whereas environmental organisations advise consumers against this kind of disposal.

The following table tries to connect the above mentioned barriers (including a few additional obstacles) with the objectives we distinguished for battery-oriented environmental policy (see section 2.6) and it also provides an assessment of the importance of the barriers in Germany and Italy.

Table 4.9 : Synopsis of barriers to battery-oriented environmental policy

Barrier	Relevant for				Importance in	
	reduction of substances	substitution of battery systems	collection and recycling	reduction of battery use	Germany	Italy
Awareness barriers						
Lack of knowledge on the environmental impacts of batteries			x	x	••	•••
Information barriers						
Degree of fame of the eco-label	x	x		x	••	
Confusing plethora of labels			x		••	
Insufficient information of traders and consumers			x		•••	•••
Distinction between "harmful" and "harmless" batteries			x		••	
Unsuitable labelling prescriptions			x		•••	•••
Reduction of battery use is hardly perceived as environmentally benign.				x	•••	•••
Economic barriers						
Development costs of "green" batteries	x	x			••	•
Higher sales price of less harmful batteries (e.g. lithium, nickel-metal-hydrid)	x	x			••	••
Additonal time and costs of take-back			x		•••	•••
Organisational barriers						
General lack of organisation and communication among the actors involved			x		••	•••
Lacking incentives to bring back spent batteries			x		•••	•••
Lacking supply of battery take-back facilities			x		•	•••
Technical barriers						
Time-lag at the creation of eco-labels	x	x			•••	
Availability of recycling technologies			x		•••	•••
Potentials for substitution are restricted by the field of application.		x			••	
Lack of availability of "harmless" batteries (e.g. lithium, nickel-metal-hydrid)		x			••	••
Other barriers						
Lack of agreement about the environmental relevance of batteries			x	x	••	

Explanation:

[x]	relevant for the objective
[•]	minor importance
[••]	medium importance
[•••]	high importance
empty cell	no relevance for the objective / no judgement possible

4.5 Comparison and conclusions

As mentioned in section 2.6 battery-oriented environmental policy can pursue different objectives:

* Reduction of hazardous substances contained in case where the respective substance is not necessary for the principal functioning of the battery system (e.g. reduction of mercury in alkali-manganese and zinc-carbon batteries).
* Substitution of hazardous substances contained in case where the respective substance is necessary for principal functioning of the battery system (e.g. substitution of nickel-cadmium by nickel-hydrid accumulators).
* Recollection and selective treatment (recycling) of batteries which still contain dangerous substances.
* Overall reduction of battery use (e.g. the substitution of non-rechargeables by rechargeables, the use of solar cells or the renunciation of battery-powered appliances).

The evaluation of the battery-oriented environmental policies in Italy and Germany has revealed that these objectives are differently weighted between and within the two countries. The following table provides an assessment of the importance of the policy objectives in Italy and Germany as it results from our evaluation.

Table 4.10: Assessment of policy objectives

Policy objective	Germany	Italy
Reduction of hazardous substances	••	•
Substitution of battery systems	••	•
Collection and recycling	•••	•••
Overall reduction of battery use	•	•

Explanation:

[•] Objective is of minor importance.

[••] Objective is of medium importance.

[•••] Objective is of high importance.

The table shows that both in Italy and Germany, the recollection and environmentally proper treatment of spent batteries is the main policy objective. Whereas, the overall reduction of the battery use apparently represents a relatively unimportant goal. The objective of reducing / substituting hazardous substances in batteries is more strongly emphasised in German than in Italian battery policy. This is chiefly due to the existence of a voluntary self-commitment between manufacturers and traders in Germany which includes targets with respect to the

further reduction and final elimination of mercury in batteries and the development of environmentally benign battery systems.

This result is quite interesting. It is not in correspondence with the hierarchy of objectives as it is formulated in the recent amendment of the German Waste Act - the Waste Management and Product Recycling Act - which stipulates the order of rank: waste prevention, recycling (i.e. recovery of secondary resources) and disposal (Art. 4 (1)).[67] The actual policy aims at the recycling and environmentally proper disposal of spent batteries and not directly at the avoidance of waste. Indirectly one can say, that the objective of reducing or substituting dangerous substances in batteries, which is at least in Germany a part of battery-oriented environmental policy, contributes to a prevention of hazardous substances in the waste, but not to a reduction of the amount of waste.

The applied instrumental set is most comprehensive for the objective of collection and recycling of course. However, since the achieved return quotas are not yet very high, a sufficient incentive for recollection seems to be missing. This might be put down either to an insufficient or even confusing information policy[68] or to a lack of economic incentives.

The objective of waste prevention is to be accomplished only by a few measures based on informing consumers.[69] Obviously, these measures are not very effective and hardly question the necessity of batteries in daily life.

In Italy, there are instruments in force only for the objective of recollection of spent batteries. However, it has not become clear from our study in how far the environmental policy actively provides information on the environmentally proper after-use-management of spent batteries or simply puts possibilities for recollection at the consumers' disposal. From the fact that today only 30 % of the municipalities offer the service of separate collection of spent batteries, one can suggest that there is hardly any active official information policy.

This aspect also illustrates that the more advanced the battery policy is, the more actors are involved in the process of policy making on the one hand and in the policy application on the other hand. According to Flatz/de Man (1994) the actors can be distinguished in the following way:

* *primary (direct) economic actors*: producers, consumers
* *secondary (indirect) economic actors*: trade and industrial associations

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[67] This hierarchy is already included in the preceding Waste Act from 1986 (Art. 1a).

[68] As already mentioned in section 4.4, a distinction between batteries which can be diposed of with the household waste and batteries that must be collected separately might confuse the consumers.

[69] Except for the planned ban on alkaline-manganese batteries which exceed a certain percentage of mercury. However, due to the fact that nearly all cylindrical alkali-managnese batteries are almost mercury free, this foreseen regulation must be regarded as rather "soft".

* *governmental actors*: state, administrations
* *non-governmental actors*: environmental and consumer organisations

Based on this categorisation, one realises that in Italy the main addressee of policy application is the primary economic actor "consumer" who has to bring back used batteries and governmental actors in the form of municipalities which offer the service of separate recollection. It is difficult to assess if in the process of policy design there are other actors than the state who take part in the elaboration of the battery policy. It emerges from its moderate degree of development that the battery-oriented environmental policy in Italy is still based on a "top-down approach" which means that the actual policy is mainly formulated by governmental institutions only.

