ReLCD

Project no.:
COOP-CT-2003-508212

Project acronym:
ReLCD

Project title:
Liquid Crystal Display Re-Use and Recycling

Instrument
Co-operative Research Project

Thematic Priority

Periodic Activity Report

Period covered: **from 8th March 2005 to 7th March 2006**

Date of preparation:

Start date of project: **8th March 2004** Duration: **24 months**

Project coordinator: **Dr. Bernd Kopacek, MSc.**
Ecotronics Eco-efficient Electronics and Services GmbH

Executive Summary

Introduction

Liquid Crystal Displays (LCDs) are widely used nowadays and dominate the Flat Panel technology. Typical applications are notebook and laptop computers, electronics organizers, mobile phones, pocket calculators, measuring and control instruments, electronic games, hand-held miniature TVs, audio-video equipment, large signboards, automotive displays and recently also PC monitors. Moreover, it is expected that LCDs will surpass the well-established Colour Cathode Ray Tubes (CRTs), still predominant in TV and PC monitor applications, in terms of revenues in a few years from now.

Currently the only way to deal with End-of-Life LCDs is disposing them in waste incinerators or landfills. Incineration of LCDs causes the same volatile products and residues as incineration of municipal waste. Among other compounds, these emissions, due to the possible content of liquid crystals of chlorine, could be made up of dioxins and furans, very toxic substances which are currently under discussion. Furthermore, it is assumed that under high thermal conditions there will be break-down products that can be toxic. On the other hand, landfilling is not ecologically efficient since it has been researched that large LCDs possess a backlight containing mercury and the battery of small LCDs may also contain mercury or cadmium, substances classified as toxic due to its accumulative effects in both human body and environment. Besides, although the environmental impact of liquid crystals has not been determined yet, liquid crystals are known to be hazardous to water (water contamination class II) and very difficult to biodegrade (0 – 30% within 28 days).

While some large manufacturers of liquid crystals made considerable efforts to prove that the waste management of their LCDs does not lead to risks for health or the environment, doubts remain regarding the composition of certain imported LCDs.

As a consequence European Commission requests the disassembly of LCDs with an area bigger than 100 cm^2 in the Proposal for a Directive of the European Parliament and of the Council on Waste Electrical and Electronic Equipment (WEEE Directive) on February 13, 2003.

Description of the project

The project methodology followed the logical processing steps of redundant LCDs within a modern recycling plant. The guiding principle was to recover LCDs at the highest possible level. For electric and electronic products there are several EOL options possible, namely: upgrade, re-use, recondition, re-manufacture, recycling of materials, and disposal. The work packages have been defined according to these options:

1. **Functionality tests and refurbishment of working units**

The aim was to bring the working units as soon as possible back to the market and extend the use time as much as possible. A quick and reliable test strategy covering various LC-Display sources, types, and sizes has been developed. The most suitable test processes have been adapted and tested. Based on the gained information about the incoming LC-Display a decision tool (software based) for the further processing route has to be developed. Moreover methods for the highest option of recovery – refurbishment and re-qualification – will be investigated. A process description of required refurbishment steps has been developed and tested.

An applicable functionality test for LCDs has been developed. The main steps and necessary elements of a test procedure were defined, and a possible methodology was evolved for the verification of LCD devices.

For supporting the proposed test system, a database was implemented and started to expanding with requirement information. This database enables to find the adequate controlling for a certain LCD module.

2. Disassembly, identification of materials and material recycling

LCDs which are not suitable for re-use have to be further processed according to the end-of-life options. The main goal was to get out very clean material fractions without contamination of hazardous substances, what makes an efficient material recycling possible. Therefore, identification of materials and in this context the identification of hazardous substances is a key to a successful recycling system. Tests have been carried out to find the optimal balance between manual and automatic disassembling solutions.

A strategy for the recycling of the different material fractions / parts of a LCD has been developed

3. Design, implementation and testing of the system in a laboratory

The objective was to find a treatment technology for Liquid Crystal Displays which separates into hazardous (backlight lamp) and non-hazardous (rest) material fractions.

The following treatment technologies have been tested:

- Manual dismantling
- Water Jet Cutting
- Laser Cutting
- Circular Saw

And evaluated considering the following parameters:

- Mean processing time
- Maintenance costs
- Personnel costs
- Material revenues

4. Closing the life cycle of LCDs

The experiences made in the project will be used as input for manufacturer of LCDs. Guidelines and design aspects for eco-efficient LCDs will be elaborated.

The aims of the project can be summarised as follows:

- To find a cheap and fast test methodology to verify if the obsolete or excess LCDs are still working,
- To develop a technology to refurbish the working LCDs and re-integrate them into repair and in exemptions also in production processes
- To find a test method to detect hazardous substances in LC-mixtures
- To develop an eco-efficient disassembly and recycling technology for the non-working LCDs that fulfils the WEEE-Directive of the European Commission
- Develop, implement and test a pilot plant system incorporating the previous developed technologies to an integrated system
- To research possible enhancements to the existing LCD design and production in order to come to a more sustainable life-cycle of LCDs

- By all these measures decrease the amount going to landfill or incineration as well as decrease the threats to the environment and mankind of today´s state-of-the-art technology.

Information Platform / User Group

In order to transfer the compiled information, an information platform (on the web) has been established for sustainable LCD design, production and recycling. The information platform provided the overall framework for communication and exchange in this field (by means of a web page, help desk, news group, etc.).

A key method for the technology dissemination was the formation of a user group. The project has been discussed in more detail and a continuously exchange will took place during the course of ReLCD

Companies of the following sectors have been invited to join the User Group:

- Producers of LCDs
- Producers of electronic and other products containing LCDs (incl. SMEs)
- Companies active in repair
- Recycling companies
- Waste management companies

The following large companies as well as SMEs joined the User Group:

- Apple
- Sony
- Matsushita
- Nokia
- Flextronics
- EARN (European Advanced Recycling Network):
    - Stena
    - Indumetal
    - Electrocycling
    - Coolrec
- LG
- Samsung
- Hitachi Displays

Project Consortium

ReLCD includes 3 industrial SMEs and 3 RTD organisations from 5 countries (AT, DE, HU, ES, UK). All of its members are deeply involved either in eco-efficient electr(on)ics or electr(on)ics recycling and are therefore capable to exploit the results.

In addition technology dissemination will be done by users incl. producers of LCDs, producers of electronic and other products containing LCDs (incl. SMEs), companies active in repair (mainly SMEs), recycling and waste management companies.

Project Coordinator:

- Ecotronics Eco-efficient Electronics and Services GmbH (AT)

Project Partners:

- Acitve Active Disassembly Research Ltd (UK)
- RelektrA GmbH (DE)
- Austrian Society for Systems Engineering and Automation (AT)
- Fundacion Gaiker (ES)
- Bay Zoltan Foundation for Applied Research (HU)

For publishable results see

http://www.activedisassembly.com/projects/eu/public.htm

Section 1
Project objectives and major achievements during the reporting period

The objectives of the project can be summarised as follows:

- To find a cheap and fast test methodology to verify if the obsolete or excess LCDs are still working,
- To develop a technology to refurbish the working LCDs and re-integrate them into repair and in exemptions also in production processes
- To find a test method to detect hazardous substances in LC-mixtures
- To develop an eco-efficient disassembly and recycling technology for the non-working LCDs that fulfils the WEEE-Directive of the European Commission
- Develop, implement and test a pilot plant system incorporating the previous developed technologies to an integrated system
- To research possible enhancements to the existing LCD design and production in order to come to a more sustainable life-cycle of LCDs (Guidelines for Sustainable LCD Design, Production and Recycling)

The objectives of the reported working period and the work performed can be summarised as follows:

WP1:

- One task of second reporting period was to complete the development of test strategy, and it was closely connected to the work accomplished during the first reported period
- Test strategy was modified according to new ideas and requirements arised during the reporting period;
- Data collection about displays have to be tested;
- Further development and expansion of database;This task was ended in the middle of the reporting period and was continued with practical working out of test system in WP 3.;
- The other task of the second reporting period was to develop a refurbishment method for used LCDs. This task includes the following questions:
    - What are the possible inputs of the refurbishment;
    - Possible and necessary steps of refurbishment;
    - Necessary equipment for refurbishment;
    - Repairing possibilities of LCD modules;
    - Existing display refurbishment activities;
- Practical working out of the LCD test system continued
- The developed test equipment was tried out in a large number and several different types of displays;

- As a possible option to ease testing procedure, a bar code reader system was adapted to the developed database. It helps to simplify the identification of displays and setting of test equipment during the functional test;

WP2:
The objective of the reported working period (from March 2005 to March 2006) is the evaluation of existing method for material recycling and the development of new recycling technologies.

