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Recycling of Plastics from LCD Television Sets

Pilot project on mechanical plastics recycling from post-consumer flat panel display-LCDs

In 2013, EFRA finalized a pilot project on the recycling of plastics containing flame retardants from Liquid Crystal Display (LCD) TVs in cooperation with the REWARD and PRIME projects. Important partners of the pilot project included TV manufacturers, plastics & flame retardant manufacturers, waste management operators, recyclers and knowledge centres.

EFRA is committed in contributing to the achievement of the highest possible recycling rates and to produce high quality recyclates from waste containing flame retardants (FR). Plastic waste containing flame retardants from LCD sets is a fast increasing waste stream, which is forecast to represent a total annual volume of 100,000 tons in Europe. It is therefore essential to provide proof of recyclability for these plastics.

The aim of this study:
To analyze the technical feasibility of recycling flame retardant plastics and to demonstrate closed-loop recycling of flame retardant plastics from end-of-life (EoL) TVs, whilst considering both economical and ecological constraints.

WEEE: a growing resource

In Europe the annual amount of waste plastic originating from Waste of Electric and Electronic Equipment (WEEE) is expected to increase to 2.5 million tons, of which 700,000 tons is expected to contain FRs.

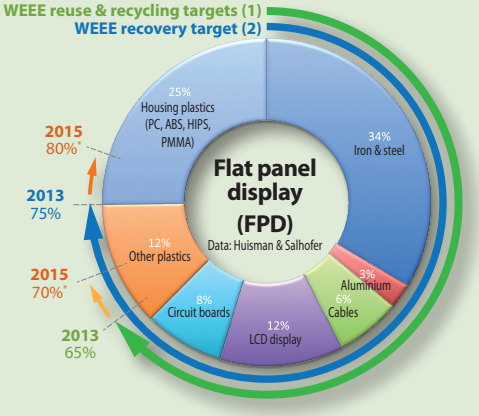
In addition, up to 3.9 million tons of similar engineering plastics can be expected to arise in Europe from End-of-Life Vehicles (ELVs). From the collected WEEE, only 12% wt. of plastics and almost no FR plastics are currently recycled in Europe. Furthermore, over 50% wt. is assumed to be exported from Europe. For plastics from ELVs, similar recycling rates are expected.

Materials from WEEE are very diverse and can include potentially harmful pollutants such as lead, chromium VI, cadmium, mercury. On the other hand, WEEE contains valuable resources like precious metals, and of course a substantial amount of high quality engineering plastics. Therefore, **WEEE should be seen as a haven of growing resource**.

Higher EU recycling targets needed for plastics

In the EU, WEEE is managed under the WEEE Directive (2012/19/EU Directive), which includes stringent recycling targets for WEEE collection, as well as recovery, reuse and recycling targets. These recycling and recovery targets range from 50% to 80% wt. For the post-consumer LCD televisions waste stream, percentage targets will increase for recycling from 65% to 70% wt. in 2015, and for energy recovery from 75% to 80% wt. Around 26% wt. of WEEE plastics and 31% of the current plastics of waste FPDs are flame retardant and some categories contain up to 30% wt., so plastics need to be recycled to meet these targets. In addition, the European Commission has the ultimate goal of zero landfill by the year 2020, as stated in the EU Greenpaper (http://europa.eu/rapid/press-release_IP-13-201_en.htm). Therefore, without further developing recycling of the plastic components from LCDs, the relevant EU recycling targets will not be met.

Graph 1.



WEEE Directive recycle targets and plastics of TV sets materials recycling (Graph 1.)

The graph depicts the material content of FPDs, compared to WEEE directive reuse, recycling and recovery targets.

The materials distribution from post-consumer flat panel display units (FPDs) varies from one model to the other. FPDs are a combination of plasma screens, LCDs screens either with LED or Cold Cathode Fluorescent Lamps (CCFL) as back lighting and OLED screens. On average, the plastics fraction represents around 40% wt. It is clear from Graph 1. that mechanical recycling of the plastic fraction from FPDs will be critical to meeting the re-casted WEEE directive recycling target.

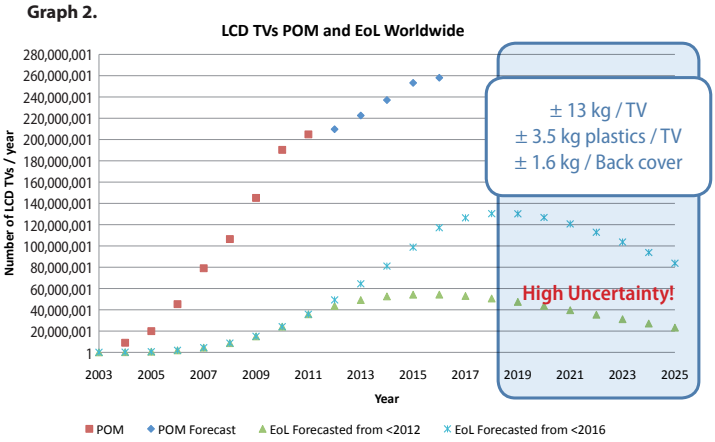
(1) Includes reuse & recycling (see thereafter) as well as energy recovery. **(2)** Includes reuse of parts materials recycling
* Targets applicable to brown goods from the Common Position on the recast WEEE Directive (2011)