In contrast to the Italian situation one can regard the German way of designing environmental policy for batteries as more a kind of pluralistic "bottom-up approach". This suggestion is to indicate that there are several different actors that participate in the process of policy making and application. The table 3.9 "Overview of battery-oriented environmental policy instruments in Germany" (cp. section 3.3.3) has shown that in the implementation process of battery policy there are governmental and non-governmental actors (Ministry for the Environment, Ministry of Economic Affairs, Federal Environmental Agency, environmental and consumer organisations) and secondary actors (trade and industrial association) involved. The relevant actors with respect to the functioning of the voluntary take-back system are producers, traders and consumers, i.e. primary and secondary economic actors. With respect to the application of other instruments there are only the primary economic actors, i.e. producers and/or consumers involved.

A comparison between Italy and Germany with regard to the instruments which are in force or being discussed at the moment seems to be quite difficult. This can be put down to the fact that the discussion about batteries is far more developed in Germany than in Italy. However, it is interesting to note the following points:

* In Italy deposit-refund schemes are regarded as appropriate tools for the battery policy by the interviewed actors, whereas in Germany there seems to be a consensus only on the presumed innovation incentive which is created by this instrument. All other aspects connected with deposits (efficiency, acceptance) are discussed very controversially in Germany.
* The innovation incentive that comes from bans on certain battery systems is in both countries regarded as rather high, especially by the interviewed manufacturers.
* The "soft" information instruments, such as eco-labels or consumer advice, achieve a relatively high acceptance in both countries.

This comparative assessment can only provide some preliminary hints with respect to the evaluation of instruments in the selected countries. As already mentioned in section 4.3.3, the actors' judgement, especially in Italy where there are only a few experiences with battery-oriented environmental policy, must be interpreted very carefully.

5 Conclusions

In this final chapter we will draw some conclusions from the findings of the preceding chapters. The focus will be on the four poles we have stressed as determining factors for battery-oriented environmental policy: the objectives, the product group, the applied/discussed instruments and the involved actors. Additionally, we will take a prospective view, which takes the future developments of batteries and their fields of application into account, and we will also emphasise the differences and similarities within the EU and other countries we have investigated. Finally, we will give some recommendations.

5.1 Objectives

The four objectives that are relevant for battery-oriented environmental policy (cp. section 2.6), namely

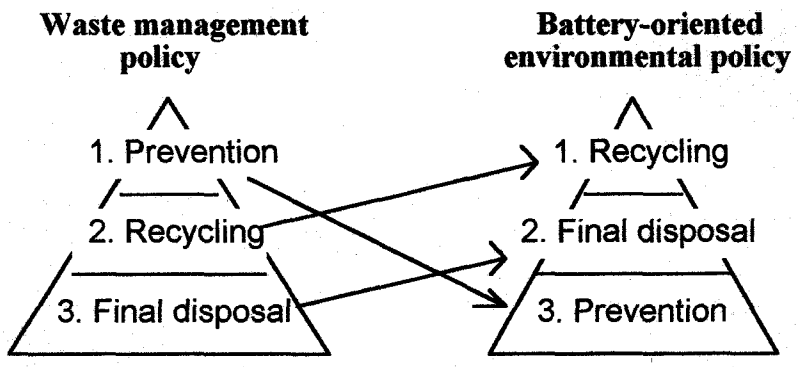
* reduction of hazardous substances contained in case where the respective substance is not necessary for the principal functioning of the battery system (e.g. reduction of mercury in alkali-manganese and zinc-carbon batteries),
* substitution of hazardous substances contained in case where the respective substance is necessary for principal functioning of the battery system (e.g. substitution of nickel-cadmium by nickel-hydrid accumulators),
* recollection and selective treatment (recycling) of batteries which still contain dangerous substances,
* overall reduction of the battery use (e.g. the substitution of non-rechargeables by rechargeables, the use of solar cells or the renunciation of battery-powered appliances),

have a more or less explicit character. The first two objectives can be subsumed under the goal "development of environmentally sound battery systems" which is being laid down, for example, in the EC battery directive. Correspondingly, the third objective, "recollection and recycling", must be regarded as an explicit objective of battery policy. In contrast, the fourth objective, "reduction of the battery use", represents an implicit one, indicated mainly by the existence of eco-labels for solar-powered appliances and mechancial watches.

It has become obvious that these objectives are differently weighted. The recollection and environmentally proper treatment of spent batteries is the main policy objective, whereas the overall reduction of the battery use apparently represents a relatively unimportant goal. The objective of reducing respectively substituting hazardous substances in batteries is sometimes emphasised. It can be interpreted as a waste prevention strategy, at least an avoidance of heavy

metals, such as mercury and cadmium, in the household waste streams. A comparison of the "usual" waste management policy with the policy objectives of the battery-related environmental policy is depicted in figure 5.1 below.