This objective has been carried out in Task 2.3, and the work performed can be summarised as follows:

- Definition of the recycling options for each LCD component.
- Characterisation of the recoverable components.
- Development of recycling schemes.
- Evaluation of the plastic material recovered: measurement of mechanical properties.

WP3:
The main objective of Workpackage 3 (WP3) was to find a treatment technology for Liquid Crystal Displays which separates into hazardous (backlight lamp) and non-hazardous (rest) material fractions.

- The following treatment technologies have been tested:
    - Manual dismantling
    - Water Jet Cutting
    - Laser Cutting
    - Circular Saw
- And evaluated considering the following parameters:
    - Mean processing time
    - Maintenance costs
    - Personnel costs
    - Material revenues

WP 4:

- Development of design guidelines of LCDs
- Exchange of information via User Advisory Board

All contractors have been involved to perform the work.

Summary of the main achievements for the reporting period:

WP1:

- Database was greatly extended, besides its interface is more user-friendly and informative;
- An LCD module test equipment was developed, and a prototype was made. It is available for testing LCD modules with different interfaces and connector types, which means a relatively high universality;
- According to the additional experiences during practical work, test strategy was improved and finalised;
- Refurbishment method that consider special requirements for handling Liquid Crystal Displays was worked out, steps of refurbishment were defined;
- Deliverable 3th, the report about refurbishment methods including detailed description of methodology was prepared and sent to the coordinator;

WP2:

The main achievements of this period have been:

- Definition of a feasible recycling scheme.
- Determination of the quality of the recyclable materials and evaluation of their incorporation to the current market.

WP3:

The main achievements of this period can be summarised as follows:
Although the materials used in the panel are similar the fixing mechanisms differ from manufacturer to manufacturer. The processing sequence is different from panel to panel. Because of the complex structure of LCDs the most efficient treatment can only be achieved by manual dismantling. The complex structure and huge variety of different panels also prevent the automation of the process.

WP4:

The main achievements in WP4 has been the exchange of information with the User Adivsory Board and the development of guidelines for sustainable LCD design.

Section 2

Workpackage progress of the period

Work package title: **LCD Test & Refurbishment**	WP No: **1**
Starting Date: Month 1	Duration: 18 months

Objectives:

- to find a test strategy for incoming, used LC displays according to their function
- to evaluate, whether the LCD is qualified for refurbishment or for material recycling.
- to develop a method to refurbish LCDs
- to work out guidelines on LCD extraction for pre-disassembly centres in order to enable re-use

Deliverables:

D1 LCD test strategy and description of methodology (Report)

D2 Pilot database of LC-Displays for the test

D3 Refurbishment methods including detailed description of methodology (Report)

Milestones:

M 1.1 Functionality test method has been found and pilot database established

M 1.2 Refurbishment criteria and method have been proven

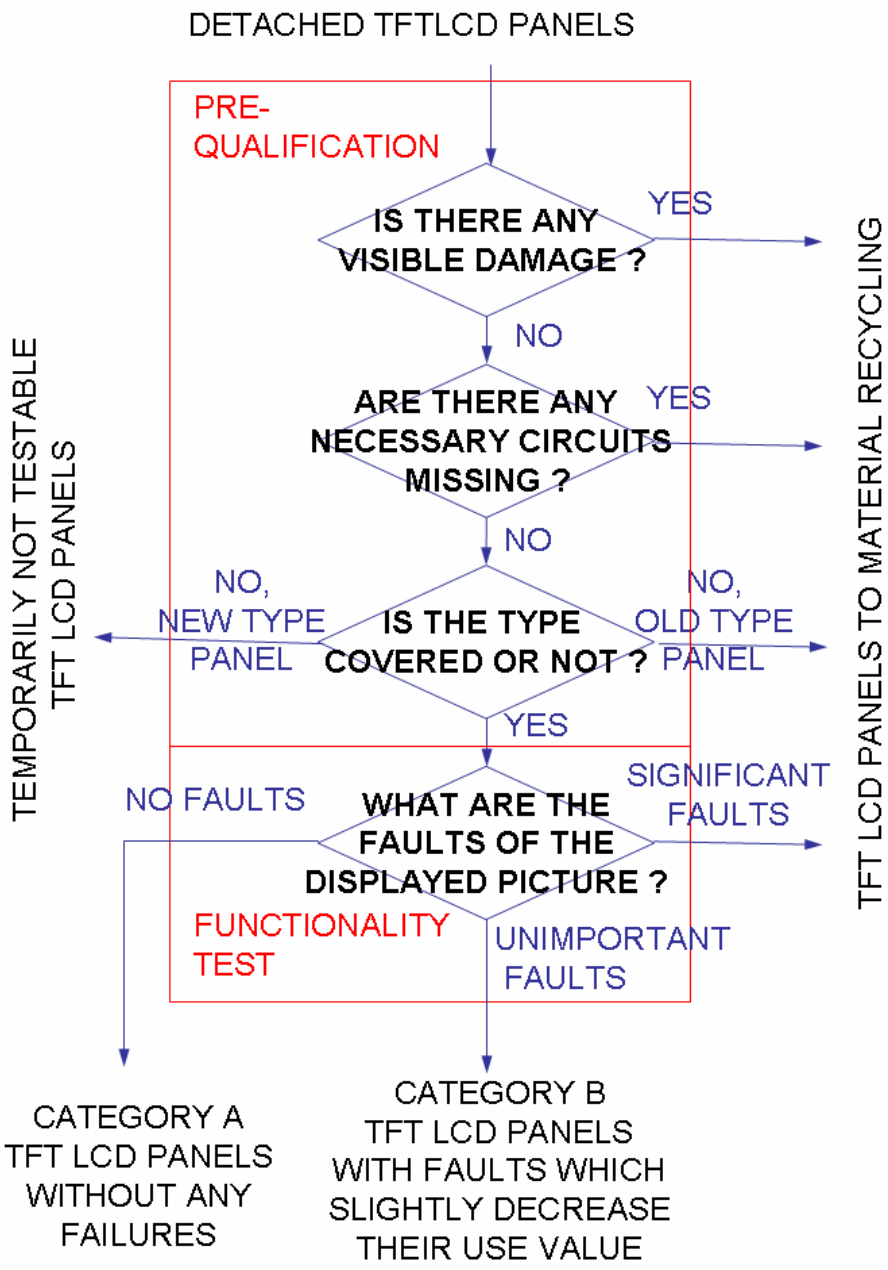
Progress towards objectives:

Task 1.1: Development of a test strategy

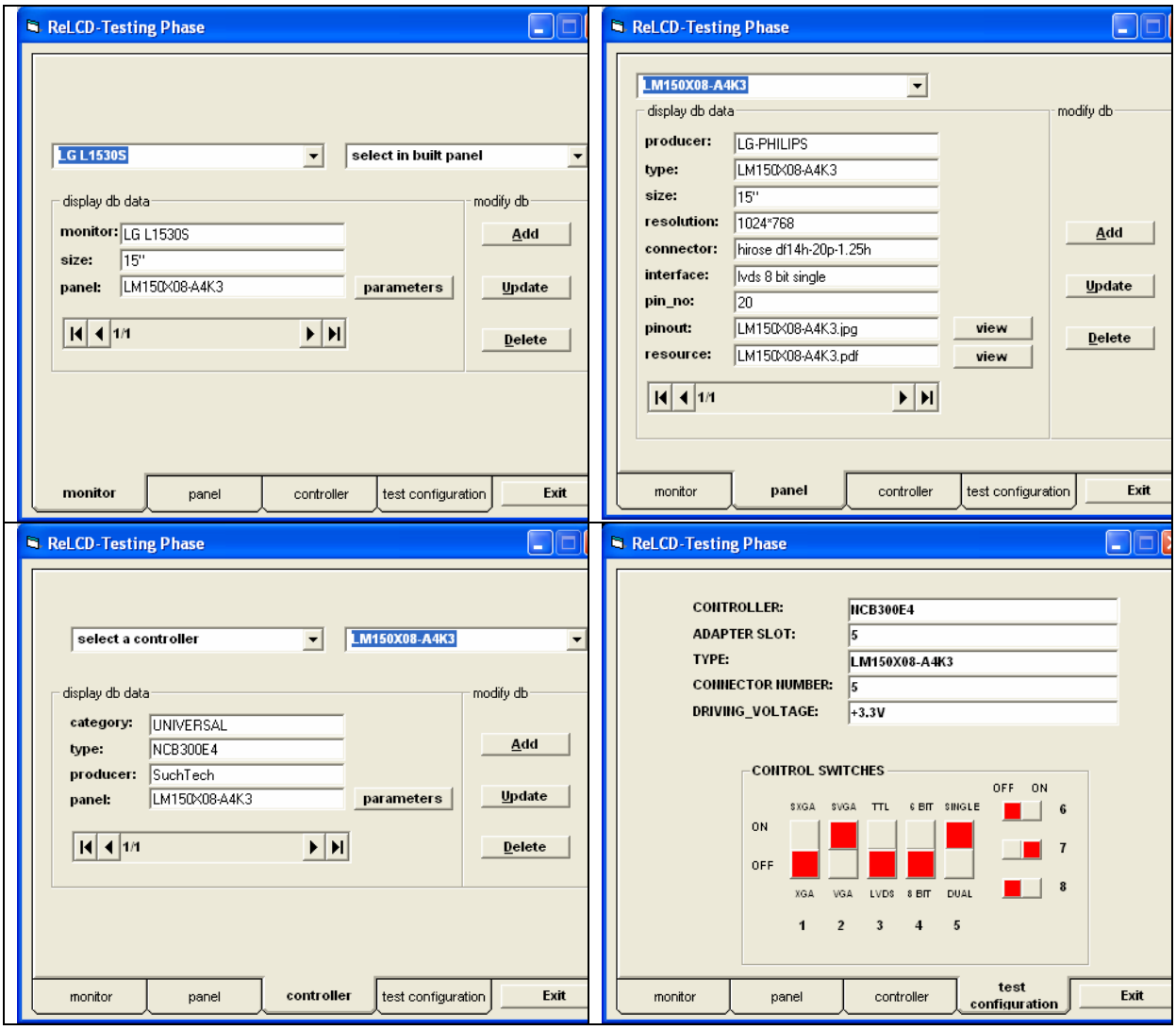
The main part of this task was fulfilled during the previous reporting period. This stage was for improving and completing these results, and preparing them for working out in practice at WP 3. During the second reporting period this task was focused on reconsidering and modifying test conception according to the results of practical working out of test system in WP 3, additional data collection, and improvement of testing database software.

Subtask1: The test conception was simplified as it is focused only on detached TFT modules, and the existence of universal test unit is supposed. The experiences during practical trials with the developed test equipment and database software helped to identify unnecessary steps and form testing procedure as simple as possible. The steps of testing procedure were exactly defined including necessary conditions, tools, and possible barriers.

The flow chart below details the work within subtask 1.



Subtask2: Test database was also greatly improved, both its data set was enlarged and its interface was adapted to be more informative and user-friendly. The latest version of database contains all necessary technical information of 494 LCD modules. The interface of the database makes the work of testing staff more simple and fast by providing information about necessary connector types and interface setting for each LCD module types. Additionally it also gives information about the type of LCD module built in a given LCD equipment (mainly LCD TFT monitors) at 275 monitor types. The picture below shows main windows of the database application.



Task 1.2: Refurbishment / Re-qualification of LCDs

Subtask1: The aim of task 1.2 was to develop a methodology for refurbishment of used LCDs. The task mainly covered the working out of detailed process descriptions, and defining steps of refurbishment. It is started with information collection about existing refurbishment practices. As the existing activities related to other products and pot particularly to Liquid Crystal Displays, these were adapted to this task. It was identified, what are the possible inputs (e.g. detached modules, desktop monitors, etc.), and the necessary steps were formed according to their special requirements. However, as other tasks of workpackage were focussed on detached modules, this subtask was also concentrated on them.

The possible and necessary refurbishment steps were defined and briefly summarised, and the proposed refurbishment procedure was formed.

As an option, the possible repair activities were also surveyed and summarised in the report.

The pictures below illustrate the replacing of a polariser layer as one possible technology for LCD refurbishment.

Deviations from the project workprogramme, and corrective actions taken/suggested:

NONE

Work package title: **Technology of LCD Disassembly & Recycling**	WP No: **2**
Starting Date: Month 4	Duration: 12 months

Objectives:
1.) Detection method to determine consisting materials/substances
2.) Components/materials/substances separation method
3.) Material Recycling

Deliverables:

D4 Report on possible ways to detect materials/substances used in LCDs, description of best methodology

D5 Report on separation methods, proposal on possible technology including a detailed description

D6 Report on best available and developed methods for material recycling

Milestones:

M 2.1 All detection methods have been investigated and the most promising identified and tested

M 2.2 All separation methods have been investigated and the most promising identified and tested

M 2.3 All recycling methods have been investiga ted and the most promising identified and test

Progress towards objectives:

Task 2.3: Evaluation of existing methods for material recycling and development of new recycling technologies

According to the activities carried out in the task 2.2, all the LCD components that have been separated, have been analysed in order to find the most feasible recycling option for each one, summarised in Table 1.

Table 1. Current recycling options for material recovered

	Most Feasible Option	Secondary Option
Display	Option: Management *Cost: -0.10 €/kg Application: Landfill	Option: Material Recycling Price: ? Conditioning: Organic matter removal Application: ?
PMMA	Option: Material Recycling **Price: €/kg Conditioning: Grinding Applications: Head lamps, sinks	Option: Reuse Price: ? Conditioning: ?
Metals	Option: Material recycling **Price: 1.11 €/kg	

	Conditioning: Scraps Applications: Blast furnaces	
PCBs	Option: Material recycling *Price: 0.18 €/kg Applications: Copper smelter	
Plastic frames (PC)	Option: Material recycling **Price: 0.61-0.72 €/kg Conditioning: Grinded scraps Applications: Injection parts	Option: Reuse Price: ? Conditioning: ?
Films	Option: Management *Cost: -0.10 €/kg Application: Landfill	Option: Material recycling **Price: 0.23-0.42 €/kg Conditioning: Grinded scraps Applications: Fibres, strappings, sheets

*Cost for inert waste in Spain. to be checked for particular situations and wastes
**Source: Spanish "Recycling & Recovery" Magazine

Taking account the recycling options described before, just two of the LCD components could be reused by means of a reprocessing step, PMMA and PC. In order to characterise the possible fillers in these recoverable components, several calcinations tests have been carried out, burning to ashes the plastics at high temperatures and remaining the fillers. The results are showed in Table 2.

Table 2. Contained fillers in LCD components, PMMA and PC

	FILLER	% FILLER
PMMA	-	-
PC black	Fibre glass	7.95
PC white	Fibre glass	22.82

POLYCARBONATE FILLERS	
	
Black polycarbonate	White polycarbonate

Once considered all options for each LCD component, it is time to define a recycling strategy. For that it is necessary to take account the current directive about WEEE which establishes that all the LCD smaller than 100 cm^2 can be landfilled while the LCD bigger than 100 cm2 must to be accurately treated.

