# Disassembly and Recycling of Consumer Goods

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Paper presented at the R´99 Congress (Recovery, Recycling, Re-integration), February 1.999
www.environmental-expert.com/events/r2000/r2000.htm

## Abstract

***This paper presents results of the EU-project "DISCO" (Disassembly and Recycling of Pure Materials from Consumer Goods). The project concentrated on the development of new concepts for disassembly and quality sorting of specific electronic products, which have a standard design in relation to the number and type of selected components ("key-products" like keyboards, telephones or calculators). Since during recycling already minor contaminations of pure materials result in the degradation of sorted components, the quality assurance of sorting processes was a focal point of the project. Consequently, semi-automated solutions for "key-products" have been investigated, based on automated recognition and sorting of pure plastic components by means of a robot and sensory systems.***

## Introduction

The Austrian Research Centers are actively involved in the development of new methods for improved recovery of pure plastics from electronic scrap. During the EU-Environment project "Recycling of Mass Consumer Products", advanced solutions for the efficient recycling of certain types of mass consumer products have been realised. The technical feasibility of automated keyboard disassembly and the recovery of pure plastic materials from selected products have been demonstrated.

Based on experiences from this Environment Project, the proceeding Innovation Project "DISCO" concentrated on preparatory works for the industrial implementation of corresponding hardware solutions for "key-products", like computer keyboards, telephones, calculating machines. It was a main goal of this project to develop appropriate technical solutions for the semi-automatically recovery of selected plastic parts from these products, supported by measuring / detection systems to avoid contaminations and to assure defined qualities of recycled plastics. For this purpose, R&D activities have been carried out together with partners from Germany, Switzerland, Sweden and Austria.

## Obstacles for the automation of disassembly processes

Assembly automation for consumer electronics has become a standard in many industries today, especially in high-wage countries like in the European Union or in Japan and USA. To achieve economic solutions, products and automated tools (handling devices, robots, sensory systems etc.) are developed in a process of simultaneous engineering**,** allowing to develop optimal solutions for the automation of assembly processes. In this way assembly times per unit can be reduced considerably, compared with separated design processes for products on the one side and for assembly automation on the other side. Thus, the consequent application of methods of simultaneous engineering also serves as a tool for quality assurance and cost optimised assembly of mass products.

In contrary, the automation of disassembly requires a different approach, since the presuppositions for the achievement of efficient solutions also depend on external factors, like condition of products or possibilities for the identification of products, when delivered to a recycler. The disassembly process demands first of all higher (technical) flexibility of disassembling components. It also requires more dynamic planning / scheduling, based on factors like wide product mix within a family of recycling products, unscheduled return of products etc.

Usually there do exist numerous variants of a product, and / or several manufacturers, e.g. concerning computer keyboards, walkman etc. Such products may be delivered more or less damaged to recycling yards or recyclers. Thus it is obvious that also high sophisticated solutions for disassembly automation either would be confined to a limited number of products or the expenses for re-programming and re-tooling would exceed financial limits.

Due to these facts, planning and development of efficient disassembly solutions, based on a high degree of automation, are combined with considerable efforts in logistics and organisation

of selected waste streams. Without support by legal measures of local or national governments, recyclers will not be in the position to cope with deficiencies of existing practices for collection and distribution of electronic scrap.

## Design for disassembly

In principle, most existing types of electronic products could be dismantled automatically in specialised laboratories, by means of high sophisticated solutions, applying robots combined with sensor systems / vision, artificial intelligence etc. By this way, a kind of ´reverse-assembly´ would be carried out, trying to dismantle single units with specific hardware and software tools. Due to the following main confinements such solutions are not directly applicable to recycling works:

1. Costs per dismantled unit are extremely high

2. Cycle times are also very high (several minutes)

3. Specialists are required for operation and programming

4. Reliability of ´high-tech´ recycling is rather low

5. Necessary data for tool manipulation and programming are usually not available

6. Pre-sorting according to the product type or product integrity

Recyclers need simple, robust and proven solutions, which can be operated by workers, allowing them to repair or re-tool without help of experts. Thus it is necessary to develop dismantling systems which use standard machines combined with flexible tools and fixtures, applicable for a wide range of products and adaptable product design accordingly. These facts can be summarised as follows:

To carry out e.g. keyboard dismantling as a kind of ´reverse-assembly´, applying special purpose tools and high sophisticated machines, is neither technically nor economically a feasible solution for practical use. Economic solutions are expectable, if "key-products" of a certain type and range can be disassembled by means of flexible tools and standard automation. To achieve this goal, special redesign measures have to be realised for the products concerned. Redesign measures must be carried out simultaneously with the development of disassembly solutions, taking into consideration the problem of acceptance by manufacturers. All these measures will have to cope with the problem that recyclability and also consumer acceptance must not be reduced.