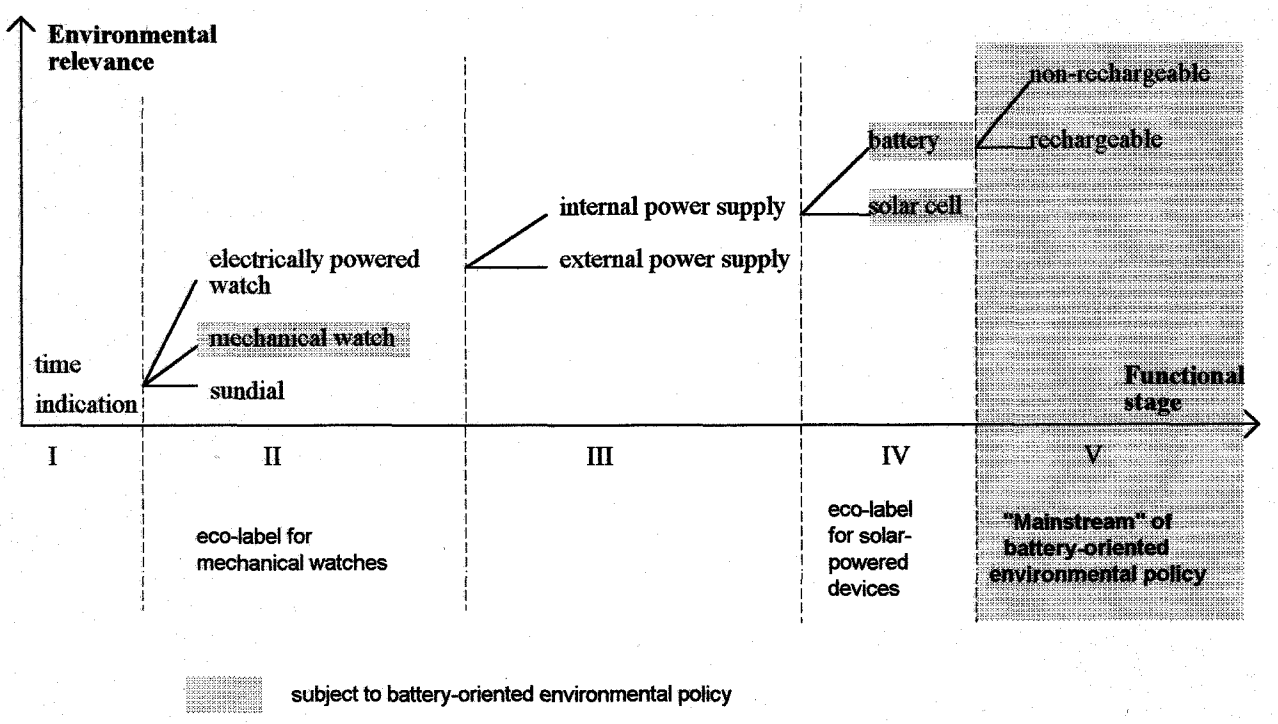
Figure 5.1: Hierarchy of objectives



This comparison reveals that the ranking of the objectives of battery policy does not coincide with the ranking within "usual" waste management. Battery policy firstly aims at recollecting and recycling spent batteries. For those battery systems which are either not recyclable or where the recycling is not possible or apparently ineffective (e.g. due to low content of recyclable materials contained or to missing recycling technology) the environmentally proper landfilling (hazardous waste landfilling) is the most appropriate alternative. The prevention of waste in the sense of reducing the use of batteries where this is possible is of least importance, except for the reduction of mercury and cadmium in the waste streams.

If we regard the "functional chain" we have developed in section 2.4 it becomes obvious that the actual policy on batteries - the "mainstream" - is basically directed to the latest stage (cp. figure 5.2, *grey coloured area*). Earlier stages which question the necessity of using batteries in general are not addressed; the only exception being the German eco-label for solar-powered appliances and mechanical watches (stages IV resp. II). Correspondingly, the "general" environmental relevance of batteries ("energy filter") is not taken into account, but mainly their "specific" relevance (dangerous substances contained) instead.

Figure 5.2: The focus of battery-oriented environmental policy (own elaboration)



However, this orientation of product-related environmental policy in the case of batteries might turn out to be crucial. In general, an environmental optimisation of products - more exactly "functions" or "services" - is the easier the earlier we are in the functional chain (cp. IÖW 1993, p.10). With respect to our example "time indication" this means that the negative environmental impact of a watch which is being equipped by a mercury-oxide battery can be reduced only by lowering the mercury content or by collecting and recycling the spent battery[70]. In contrast, the use of a mechanical watch would a priori avoid the application of this heavy metal and thereby offer a considerably larger potential for environmental optimisation.[71] The case study has provided some evidence that the predominating "late-stage" focus has a "function conserving" effect (IÖW 1993, p.11), in the sense that environmental benefits are mainly being sought in the batteries themselves (reduction of the heavy metal content, recycling of spent batteries etc.). Whereas the application of batteries as such is rarely being addressed (e.g. in the case of hearing-aids the financing only of zinc-air batteries by Danish health insurances)[72] and the need to apply batteries is seldom doubted (e.g. the German eco-label for mechanical watches).

[70] The possible environmental impact of the recycling process is neglected for the sake of simplicity.

[71] A similar example pertains to the differences in environmental terms between a usual screw driver and an electric nickel-cadmium powered screw driver.

[72] One has to note here that the example mentioned does *not* represent a governmental policy approach. However, it has been one of the few measures reported that is being directed to the use stage.

Apart from the consideration of the functional chain, it is worth mentioning that the different policy objectives might compete with each other in the sense that the realisation of one objective counteracts the realisation of another. Assessing the importance of these trade-offs is very difficult. However, they should be taken into account if the respective goal accomplishment is studied. In the following we will briefly summarise some of these possible **trade-offs**:

* The elimination of mercury from alkali-manganese and zinc-carbon batteries makes the recycling of these batteries more difficult because the content of recyclable materials (i.e. mercury) in the batteries might be too low for an effective or efficient recycling.
* The substitution of certain battery systems by their environmentally more benign alternatives can counteract the objective of an overall reduction of the battery use if the final user consumes a bigger amount of the alternative due to its environmental "soundness".
* If the collection and recycling of spent batteries covered all battery systems and achieved high recovery rates, then the reduction of the overall battery use could completely lose its environmental significance.
* A considerable reduction of the overall battery use would automatically reduce the amount of recyclable batteries and thereby negatively influence the profitability of the recycling process (loss of economies of scale, lower capacity utilisation).

Besides the bias in the hierarchy of objectives and the possible trade-offs among them, it has become clear from our evaluation that the recollection and recycling of batteries, which is being dealt with by the largest range of policy instruments, is not yet working sufficiently. The recovery rates rarely exceed 30%. In Italy, the return quotas might be even smaller, because only one third of the municipalities, which are in charge of the recollection of spent batteries, offer this service.

In this context, one must mention that merely two of the EU Member States have transposed the EC Directive on Batteries and Accumulators Containing Dangerous Substances into national legislation (91/157/EEC with its amendment 93/86/EEC) which the Member States had to comply with before December, 31st 1993. This Directive also stresses the selective collection and separate disposal of labelled batteries. (Today it would mainly apply to mercury-oxide button cells, nickel-cadmium and small lead accumulators.) It calls on Member States to implement an effective and selective recollection system.