According to this, the first step would be the testing made by Bay Zoltan, which would confirm LCD state and separate reusable LCD. In the other hand, damaged LCD would be treated in a second step, although for its definition it is necessary to take

account again the directive WEEE which forces to remove and manage properly all lamps with Hg.

This condition implies a decontamination step previously to the recycling scheme in order to remove the Hg lamp. This removal could be carried out in two different ways:

- **Manual dismantling:** in the purpose of removing the Hg-lamp by a manual dismantling, it has been tested that all the LCDs components are obtained separately so this way for the removal of the lamp will determine one of the possible recycling scheme.

- **By a cutting system:** the decontamination of the Hg-lamp will be carried out by means of a first identification in order to know the position of the lamp, followed by a cutting system, as it is shown in the Figure 1.

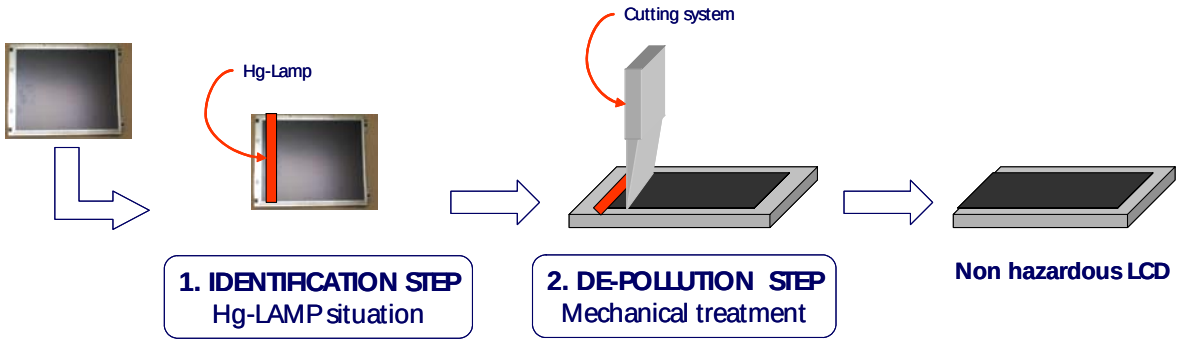


Figure 1. Hg-Lamp removal by a cutting system.

According to these different ways for removing the lamp, two recycling schemes have been developed and described next.

① Recycling scheme: Manual Dismantling

As it has been described before, a manual dismantling has been chosen for the decontamination step, however it has been tested that at the same time the lamp is recovered, the rest of the components are obtained too. In this way, just a sorting step would be necessary after the dismantling in order to separate each fraction, obtaining LCD materials without impurities. In Figure 2 it is shown the complete process.

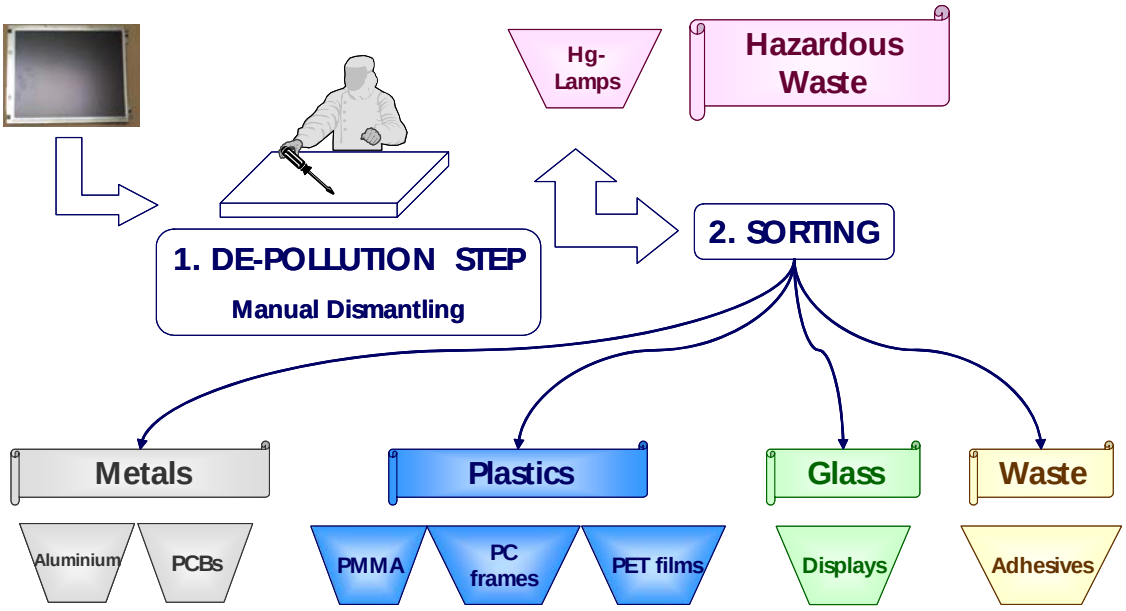


Figure 2. Recycling scheme by Manual Dismantling

② Recycling scheme: Mechanical Treatment

After the Hg-lamp removal by the cutting systems, a mechanical treatment has been defined in order to obtain the components separated, employing different recycling technologies. In Figure 3 it is shown the proposed scheme. Firstly, a LCD without toxic lamps is shredded in order to reduce the size and separate the components between them because at the beginning they are joined by the screws and different kind of clips. Secondly LCD pieces are transported to an aspiration system where the films and dust are removed due to its low density. The next step is an Eddy Current device where the ferrous and non ferrous components are separated from a mixed fraction (PC, PMMA and Glass). This mixed fraction is treated in a Densimetric Table, where the differences between the plastic and the glass densities would make possible the separation in two fractions, the plastics (PMMA, PC) and the glass.

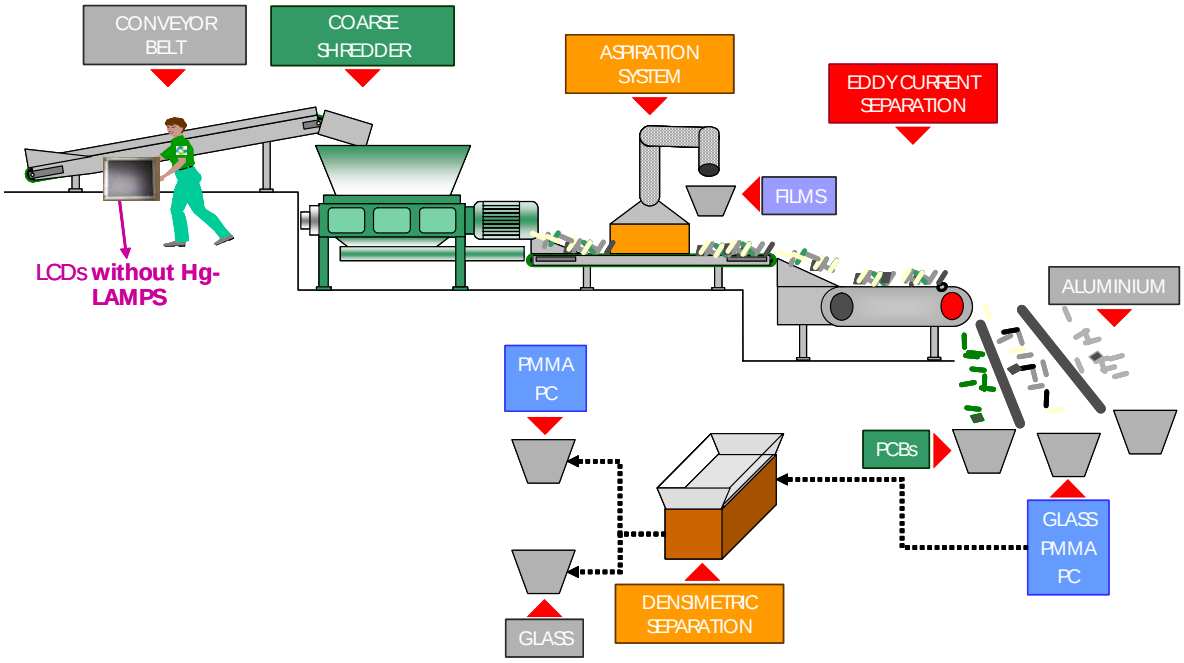


Figure 3. Recycling scheme by Mechanical Treatment

Deviations from the project workprogramme, and corrective actions taken/suggested:

NONE

Work package title: **Design & Evaluation of a laboratory pilot system**	WP No: **3**
Starting Date: M 10	Duration: 15 months

Objectives:

- to design and set up a pilot system (in a laboratory scale) for the testing, refurbishment, disassembly, material separation and recycling of LCDs
- to evaluate the environmental and economical feasibility of this system

List of deliverables:

D7 Layout of the pilot system
D8 Prototype (laboratory scale) of the pilot system
D9 Evaluation Report

List of milestones:

M 3.1 Overall pilot system and each module specified
M 3.2 Modules and overall system implemented and in operation
M 3.3 Evaluation finished

Progress towards objectives:

The objective was to find a treatment technology for Liquid Crystal Displays which separates into hazardous (backlight lamp) and non-hazardous (rest) material fractions.
The following treatment technologies have been tested:

- Manual dismantling
- Water Jet Cutting
- Laser Cutting
- Circular Saw

And evaluated considering the following parameters:

- Mean processing time
- Maintenance costs
- Personnel costs
- Material revenues

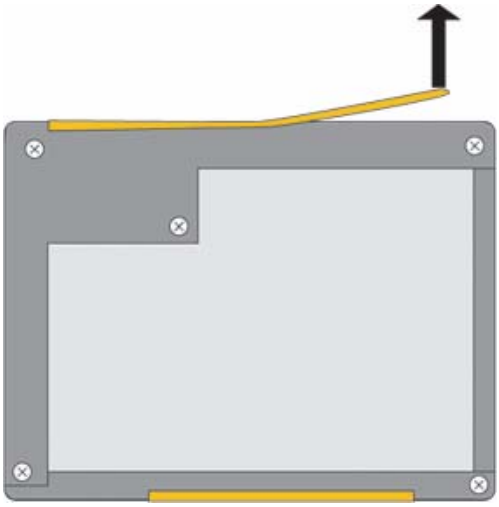
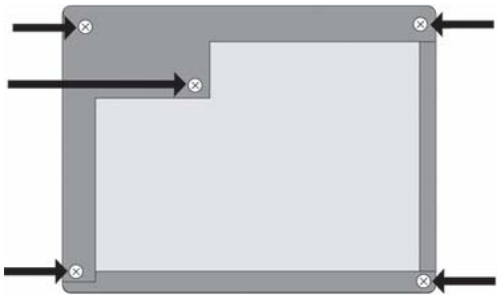
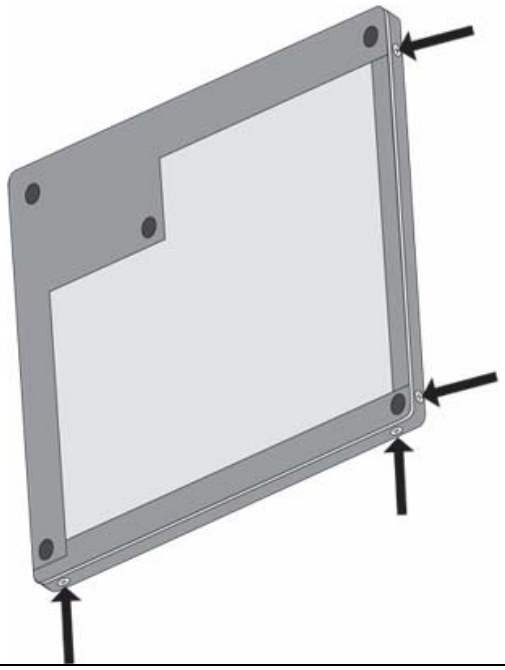
Although some alternative treatment technologies were investigated the best results were achieved by manual dismantling. Both the costs per item and the quality assessment reach the best results. Especially the high investment costs of jet cutting and laser cutting result to an inefficient cost trend especially for low volumes. After the amortisation time and huge volumes Laser cutting can be competitive to manual dismantling. As the recycling amount of LCDs for the next years is hard to estimate high investment costs will also cause to a high financial risk.

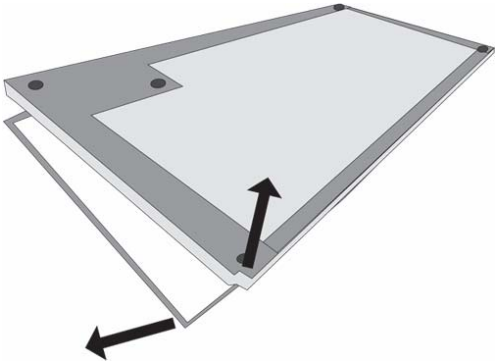
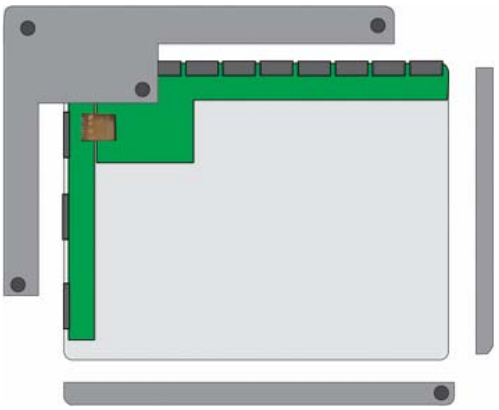
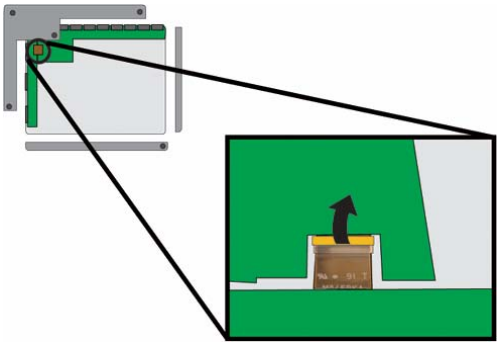
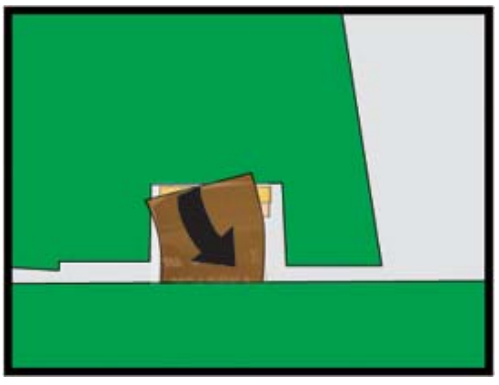
Sawing technologies like circular sawing or band sawing will be inefficient because of the material composition of LCD panels. Although a huge variety of special designed saw blades are available no one fits all requirements which are necessary to cut LCD panels. Especially the content of glass result to difficulties and the lifetime of the sawing-blade is reduced heavily. The short lifetime of the sawing equipment will result to very high variable costs. Hence sawing can never be competitive to manual dismantling.