More flame retardant plastic from LCD TV sets and also more LCDs are reaching their end-of-life

A CENELEC standard, applicable to television sets since July 1. 2010, requires that external housing resists candle flame ignition (EN 60065/A11: 2008), which will result in a significant increase in the share of plastics from LCD TV sets that contain FRs (UL94 V1 or better).

In addition, TV sets have undergone a major evolution, with a shift away from traditional Cathode Ray Tube (CRT) technology to newer technologies i.e. Flat Panel Displays (FPD) including LCD/LED and plasma technologies. The production of CRT TVs rapidly decreased while the number of FPDs Put on Market (POM) dramatically increased; from a few thousand up to almost 200 million FPDs globally in 2013 (see Graph 2). Normally these TVs will appear via a shift in the WEEE fraction for CRTs (10-15 years) and for LCDs (average 7 years) later.

Graph 2.



The LCD recycling pilot project

Problem: Despite the amount of valuable materials contained in WEEE, and the targets and regulatory obligations related to their recycling, only 12% wt. of the collected WEEE plastics were recycled in Europe in 2010, according Plastics Europe.

Objective: To advance the techniques enabling high rates for closed-loop recycling of the plastic fraction containing phosphorus based or brominated flame retardants of Flat Panel LCD Displays.

Methodology: The project analyzed the technical feasibility and economic viability of closed loop recycling of EoL LCD TVs, through selective collection, dedicated shredding or disassembly, separation and marketing of recovered substances for reapplication in LCD housings or similar applications.

The project was split into 3 parts: plastic properties analysis, recycling trials and miscibility testing.

1. Plastics properties

Objective: Characterization of the waste stream and analysis of the quality and value of disassembled fractions is necessary to obtain information on the highest possible recycling rates. The recyclability of the plastics PC/ABS and HIPS/PPE with phosphorus based FRs (PFR) and HIPS and ABS with/without brominated FRs (BFR) and ATO (antimony trioxide) and the plastic composition of 610 LCDs TVs was evaluated.

Results

- 17% of plastic back covers contain HIPS with 2 types of BFRs and 26% contains PC/ABS with PFRs
- A recycler checked possible new outlets via TP Vision which was working well
- Physical properties of aged plastics with PFRs/BFRs were tested by SABIC, Bayer, Styron and Total and further mixed with virgin plastics (80-90% wt.). They showed good recyclability and could be successfully reapplied in new back covers
- For aged plastics, additional additives can be required.

2. Recycle trials (manually and mixed)

Objective: To obtain correct information on the efficiency of sorting post-consumer plastic mix from LCD TV sets in an industrial setting, into "single type" plastics for reapplication into the same applications as the original, in this case to be reapplied as housing plastics.

Results

- Separation of plastics with BFRs using XRF and DE-XRT (Dual Energy X-Ray Transmission) was satisfactory
- Identification of a black plastics issue for sorting and identification using sliding spark (SSSP) and FTIR hand scanner
- Density separation of PC/ABS and HIPS/PPE with PFR requires further investigation and optimization
- Due to many types of plastics (up to 300 in WEEE), there are challenges for high precision sorting.