5.2 Product group

The EC Battery Directive mainly focuses on mercury-oxide button cells and nickel-cadmium accumulators. As we have stated in earlier sections the almost complete elimination of mercury from alkali-manganese and zinc-carbon batteries has been realised leaving the mercury-oxide battery as the major application field for mercury. The same holds true for nickel-cadmium accumulators. Meanwhile, they are the biggest source of cadmium compared to other applications of this heavy metal.

Mercury-oxide button cells are mainly used for hearing-aids. In this application field they can be substituted by zinc-air batteries. In Denmark, for example, the health insurances only refund the costs for these mercury-reduced substitutes. In Germany, the substitution is promoted by the eco-label on zinc-air batteries, but obviously it has not yet achieved sufficient market share (cp. section 4.2.2). A confining factor for a complete substitution is the limited applicability of the zinc-air battery in those hearing-aids which need a strong electrical power supply.

Nickel-cadmium accumulators are characterised by a large and still growing field of application areas. The cylindrical version can be used in entertainment electronics (e.g. walkmen, radios) for example. In the form of power packs they are built-in in wireless electrical hand tools, in electric razors, portable computers etc. In a few specialised applications they can be substituted by rechargeable lithium batteries or nickel-hydrid batteries. But until now these two battery systems have not realised a sufficient market penetration, due on the one hand to their limited applicability and on the other hand to their high price. Therefore one should take into account the following rules with respect to the application of nickel-cadmium batteries (cp. Österreichisches Ökologie Institut 1991, p.41):

* prefer mains operated devices where this is possible,[73]
* if the use of wireless appliances is necessary, alternatives to batteries and accumulators should be taken into account (e.g. solar cells),
* wether a non-rechargeable battery or a rechargeable nickel-cadmium accumulator is appropriate, depends on the respective application area (rechargeables are most appropriate in case of regular use of the electric device)
* if nickel-cadmium powered appliances are used, one should prefer replaceable accu-packs[74].

[73] One could add: prefer the use of non electrically powered appliances. However, this recommendation might be confined. In general, only the elaboration of LCAs can prove the relative environmental soundness of a product alternative.

[74] Accu-packs consist of several nickel-cadmium accumulators in one case.

The replaceability and universal applicability of the accu-packs can be supported by standardising their construction.

The substitution of non-rechargeable batteries by rechargeable nickel-cadmium accumulators represents a useful alternative from an environmental point of view only if the recollection and separate treatment of the spent accumulators is ensured. Otherwise large quantities of cadmium are going to be dispersed into the environment via different waste streams.

Moreover, a further development of **environmentally sounder battery systems**, such as mercury- and cadmium-free lithium batteries or cadmium-free nickel-hydrid batteries, should be promoted. This approach should also take into account the imports from Eastern Asian countries (South-Korea, Taiwan, China) because the batteries imported from there are still characterised by a relatively high percentage of mercury.

5.3 Instruments

With regard to instruments dealing with potential environmental problems emanating from batteries, several proposals for improvement have been made.

The first aspect concerns the **information** function of the instruments. Apart from realising that the labelling prescriptions that are included in the EC Directive 93/86/EEC (crossed out dust bin) seem to be more appropriate than the ISO recycling symbol for the purpose of realising high recovery rates of spent batteries (they clearly indicate that the respective battery must not be disposed of with domestic waste) it has been proposed (RSU 1990, p. 235) to

* obligatorily label all batteries which contain more than 0.025% of cadmium *plus* mercury by weight,
* mark the main hazardous substance which is contained in the battery on the battery case or on the packaging of the battery and also to put a notice "RETURN" on the battery,
* oblige suppliers of batteries and battery powered appliances to mention the need for recollection in their advertising.

Moreover, the publication of substance flows (balance of inputs and outputs) by the battery manufacturers as it is partly practised in Switzerland appears to be an appropriate means to assess the environmental relevance of the production, use and disposal of batteries in quantitative terms. A public authority should be entitled to assess and control these balance sheets and could thereby support the credibility of the calculated estimates for the return quotas of batteries. (RSU 1990, p.235)

The identification of the trade as one major bottleneck within the recollection chain suggests that improvement is required in the information offered by the retailers. This could be realised

by the introduction of an obligation to inform about battery collection at the point of sale. Until now retailers are not obliged to provide information on the recollection of spent batteries.

The appropriateness of **economic instruments** in the framework of battery-oriented environmental policy should be investigated again. The example of a type of voluntary disposal charge in Switzerland has revealed how at least the economic efficiency of battery collection and recycling can be improved. In Denmark, a disposal charge on nickel-cadmium accumulators has been introduced to cover the costs of collection, reprocessing and information campaigns. Additionally they apply financial assistances, i.e. they reserve funds for the implementation of substitutes for cadmium. In order to compensate price differentials between a relatively harmful battery and its less harmful, but more expensive alternative (e.g. nickel-hydrid instead of nickel-cadmium accumulator) eco taxes might be considered again. Moreover, rebate schemes combined with disposal charges (cp. section 4.2.3.2 c)), are worth being examined more deeply.

Recently, it has even been proposed (Stiftung Arbeit und Umwelt, n.y., p.36) to apply tradable permits to the use of cadmium in batteries: The permitted amount of new cadmium is derived from the difference between overall cadmium consumption in accumulators and a fixed amount of recycled cadmium. The recycling companies receive permits for the amount of secondary cadmium and are allowed to sell them to the battery manufacturers. If recycling quotas are not met secondary cadmium will become scarce and prices for the permits will rise. Hence, the recycling of spent nickel-cadmium batteries will become more profitable.

The question of wether deposit-refund schemes should be installed, at least for selected battery systems (mercury-oxide button cells and/or nickel-cadmium accumulators), cannot be decided on the basis of the available information. Both the pros and cons that have been formulated within the controversial discussion about this instrument (cp. section 4.2.3.2) appear to important. However, those who strictly reject this instrument are obliged to offer alternative proposals that can to considerably increase the return quotas for spent batteries. Even very intensive information campaigns promoting recollection on a voluntary basis have not succeeded in realising high recovery rates.