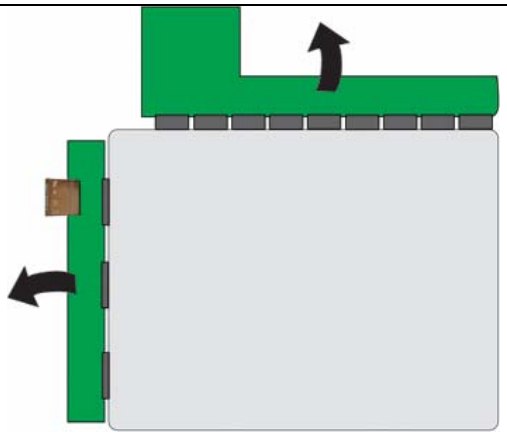
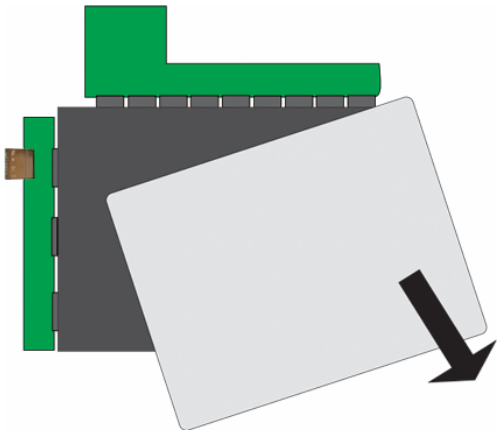
It can be also stated, that some manufactures already consider requirements for dismantling. Our investigations show that already 40% of the panels are designed disassembly friendly. As we expect a rising of the percentage in the future manual

dismantling will become efficient anymore. A percentage of 60% will reduce the mean dismantling time to 1,4 min. An dismantling time of 1,4 min per panel prefer manual dismantling to other technologies (e.g.: Laser cutting …) even in countries with high labour costs.

The following Figure shows the guideline for manual dismantling of LCD-modules:

1. Remove tape from all edges.	
2. Unscrew all Philips screws from back face.	
3. Unscrew Philips screws from all sides.	

4. Prise off bezel from front face. Use your fingers, but be careful as bezel can be very sharp.	
5. Remove all metal plates from back face.	
6. To remove cable, first push up cable securing flap.	
7. After lifting the cable securing flap, the cable can be pulled out.	
8. Lift up all circuit boards.	

	
9. Lift off all layers to reveal LCD. The LCD is connected to the circuit boards. These connections can be removed by simply peeling the circuit board tabs away from the glass plates of the LCD.	

In accordance with WP2 conclusions, **Mechanical Treatment** has been selected as the most feasible recycling option for the LCD without Hg-lamp recycling, because of its versatility and profitability. In Figure 4 it is showed the defined scheme with Industrial equipment.

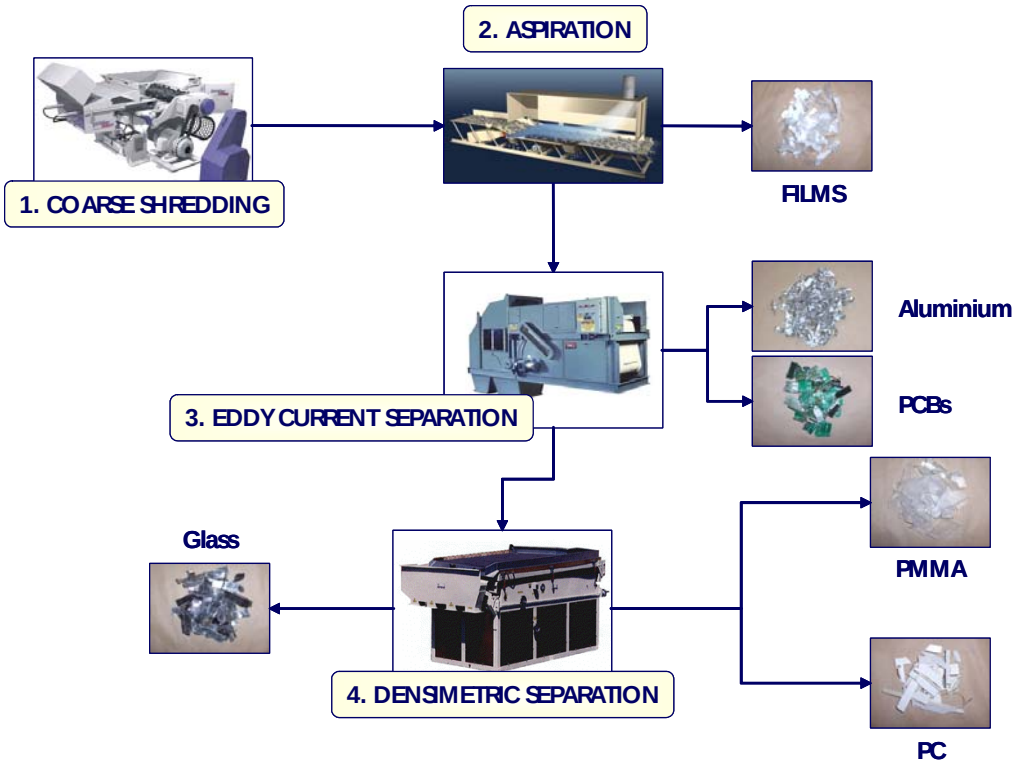


Figure 4. Industrial equipment for LCD recycling by mechanical treatment

However, the most difficult step has been the Densimetric separation. Densimetric tables are used to provide a separation of particles differing in their specific gravities. The specific gravity of a particle is the ratio of its density to some standard substance and air is used as the separating standard through the process of stratification. Stratification occurs by forcing air through the particle mixture so that the particles rise or fall by their relative weight to the air.

All gravity separators have five variable adjustments that must be properly adjusted and balanced to obtain optimum separations. These are feed rate, end raise, side tilt, eccentric speed, and air control. In Figure 5 a scheme of GAIKER's device is shown.

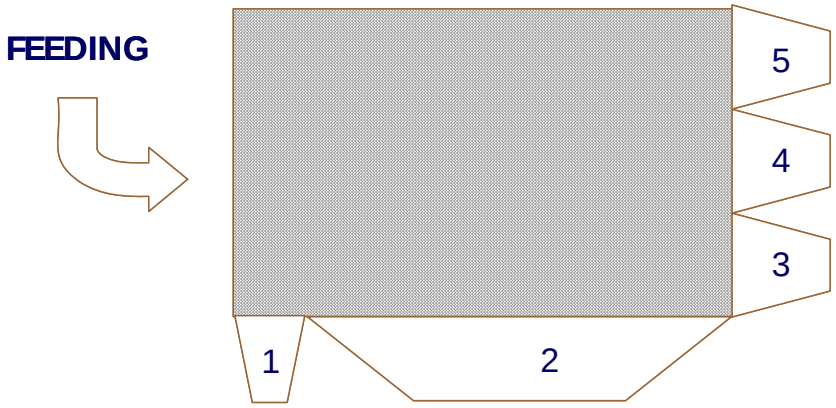


Figure 5. Top view of GAIKER's densimetric table.

The main objective of the Densimetric table in LCD recycling is to separate some of LCD materials, the glass and a mixture of PMMA/PC. For this purpose, several tests have been carried in order to optimise the step, obtaining plastics without any impurity of glass. The sample composition which has been tested is detailed in Table 3:

Table 3. Initial composition of sample by weight

Fraction	%
Glass	27,7
PC	4,50
PMMA	67,8

As it has been described before, the Densimetric table has five different parameters to adjust, however the size and shape of the particles have influence in the results too. According to this, the sample has been reduced to different size particle and the tested. The final results obtained are detailed in Table 4:

Table 4. Recovery ratio of LCD materials

RECOVERY RATIO FOR EACH MATERIAL	GRINDED 15 mm			SHREDDED		
	GLASS	PC	PMMA	GLASS	PC	PMMA
RECOVERY FRACTION	7,00%	38,9%	91,0%	15,8%	85,1%	80,7%
REJECTED FRACTION	93,0%	61,1%	9,00%	84,2%	14,9%	19,3%
TOTAL	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**

Finally, the composition of the rich final fraction (branded as recovery fraction in Table 4) has been calculated and it is detailed in Table 5:

Table 5. Composition of final rich fraction by weight

COMPOSITION OF RICH FINAL FRACTION (by weight)	GRINDED 15 mm	SHREDDED
GLASS	3.0%	6.9%
PC	2.6%	6.1%
PMMA	94.4%	87%
TOTAL	**100%**	**100%**

In this workpackage a further task was to prepare the layout of the functionality test module, and to develop the necessary test equipment for it according to the results of previous research in WP 1.