## Limitations for automated disassembly

### a) Technical limitations

There are two main limitations for the technical feasibility of automated disassembly, (1) the high variety of products collected by recycling yards and (2) the unfavourable design of products**,** since the disassembly option has not been taken into consideration during the design process yet. The presorting of products is not practical of several reasons, e.g. personnel from recycling yards are not trained accordingly to recognise and distinguish different products like keyboards and calculators and it is a matter of space and time to store necessary amounts of pre-sorted products.

The return of old keyboards and the composition of types reflects the variety of producers. As with other mass products, designers of "key products" did not and presumably do not consider criteria for disassembly of products at the end of use. To allow automated disassembly at a recycling workshop, existing variations of keyboard designs would necessitate high

sophisticated technical solutions, integrating sensory systems and artificial intelligence. Technically it would already be feasible today on a laboratory scale (as outlined above), but the rather rough and "low-tech" environment at recycling works does not allow to introduce such solutions in the daily business.

### b) Economical limitations

Main economical limitations are low prices for regranulates (according to investigations of Swedish conditions) and low volumes of "key-products", collected for recycling. Low prices for recovered and sorted plastics are on the one hand a result of lacking quality standards for returned plastics; on the other hand, a market price for a certain sort and quality of plastics will only emerge, if minimum quantities are offered by recylers. These quantities are a technical precondition for the industrial upgrading process of return plastics.

This means that the interdependence of quality, quantity and market development has to be broken up, preferably with the introduction of quality agreements between recyclers and producers of virgin plastics, parallel to the continuous increase of sorted quantities.

## Quality assurance of disassembly processes

The total amount of pure plastics, recycled from electronic scrap, could be increased substantially, if the reliability of decisions on plastic sorts and contents of additives could be improved during the recycling process, in order to reach and to guarantee quality standards, to be agreed between recyclers and producers. Since the pre-disassembly of electronic products by users is not practical, it remains an obligation of recycling companies to introduce quality assurance systems for return plastics (re-granulates), in accordance with the requirements of selected buyers.

Due to the actual market conditions, recyclers are frequently dependent on "plastic brokers" and thus the quality of return plastic can not be agreed and adapted to the requirements of selected producers in a direct way. But to allow direct bargaining between recyclers and producers, the lot-sizes of single sorts of return plastics have to be increased substantially. Since there is no functioning market on return plastics, e.g. in Sweden, it should be an indirect goal of recycling projects, to create conditions for a functioning market.

The introduction of quality standards, as a main requirement could be achieved by the realisation of Disassembly & Quality Sorting Systems (DQS) at selected recycling companies, integrating measuring / identification and automated handling devices. Such systems would allow to sort defined qualities of return plastics automatically and thus to avoid contaminations, as it happens during the manual sorting process. Simultaneously, it would be possible to guarantee for the sorted materials. DQS-systems, as a possible technical solution for European recyclers, would apply an industrial robot for handling, preparation and sorting of selected plastic parts and several identification systems for the detection of plastics sorts / qualities, to allow proper separation.

## Results of the project

Based on a practical situation at a Swedish recycling works, the potential implementation of a DQS-system has been investigated. In case of realisation, the system could be integrated into a semi-automated technical solution, where selected parts of products (like housings of keyboards or telephones) are dismantled manually, supported by mechanised tools. Identification as well as sorting of recovered parts would be carried out automatically. Consequently, manual labour would remain the main cost factor within the system and thus its economy is dependent on the geographical location of the system (low-wage areas) and supply of plastics (sufficient volumes of certain types of "key-products"). In addition, the amount of payments from consumers for return of products and revenues from sorted return plastics are decisive economical factors. These findings, which are based on investigations of the Swedish market, can be summarised

as follows:

- Fully automated disassembly of most of today's electronic scrap (e.g. computer keyboards, telephones or calculators) is technically feasible on a laboratory level, but economically not reasonable under prevailing conditions, concerning product design, market, regulations etc.
- The existing design of "key-products" still requires intensive, manual interventions for dismantling, if certain components of the product are to be recovered separately.
- Poor cost / benefit relations mainly result from high personnel costs (due to manual interventions), and low benefits from return plastics, since the market for sorted, technical plastics is not developed yet.
- Currently, recyclers are not prepared yet to collect the necessary high volumes of electronic scrap, containing a certain product type (> one ton per day), to charge the proposed DQS-system to capacity.

To cope with these deficiencies, substantial changes of product design (by means of Re-design / ECODESIGN) are necessary, allowing to apply standard solutions for (semi-) automated disassembly ("advanced dismantling") of products. As a result it should be possible to reduce manual labour, which is still the main cost factor, as outlined for the proposed DQS-system. Only when appropriate design solutions can be realised, the economic operation of disassembly systems may be expected and recyclers will be more inclined to apply those systems. Thus, future initiatives in the area of electronic scrap, dealing with disassembly automation, should concentrate first of all on product design, simultaneously to the development of "low-tech" disassembly solutions, to achieve economic solutions which are acceptable for recyclers.

## Literature

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