Macauly et.al. (1992) propose some other economic instruments which are appropriate for battery policy, especially dealing with nickel-cadmium accumulators. These encompass a cadmium input tax, which discourages cadmium use and encourages substitutes, and moreover helps financing subsidies for collection, which are to provide incentives for removing cadmium from normal waste streams. (Cp. section 4.2.3.2)

Among the **voluntary measures** the self-commitment by the battery industry and trade which has been agreed upon in Germany in 1988 is the most prominent one. However, it could only contribute to large reductions of mercury in zinc-carbon and alkali-manganese and to the

development of less environmentally harmful battery systems (e.g. lithium batteries, nickel-hydrid accumulators, zinc-air button cells) which until now are not yet wide spread. With respect to the recollection of labelled batteries it must be regarded as a failure.

One can doubt if such a commitment would have been agreed upon without the existence of waste legislation that includes the possibility to oblige producers to take their products back after use. In this sense, a "threat and control" policy of the state, which on a legal basis includes the objective of preventing and reducing hazardous substances in the waste, might create a strong incentive for innovation processes. In general, one must consider the following aspects in the context of voluntary agreements as an effective instrument of product policy (cp. Hansjürgens 1994):

* "Threatening potential" of the state: Do producers which do not comply with certain environmentally relevant product standards (or product recovery rates) within a certain period of time face a credible threat by the government (e.g. introduction of bans on products or of a deposit-refund system)?
* Narrow oligopolistic market structures appear to support cooperative behaviour of producers.
* A current control of arrangements is necessary for a permanent functioning of voluntary self-commitments.

The third argument hints at a weak point of battery policy. The German example has revealed that control of the voluntary self-commitment turns out to be difficult - mainly due to unreliable information.

Moreover, the advantages and disadvantages of voluntary agreements as far as they refer to the battery issue can be summarised in the following way (Wicke 1981):

* Participating companies are free to choose the least cost solution for achieving the agreed objective (cost-efficient instrument).
* Voluntary agreements are in concordance with the institutional framework of a private market economy.
* If the responsible actors (here: battery producers, traders and consumers) are not in keeping with the agreed goals and deadlines, the environmental problem which is to be solved by the commitment might be drawn out.

The third argument addresses an interesting aspect. Due to recovery rates which rarely exceed 30 % on average, one can conclude that in Germany as from the introduction of the self-commitment in 1988, two thirds of annually consumed batteries are not being collected and put to recycling. If one assumes that these huge amounts of batteries have been disposed of with the normal household waste at the end of their life-span they are now "lost" for environmen-

tally proper waste management. In this sense, one can say that due to lack of more stringent policy instruments in earlier years, the environmental problem (avoidable emissions of heavy metals) has been drawn out. That is it has not been mastered the way it could have been.

5.4 Actors

The preceding discussion of the objectives of battery-oriented environmental policy, of the product group of batteries and policy instruments has shown that there are several tasks left for involved actors.

In the framework of the survey we carried out among **battery manufacturers** in Germany, they were asked in which areas of battery policy they see a need for further action. Since only about 15% of the manufacturers answered our questionnaire, the results cannot be regarded as representative. However, they provide some hints as to those areas which are of importance for future measures and which might find a relatively high acceptance among producers. The areas they indicated as needing action are:

* Forcing environmentally benign product innovations in the area of batteries and accumulators.
* Improved consumer information about the proper return of used batteries and accumulators and also about the composition of battery systems.
* Extended information by retailers about their tasks within the return process.
* The innovation of effective and efficient recycling technologies.

Moreover, one producer called for the putting up of more boxes for battery collection in public.

This list of proposals reveals that only the first aspect - forcing environmentally sound product innovations - can directly be influenced by producers, whereas improved information for the consumers and promoting extended information activities of retailers can only indirectly be influenced by them. This would, for example, require improved labelling of the batteries: heavy metal contents, label indicating separate collection, putting labels on the appliance itself, on the packaging and also in the operating instructions.

This list of proposals as it has been stated by some battery manufacturers shows that **retailers** are "gate keepers" in a twofold sense: on the one hand they provide the consumers with necessary information about the recollection, on the other hand they "re-distribute" collected batteries to producers or the recycling companies. The first aspect certainly is a crucial one. Retailers have to offer the service of battery collection more actively: providing posters, leaflets, clearly visible boxes. Moreover, they have to take care to separate different battery

systems (nickel-cadmium accumulators versus mercury-oxide button cells) during the recollection. The training of vendors with respect to these issues should be supported in the future.

Consumers are responsible for bringing back used batteries. Our evaluation suggests that they are not sufficiently informed about the environmental relevance of batteries or the need to collect at least certain battery systems, and do not face a strong incentive to bring batteries back. Information policy and creation of return incentives is the task of the other actors (producers, retailers, the government). Consumers are urged to be more conscious of their use of batteries. At first, they have to reflect on the necessity to use battery powered or even electrically powered appliances. They should avoid buying devices with permanently built-in batteries, such as "singing" congratulation cards, "throw-away" watches, etc.. For the selected application field, they should choose the "right" battery: regular use of an electric device requires rechargeable accumulators, non-regular use non-rechargeable batteries. Additionally, they can influence the development and increase the market share of environmentally more friendly battery systems through their purchasing decision. As a general rule, they should never discard a spent battery along with the normal household waste. It would be easier for them if they could bring back all used batteries and had not to distinguish between batteries which allegedly can be disposed of with the household waste and batteries which have to be collected separately. The criticism that a general bring back of all kinds of batteries would cause unnecessary and unbearable costs during the sorting of collected batteries can be refuted meanwhile. As already mentioned in section 2.4.2 an invisible marking system based on ultraviolet bar code recognition has been developed for batteries. The bar codes will be able to give information not only about the contained substances, but also about the producer of the battery. This might provide the possibility to charge the producer for the disposal of every single battery.

Consumer and environmental organisations are called upon to especially support information activities. It has been stated in section 3.3.2 that at least in Germany their programmes have a more far reaching scope than other policy measures. They doubt, for example, the usefulness of batteries in some application areas and recommend the use of mains-operated appliances. This kind of consumer advice, which mainly serves the objective of reducing the use of batteries and thereby the objective of waste prevention might be appropriate also for other countries. The Italian survey has shown that the environmental and consumer organisations in this country are obviously not so well informed about the battery discussion.