Subtask1: As the key component of the LCD test system, a special LCD module test equipment was developed, and a prototype was built, put into operation and tested with a huge number of different LCD module types. The developed test equipment is based on a semi-universal controller board purchased from a vendor.

To form the test equipment as universal as possible, connection between the equipment and LCD modules with different connector types had to be solved. Therefore different connectors were collected mainly with the help of partners, and were adapted to the test equipment. Making connectors available to attach them to the controller board of test equipment was one of the most labour-consuming part of this subtask.

The other important problem had to be solved for universality was to adapt pin configuration of controller board to different LCD module types. For this purpose, special patching boards were made that enlarge the number of testable LCD module types.
A wide range of different display types were collected, and the usability of the developed test equipment was demonstrated.
The test system was complemented with a bar code reader that is integrated with the database software. It maintains the testing procedure by simplifying identification of displays and setting of test equipment during the functional test

Subtask2: A proposed layout of the functionality testing module in the LCD recycling laboratory pilot system was worked out, having regards to logistical aspects. The tasks and localisation of its parts (input and output stocks, functionality test and backlight remover workstations) were exactly defined, and its operation was considered with different scenarios

Deviations from the project workprogramme, and corrective actions taken/suggested:

NONE

Work package title: **Guidelines for Sustainable LCD Design, Production & Recycling**	WP No: **4**
Starting Date: M 16	Duration: 9 months

Objectives:

- To elaborate “Guidelines for Sustainable LCD Design, Production & Recycling”
- To establish an information platform in order to transfer these outcomes

Deliverables:

D10 Information Platform established & start of public project presentation
D11 Guideline for sustainable LCD design

Milestones:

M 4.1 Information platform and User Advisory Board established
M 4.2 Guidelines for Sustainable LCD Design, Production & Recycling ready

Progress towards objectives:

Task 4.1 Guidelines for Sustainable LCD Design, Production & Recycling

The main result of WP4 consisted of the aim for the optimum re-design of LCD containing products with economical EoL in mind. Investigations were made on different types of joints/releasable mechanisms within the various sub and macro-assemblies of laptop and desktop LCDs. A large number of specialized ideas were thoroughly investigated. The candidate products will need to be re-designed and assembled such that they are economical to disassemble at their EoL in 2 or 3 years. These concepts ranged from radical and ‘blue sky’ to more conventional readily achievable designs. As planned at outset of the project, Active Disassembly (AD) and Active Disassembly using Smart Materials (ADSM) were the main technological themes.

General Design for Disassembly (DfD) guidelines have been compiled and referenced from existing sources, including those set out by Boothroyd and Dewhurst. This task was carried out as a starting point to producing applicable guidelines for sustainable LCD design, production and recycling, as well as forming the basis of the future concepts we have created for the problems found in existing LCD module design. The DfD guidelines cover material selection, component design & product architecture, use of fasteners and design for Active Disassembly.

Similar to the DfD guidelines, general Design for the Environment (DfE) guidelines have been compiled to outline environmentally-sensitive design strategies which can be applied to guidelines for sustainable LCD design, production and recycling. The document takes into account the entire product life cycle from material processing to product end-of life, and covers both the material and logistic elements of environmentally-sensitive design.

Task 4.2 Information Platform - User Advisory Board

The User Advisory Board consists of the ReLCD consortium and the LCD manufactures and recyclers from around the world.

From the beginning of the project, various problems relating to existing LCD macro and subassembly construction were explored by the entire consortium. These problems and suggested solutions were presented to the established User Advisory Board at the mid-term meeting. Examples of this information includes materials used, the mercury-containing backlight on older models, fasteners, and location of internal components (i.e. the PCBs) etc. With suggestions from the User Advisory Board at the mid-term, recommendations were investigated resulting in potential design problem solutions. To this end, the concepts for future design of LCD macro, subassemblies, connectors and fasteners. Furthermore, a wide range of initial concept solutions making use of ADSM technology has been explored with additional Active Dissassembly concept solutions modeled in 3-D addressing the problems of current LCD designs highlighted by the User Advisory Board.

The information loop initially frequented by the User Advisory Board will continue to serve the consumer eletronics LCD sector through a dedicated website for ***`design-manufacture-to-recycler-to-design'*** information loop to improve subsequent reiterative design and life cycle processes. The current website is:

www.activedissassembly.com > Projects > ReLCD

For the information platform, GAIKER has contributed with the recording of a video demonstration, on which recycling scheme steps are showed with the preparation and obtaining of the recycled plastic materials (PMMA, PC and mixtures of PMMA/PC). Some images of the video-demonstration are showed in the figure below.

Images captured from the video demonstration downloadable at the ReLCD Webpage

Deviations from the project work programme, and corrective actions taken/suggested:

During the project it became evident that more time would have to be devoted to WP4. This was largely due to the observation for the need of a varying level of re-design required for larger LCD containing products. Due to the economic realities of the current recycling logistics, limited (but usually non-existent) profit could be realized and therefore, a relatively few LCDs would be practically recycled. From the investigation of the current practise in LCD recycling from WP1 & WP2, it became obvious that too few working LCD products would reach our recycling facilities for economic refurbishment. It was therefore decided that there would be a significant resource allocation shift to WP4 to investigate answers to this unforeseen market balance. In the future with significantly improved DfE and DfD considerations at the outset of LCD design, recycling logistics would be profoundly improved. Superseding this, 'Design for Active Disassembly' (DfAD) taken into consideration, at the outset, would further improve this situation. These revolutionary changes would result in drastic reductions of this sector of consumer electronics products destined for landfill. Additional benefits would be realized by a new recycling industry of jobs.

List of deliverables

Del. No[1]	Deliverable name	WP No	Lead Part.	Est. person-months	Nature[2]	Delivery date
D1	LCD test strategy (Report)	1	BZF	15	R	M7, Year 1
D2	Pilot database for the test	1	BZF	3	P	M12, Year 1
D3	Refurbishment methods	1	BZF	15	R	M5, Year 2
D4	Report on possible ways to detect materials/substances used in LCDs	2	Gaiker	16	R	M11, Year 1
D5	Report on separation methods	2	Gaiker	11	R	M1, Year 2
D6	Report on best available and developed methods for material recycling	2	Gaiker	8	R	M3, Year 2
D7	Layout of the pilot system	3	Ecotronics	20	O	M3, Year 2
D8	Prototype (laboratory scale) of the pilot system	3	Ecotronics	15	P	M6, Year 2
D9	Evaluation Report of test phase	3	Ecotronics	7	R	M12, Year 2
D10	Information Platform & public project presentation	4	SAT	10	O	M6, Year 2
D11	Guideline for sustainable LCD design	4	SAT	10	O	M12, Year 2
D13	12 month report and Cost Statements (period 1)	5	Ecotronics	2	R	M2, Year 2
D14	Mid-Term Assessment Report, Draft Exploitation Plan	5	Ecotronics	1	R	M2 Year 2
D16	Final Technical Reports and Cost Statements	5	Ecotronics	2	R	M12, Year2
D17	Final Exploitation Plan	5	Ecotronics	1	R	M12, Year 2
D18	Public Final Report	5	Ecotronics	1	R	M12, Year2
			TOTAL	139		

[1] Deliverable numbers in order of delivery dates: D1 – Dn

[2] Please indicate the nature of the deliverable using one of the following codes:

R = Report
P = Prototype
D = Demonstrator
O = Other

List of milestones

Milestone No	Milestone name	WP No	Lead Part.	Forecast Delivery date	Actual Delivery date
M 1.1	Functionality test method has been found and pilot database established	1	BZF	Month 12	Month 11
M 1.2	Refurbishment criteria and method have been proven	1	BZF	Month 18	Month 18
M 2.1	All detection methods have been investigated and the most promising identified and tested	2	Gaiker	Month 12	Month 12
M 2.2	All separation methods have been investigated and the most promising identified and tested	2	Gaiker	Month 12	Month 14
M 2.3	All recycling methods have been investigated and the most promising identified and tested	2	Gaiker	Month 15	Month 15
M 3.1	Overall pilot system and each module specified	3	Ecotronics	Month 12	Month 16
M 3.2	Modules and overall system implemented and in operation	3	Ecotronics	Month 20	Moth 20
M 3.3	Evaluation finished	3	Ecotronics	Month 24	Month 24
M 4.1	Information platform and User Advisory Board established	4	SAT	Month 18	Month 18
M 4.2	Guidelines for Sustainable LCD Design, Production & Recycling ready	4	SAT	Month 24	Month 24
M5.1	Kick-off Meeting, Steering Board, Management Office and Help-Desk established	5	Ecotronics	Month 3	Month 1
M5.2	Mid-Term Assessment Report	5	Ecotronics	Month 13	Month 13
M5.3	Mid-Term Project Review Meeting	5	Ecotronics	Month 14	Month 13
M5.4	Final Progress Report, Final Cost Statements, Exploitation Plan	5	Ecotronics	Month 24	

Section 3

Consortium management

Consortium management tasks and their achievements:

Task 5.1 Steering Board

The steering board has been established at the Kick-off Meeting in Vienna on March 12, 2004. It consisted of one representative and one substitute form each partner. Head of the steering board was Ecotronics.

Task 5.2 Management Office

The Austrian Society for Systems Engineering and Automation (SAT) provided a Project Secretariat for:

- Administration of partners,
- Administration of consortia agreements ,
- Distribution of funds,
- Compilation of progress reports,
- Organisation of meetings,
- Distribution and exploitation activities.
- preparing, updating and managing the consortium agreement between the participants

The Austrian Society for Systems Engineering and Automation will also coordinate the User Advisory Board.

The following project meetings have taken place during the reported period:

Date	Place	Descripiton
09. – 10.05.2005	Aachen	Project Meeting
15. – 16.09.2005	Vienna	Project Meeting
06. – 07.03.2006	Vienna	Project Meeting and Public Workshop

At all Meetings at least one representative of each partner has been present.

Communication
The communication among the partners worked very well during the reported period and carried out mainly via email and phone calls.

Task 5.3 Review and Assessment

The Mid-Term Meeting took place on May 9-10, 2005, at RelektrA - Aachen (Germany).

Task 5.4 Exploitation Plan

According to the DoW a exploitation plan has been prepared.

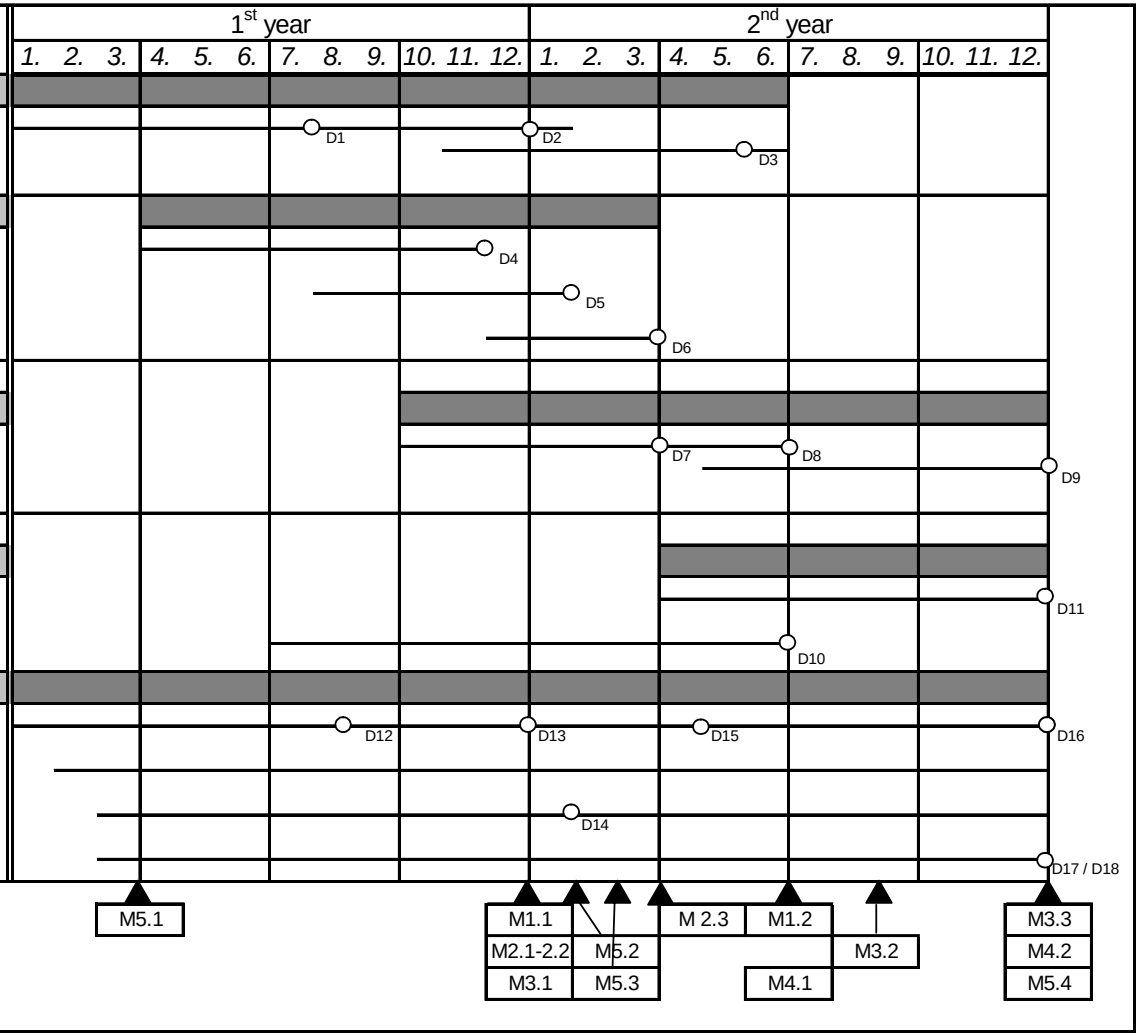
Changes in Responsibilities

NONE

Project timetable and status

STATUS: Finished

Workpackage and Task description	*Person-month*
WP1: LCD Test & Refurbishment	**33**
1.1 LCD Functionality Test	18
1.2 Refurbishment / Requalification	15
WP2: Technology of LCD Disassembly & Recycling	**37**
2.1 Material Detection	16
2.2 Material Separation	12
2.3 Material Recycling	9
WP3: Design & Evaluation of Disassembly & Recycling System	**40**
3.1 Design of System (laboratory)	35
3.2 Evaluation of System (laboratory)	5
WP4: Guidelines for Sustainable LCD Design, Production & Recycling	**18**
4.1 Guidelines (Internet)	10
4.2 Information Platform (User Advisory Board)	8
WP5: Project Management	**11**
5.1 Steering Board	1
5.2 Management Office	5
5.3 Review and Assessment	3
5.4 Exploitation Plan	2



Section 4
Other Issues

The overall contributions of the group of SMEs have been:

- Information about LCD containing products coming back for recycling – mixture of the different product types, conditions of the products, …
- Information about current practices to deal with LCS containing products
- Providing of LCD samples for tests
- Information about markets for the recycling of material fractions of LCDs
- …

The overall contributions of the group of RTD performers have been:

- Detailed analysis of LCDs – structure, material content, used controllers,…
- Development of procedures for the testing of LCDs
- Development of strategies for the disassembling and recycling of LCDs
- …

Annex

Plan for using and disseminating the knowledge