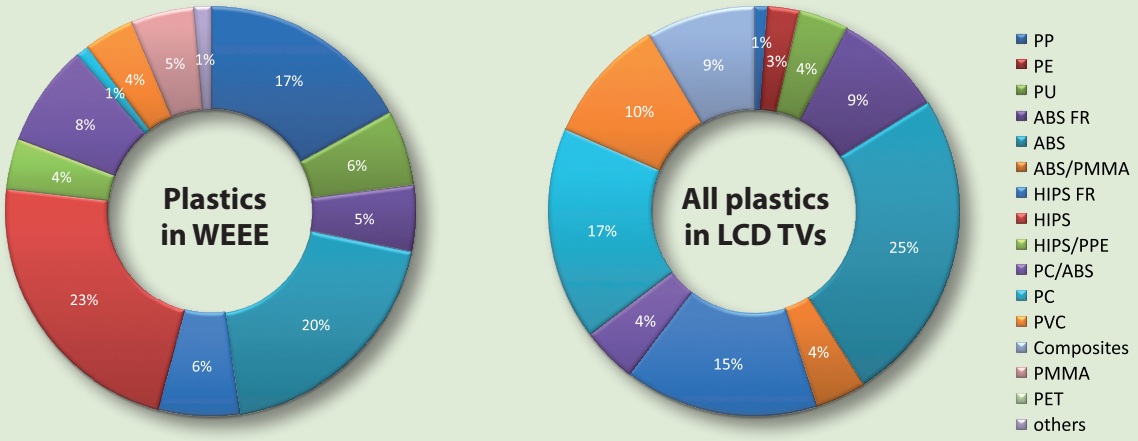
3. Miscibility Test

Objective: Miscibility effects were analyzed for the different plastics with the objective of understanding and quantifying effects of contaminants (PMMA; ABS; HIPS; PPE; PC; PET; … with/without FRs) on virgin plastics (HIPS/PPE and PC/ABS with PFRs) used in LCD back covers.

Mixtures of 1%, 5% and 10% wt. contaminants in virgin plastics were prepared, in order to characterize effects and analyze physical properties, to predict the level of separation needed during identification and sorting trials.

Results

- Effect of PMMA and ABS in PC/ABS is lowering the physical properties
- 2% wt. of contamination of other plastics can already have a substantial negative effect on the physical properties of plastic recyclates.



Average plastic composition of LCD TVs and WEEE (as obtained from prior research)

Results/key findings of the LCD recycle project and other supporting tests:

- In LCD housing, only a few type of plastics with or without FRs are present, mainly PC/ABS and HIPS/PPE with PFRs and HIPS or ABS with BFRs/ATO plus HIPS – ABS and ABS/PPMA without FRs
- Typical weight for the back cover of an LCD TV is 1.6 kg for a 33 inch size
- After disassembly and plastic identification, PFR PC/ABS can directly be recycled and reapplied for housing components. Based on the determined plastic density distributions and separation efficiencies of optical sorters, a purity of only 82% was calculated for PFR PC/ABS separated after size-reduction
- PC/ABS and HIPS/PPE with PFRs can be recycled. However, attention needs to be paid to the effect of moisture on PC molecular weight. HIPS/PPE is less susceptible to moisture than PC/ABS
- HIPS with BFRs/ATO used in LCDs has nearly the same physical properties of the plastics and is more stable for recycling compared to PC/ABS with PFR, since PC/ABS more easily downgrades because of the hydroscopic properties of PC.

Summary of main reasons for low plastics recycle rate (12% of all collected WEEE plastics EU)

- Lack of information on the polymer type and FR applied in EEE
- For manual dismantling so far, there is no reliable identification system for black plastics
- Scale of economy 20,000 ton/y recycling vs 300,000 ton/y of production
- > 300 different plastics types used in E&EE
- Limited understanding of the effect of the mixing of different plastics on the physical properties
- Ageing of plastics (UV stability/oxidation), humidity and thermal stability
- Cross contamination, interaction between different types of plastics, moisture and additives can result in lower physical properties of recyclates
- Today, recycling can be economically viable for certain plastics. However, there are still technical challenges to overcome due to the low volumes of waste plastics from LCDs and the large variety of plastic types
- Mechanical recycling of plastics is still a developing industry in Europe.

Conclusion:

Further research is needed on identification and sorting techniques supporting manual dismantling. EFRA, KU Leuven and Recycling Consults BV are currently setting up follow-up projects.

	ABS	ABS BFR	HIPS	HIPS BFR	PET	PC	PMMA	PC/ABS PFR	HIPS/PPE PFR
ABS	G								
ABS BFR	G	G							
HIPS	Y	Y	G						
HIPS BFR	Y	Y	G	G					
PET	O	O	O	O	G				
PC	G	G	O	O	G	G			
PMMA	O	O	O	O	Y	O	G		
PC/ABS PFR	G	R	O	R	R	G	O	G	
HIPS/PPE PFR	O	O	G	G	R	O	O	Y	G

G	Good miscibility (contamination>5%, properties>80%)
Y	Resonabile miscibility (contamination=2-5%, properties>80%)
O	Limited miscibility (contamination=0.1-2%, properties>80%)
R	Bad miscibility (contamination<0.1%, properties<80%)

Organizations cooperating or contributing to the project:

The European Flame Retardants Association (EFRA) initiates and supports scientific studies and research activities. These cover a wide range of topics including end-of-life treatment, recycling and environmental impact, toxicology, statistical research or the development of fire safety models.

Acknowledgements:

EFRA wishes to thank all of the project partners as listed above, for their invaluable help and support with directing and managing this key project. Particular thanks go to Jef Peeters, KU Leuven, Faculty of Engineering, for his research data input.

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The European Flame Retardants Association (EFRA) brings together the leading companies which manufacture, market or use flame retardants in Europe. EFRA covers all types of flame retardants: chemicals based on bromine, chlorine, phosphorus, nitrogen, inorganic compounds and intumescent systems.
EFRA is a sector group of Cefic, the European Chemical Industry Council.

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