The **government** sets the operating framework for the other actors. It can influence their behaviour by the application of policy instruments. At first, the government is called on to promote the instrumental options mentioned above: for example, transposing the EC Battery Directive into national legislation as soon as possible, introducing improved labelling prescriptions including an obligatory provision of information by retailers, taking "threat and control" strategies which foresee certain return quotas for spent batteries within a period of time and

the imposition of deposits if the targets are not met[75]. Moreover, the development and market introduction of environmentally more sound battery systems should be supported by offering Research & Development funds which could be financed by disposal charges. It might be useful, if the state placed an emphasis on activities focusing on those battery systems which are obviously the most environmentally harmful, i.e. mercury-oxide button cells and nickel-cadmium accumulators. In this context, it might even appear appropriate to announce a ban on these systems as from a certain year, in order to enforce substitution processes.[76]

5.5 Recommendations

In this final sub-section we list some recommendations with respect to the future design of an environmental policy which aims at mitigating the impacts emanating from equipment batteries. The order of the proposals is not to suggest any priority among them.

- The labelling activities for batteries at the level of the EU should be driven forward. The preparation of LCAs (life cycle assessment) for selected battery systems will provide fruitful insights into the "general" environmental relevance of batteries.
- Knowledge about the "energy filter" characteristics of batteries may imply a shift of policy focus from the late functional stages (environmental benefits through "greening" of battery systems and improved recovery of spent materials) to earlier stages (doubtful application areas such as "singing" Christmas cards, battery-free product alternatives such as mechanical watches). From an environmental point of view, this shift of policy focus will offer larger potential for environmental optimisation.
- In general, objectives of battery policy should be clearly stated. Before taking measures, they should be scrutinized for their appropriateness in attaining the formulated objectives and also for possible inconsistencies and unwanted side-effects.[77]
- Product policy should increase efforts which are directed to those battery systems which obviously bear the biggest amounts of heavy metals, such as nickel-cadmium accumulators and mercury-oxide button cells (e.g. by means of disposal charges or even deposit refund schemes).
- The recollection of *all* kinds of equipment batteries should be ensured in order to avoid confusion among consumers as to which batteries are "good" (disposal with household waste) and which are "bad" (separate treatment).

[75] This strategy is followed by the Dutch government. Cp. section 3.5.3.

[76] In Switzerland this regulatory option is being discussed for nickel-cadmium batteries.

[77] Possible side-effects are indicated. For example, by trade-offs among the policy objectives. Cp. sub-section "Objectives" in this chapter.

- The promotion of information work should be carried on. Possible activities encompass information campaigns for consumers and also retailers (point of recollection for spent batteries) and improved labelling prescriptions (besides the symbol of the crossed-out dust bin notes like "Return" on the battery case and the packaging are useful). Furthermore, the appropriateness of advertising rules prescribing, for example, clauses such as: "Spent batteries are taken back by retailers and municipal hazardous waste collections" in every advertisement, should be established.
- The quantitative analysis of the battery market (production, consumption and collection) has to be improved. Available figures are often incomplete and/or contradictory. Reliable data for the amount of built-in batteries is lacking. The collection and control of this data should be assigned to an independent public authority.
- The assessment of the disposal characteristics of alleged "green" batteries, such as lithium cells or nickel-hydrid accumulators, should be tackled soon.
- The German experience has revealed that the process of transposing the EC directive into national legislation should be as transparent and pluralisticly (several different interest groups) organised as possible. Otherwise the acceptance of certain measures by different interest groups might be spoiled.
- The description of the Italian situation has placed great emphasis on the information problem: Batteries are not yet an important environmental issue. This indicates a need to improve information and to make take-back facilities available on a large scale.
- Waste legislation in Germany certainly has influenced the research activities on innovative battery systems. The anticipation of product standards which prescribe the composition of products (e.g. the content of heavy metals such as mercury or cadmium) will probably promote their development. However, one could think about more ambitious measures, that formulate certain "substitution goals". For example, an obligation to equip a certain percentage of electrical appliances with nickel-hydrid instead of nickel-cadmium accumulators. Or the prescription to use only zinc-air instead of mercury oxide batteries for hearing aids as from a certain deadline.[78] The announcement of such product standards might create an incentive for further development of environmentally benign battery systems with respect to their performance[79] and applicability.

[78] In Denmark, for example, health insurance takes the costs only for zinc-air and not for mercury oxide batteries.

[79] There is no suitable present alternative to the nickel-cadmium accumulator in high-power application areas.

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Abbreviations

Abbreviation	German Name	Explanation / English Name
AbfG	Abfallgesetz	Waste Act
AgV	Arbeitsgemeinschaft der Verbraucherverbände	Consumer Organisation
BDI	Bundesverband der Deutschen Industrie	Industrial Association
BfUb	Bundesverband für Umweltberatung	Organisation for Environmental Advisory Centers
BMU	Bundesministerium für Umwelt	Ministry for the Environment
BMWi	Bundesministerium für Wirtschaft	Ministry for Economic Affairs
BUND	Bund für Umwelt- und Naturschutz	Environmental Organisation
DGB	Deutscher Gewerkschaftsbund	Association of Trade Unions
EPBA	-	European Portable Battery Association
HDE	Hauptgemeinschaft des deutschen Einzelhandels	Retailers organisation
INFU	Instiut für Umweltschutz	Institute for Environmental Protection
KrW-/AbfG	Kreislaufwirtschafts- und Abfallgesetz	Waste Management and Product Recycling Act
UBA	Umweltbundesamt	Federal Environmental Agency
VI	Verbraucher Initiative	Consumer Organisation
WWF	-	World Wildlife Fund For Nature
ZVEI	Zentralverband der Elektrotechnik- und Elektronikindustrie	Association of electric appliances producers

Annexes

Annex I: Percentage of chemical substances of selected battery systems (Baumann et.al. 1993)

Zinc-carbon	**primary**	**cylindrical**
chemical substances contained	*percentage by weight [%]*	
Zinc metallic, Zn	16.4-28.6	
Zinc oxide, ZnO	0.3-0.4	
Mercury, Hg	0	
Manganese dioxide, MnO_2	22-30	
Carbon, C	7-9	
Tin, Sn	0.05-0.07	
Iron, Fe	14-21	
Plastic, paper, bitumen	4-10	
NH_4CL, $ZnCl_2$ solution in water	14-23	
Additives	0-0.1	

Zinc-carbon	**primary**	**prismatic**
chemical substances contained	*percentage by weight [%]*	
Zinc metallic, Zn	17.3-19.3	
Zinc oxide, ZnO	0.3-0.4	
Mercury, Hg	0	
Manganese dioxide, MnO_2	33-34	
Carbon, C	10.6	
Iron, Fe	1-2	
Copper, Cu	0.2	
Plastic, paper, bitumen	12-13	
NH_4CL solution in water	23	

Alakali-managanese	**primary**	**button**
chemical substances contained	*percentage by weight [%]*	
Zinc metallic, Zn	7.1-9.9	
Zinc oxide, ZnO	0.1-0.5	
Mercury, Hg	0.6-0.8	
Manganese dioxide, MnO_2	22.3-27.0	
Carbon, C	1.2-5.7	
Iron, Fe	42.9-52.4	
Copper, Cu	2.9-4.2	
Nickel, Ni	0.7-2.1	
Plastic, paper, bitumen	2.9-4.5	
Water	4.5-6.6	
KOH	2.4-3.5	
NaOH	0.3	
Additives	0-0.2	

Alkali-managanese	**primary**	**cylindrical**
chemical substances contained	*percentage by weight [%]*	
Zinc metallic, Zn	14.5-17.5	
Zinc oxide, ZnO	0.3-0.6	
Mercury, Hg	0.02	
Manganese dioxide, MnO_2	33-38	
Carbon, C	4-5	
Iron, Fe	15-26	
Copper, Cu	1-3	
Plastic, paper, bitumen	4-6	
KOH solution in water	13-16	

Alakali-managanese	**primary**	**prismatic**
chemical substances contained	*percentage by weight [%]*	
Zinc metallic, Zn	5.4-10.3	
Zinc oxide, ZnO	0-0.4	
Mercury, Hg	0-0.34	
Manganese dioxide, MnO_2	17-22	
Carbon, C	0-3	
Iron, Fe	40-59	
Copper, Cu	2.8	
Plastic, paper, bitumen	9-11	
KOH solution in water	5-11	

Zinc-mercury-oxide	**primary**	**button**
chemical substances contained	*percentage by weight [%]*	
Zinc metallic, Zn	7.7-13.2	
Zinc oxide, ZnO	0.14-0.9	
Mercury, Hg	40-44	
Manganese dioxide, MnO_2	0-2.5	
Carbon, C	1-3	
Iron, Fe	30-52	
Copper, Cu	2-3	
Nickel, Ni	0.5-2	
Plastic, paper, bitumen	3-9	
NaOH or KOH solution in water	4-6	

Zinc-silver-oxide	**primary**	**button**
chemical substances contained	*percentage by weight [%]*	
Zinc metallic, Zn	5.2-9.3	
Zinc oxide, ZnO	0.05-0.6	
Mercury, Hg	0.4-0.6	
Silver oxide, AgO	12.5-33	
Manganese dioxide, MnO_2	1.5-13	
Carbon, C	1-2	
Iron, Fe	38-48	
Copper, Cu	3-4	
Nickel, Ni	0.5-2	
Plastic, paper, bitumen	3-8	
NaOH or KOH solution in water	4-8	

Zinc-air	**primary**	**button**
chemical substances contained	*percentage by weight [%]*	
Zinc metallic, Zn	23.4-29.6	
Zinc oxide, ZnO	0.05-0.2	
Mercury, Hg	0.8-1	
Manganese dioxide, MnO_2	0.3	
Carbon, C	1-2	
Iron, Fe	42-48	
Copper, Cu	4	
Nickel, Ni	2	
Plastic, paper, bitumen	7-8	
KOH solution in water	8-10	

Lithium manganese dioxide	**primary**	**button**
chemical substances contained	*percentage by weight [%]*	
Lithium, Li	2	
Manganese dioxide, MnO_2	29.2	
Carbon, C	0.9	
Steel	57	
Plastic	3.4	
Propylene carbonate	4.4	
1,2-Dimethoxyethane	2.8	
Lithium perchlorate	0.3	

Lithium manganese dioxide	**primary**	**cylindrical**
chemical substances contained	*percentage by weight [%]*	
Lithium, Li	2-3	
Manganese dioxide, MnO_2	27-37	
Carbon, C	2-4	
Iron, Fe	37-46	
Nickel, Ni	2-6	
organic solvent with Li-salt	12-15	

Nickel-cadmium	**secondary**	**button**
chemical substances contained	*percentage by weight [%]*	
Cadmium, Cd	18-22	
Nickel, Ni	20	
Iron, Fe	45	
KOH solution in water	18-20	

Nickel-cadmium	**secondary**	**cylindrical**
chemical substances contained	*percentage by weight [%]*	
Cadmium, Cd	18-22	
Nickel, Ni	20	
Iron, Fe	45	
KOH solution in water	18-20	

Nickel-hydrid	**secondary**	**cylindrical**
chemical substances contained	*percentage by weight [%]*	
Metal hydride -Hydrogen -Alloy from Titane, Vanadium, Chrome, Zirkonium, Nickel -Cadmium	0.4	

Lead-accumulator (small)	**secondary**	**prismatic**
chemical substances contained	*percentage by weight [%]*	
lead	60-70	

Zinc-air	**primary**	**cylindric**
chemical substances contained	*percentage by weight [%]*	
zinc	30	
mercury	0.8-1	
manganese-dioxide	0.3	

Annex II: Overview of the most important hazardous substances contained in household batteries (own elaboration).

Element	Compound	Function	Impact on health	Impact on environment[a)]
Cadmium (Cd)	metallic	anode in Ni-Cd; in Zn-anode of Zn-cells in order to provide better malleability	carcinogenic, mutagenic; causes kidney damages, bone deformations, blood disturbances; cumulative	air, soil, and water load; cannot be filtered in sewage treatment plants; acid rain increases mobility in soil; accumulates in food chain
Mercury (Hg)	metallic	to prevent corrosion in Zn-anodes; product of the discharging-process in Ni-Cd- (s)	toxic when inhaled, swallowed, or got in contact with the skin; may cause mental retardation, paralysis, convulsion; cumulative	WGK 3
	mercury-oxide	cathode in Zn-HgO (p)	very toxic when inhaled, swallowed, or got in contact with the skin; cumulative	WGK 3
	other inorganic		very toxic when inhaled, swallowed, or got in contact with the skin; cumulative	
	methyl-mercury	product of bacterial conversion of mercury	very toxic when inhaled, swallowed, or got in contact with the skin; cumulative, carcinogenic	accumulates in food chain
	other organic		very toxic when inhaled, swallowed, or got in contact with the skin; cumulative	
Lead (Pb)	metallic	anode in Pb-accumulators, electrode in some Li-cells	toxic, carcinogenic potential suspected; cumulative, various symptoms appear, particularly hazardous to children and foetus	air load out of production, water load out of dumping sites

Element	Compound	Function	Impact on health	Impact on environment
Lithium (Li)	metallic	anode in Li-cells (p,s)	caustic; reacts with water to caustic LiOH	heavy reaction with water, e.g. when cell case corrodes; incineration only up to critical concentration, otherwise danger of explosion
	LiOH	reaction product of Li with water	caustic	might emerge on dump sites when cell case corrodes
	Lithium perchlorat	electrolyte in several Li-cells	can be hazardous when inhaled, swallowed, or got in contact with the skin; causes irritation of eyes, skin, and respiratory tracts	
Nickel (Ni)	metallic	component of many cell cases	toxic, carcinogenic	air load out of incinerators
	$Ni(OH)_2$	product of discharing process in Ni-Cd (s) and NiMH (s)	carcinogenic	contribution to Ni-load out of incinerators
Zinc (Zn)	metallic	anode in Zn-Systems (p)	toxic	during production Zn and ZnO emerges
	ZnO	product of discharging, part of electrolyte in many cells; emerges in Zn-production	might be hazardous when inhaled, swallowed, or contact with skin	

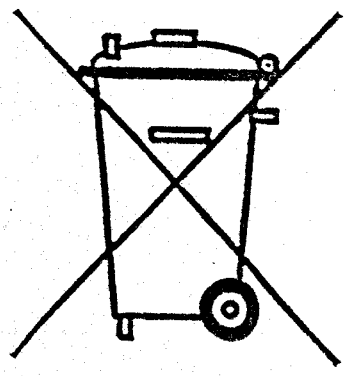
Explanation:

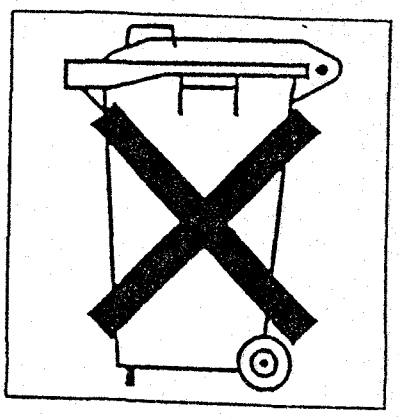
a) Wassergefährdungsklassen based on the German water balance law:
WGK 0 generally not hazardous to water
WGK 1 slightly hazardous to water
WGK 2 hazardous to water
WGK 3 highly hazardous to water

Annex III: List of components included in the Directive 91/689/EEC on dangerous waste with relevance for batteries

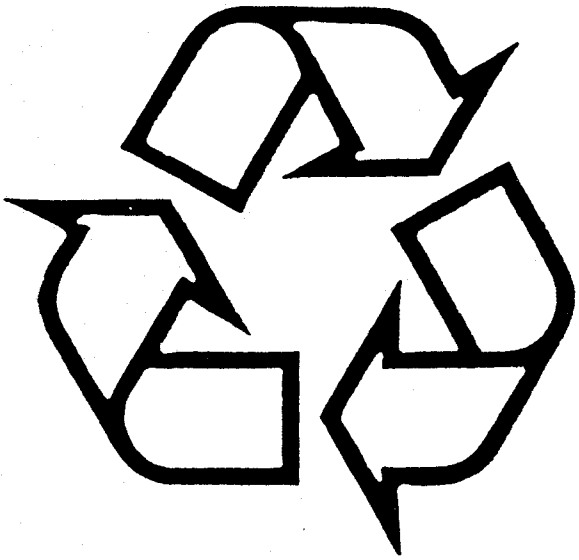
* lead compounds,
* mercury inorganic compounds,
* mercury and derivates,
* cadmium compounds,
* nickel,
* nickel dihydroxide,
* lithium,
* zinc powder,
* manganese dioxide,
* zinc chloride,
* ammonium chloride,
* sulphuric acid,
* solvents,
* cobalt.

Annex IV: Label included in the EC Directive 93/86/EEC for the amendment of Directive 91/157/EEC to technical progress





Annex V: ISO recycling symbol 7000-Reg. N. 1135



Annex VI: The German eco-label "Blue Angel"

Zinc-air batteries

Lithium batteries

Solar powered appliances

Annex VII: Categorisation of product-policy instruments

Category	Type of instrument	
I Direct regulatory instruments	1	Prohibitions / limitations
	2	Admission procedures
	3	Registration procedures
	4	Information duties
	5	Product standards
	6	Guarantee rules
	7	Obligations to take-back
	8	Quotas of returnable products
	9	Minimum use quotas of waste materials
	10	Recycling / Reuse quotas
	11	Advertising rules
	12	Distribution restrictions
	13	User obligations
	14	User benefits
	15	...
II Economic instruments	1	National product taxes
	2	National product charges
	3	Regional product taxes and charges
	4	Financial assistances
	5	Deposit-refund schemes
	6	Marketable permits
	7	Public procurement
	8	Leasing
	9	Product liability
	10	...
III Compulsory information instruments	1	Compulsory labelling
	2	Declaration of contents
	3	...
IV Voluntary information instruments	1	Test reports
	2	Eco-label
	3	Other voluntary labelling schemes
	4	Norms
	5	Quality marks
	6	Trade marks
	7	Life Cycle Analysis (LCA)
	8	Recommendations
	9	...
V Voluntary agreements	1	Legally obliging agreements
	2	Self-commitments
	3	...
VI Consumer policy	1	Consumer advisory centers
	2	...

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