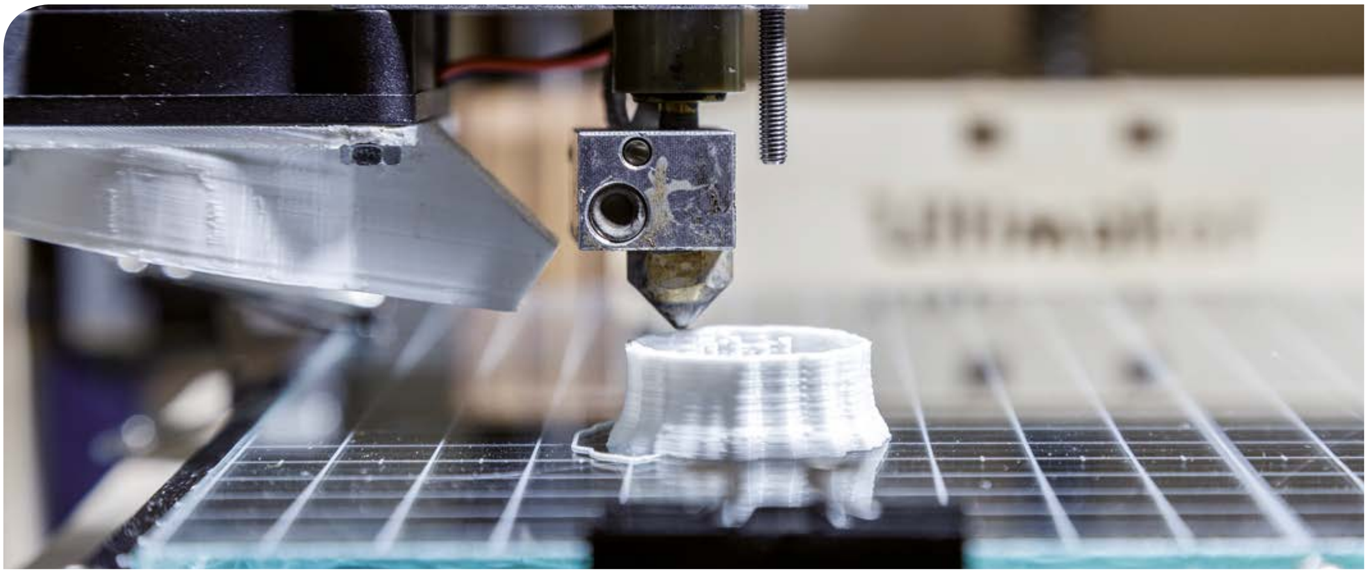


Closing Material Loops: Diverting Plastic from Waste Electrical and Electronic Equipment

Vicente Gavara, Andrés Lluna, Mayte Gil, Salvador Femenia and Pablo Domingo, Instituto Tecnológico de la Energía, Spain

Key messages

- Between 2016 and 2020, the additive manufacturing sector is predicted to consume around 250 million tonnes of virgin plastic worldwide.
- Recycling 25 per cent of the plastic consumption predicted by 2020 could avoid 300 million tonnes of CO_2 emissions, saving around 3.3 billion megajoules of energy.
- Industrial processes that divert plastic from waste electrical and electronic equipment (WEEE) into recycled plastic filaments for 3D printing could have significant climate and financial benefits.
- Recycling plastic filaments from WEEE could contribute to the demand for plastic from the additive manufacturing sector, while also closing important material loops.

Introduction

Electronic devices are an increasingly important part of everyday life; they help us do our jobs and communicate instantly with colleagues, friends and family. At the same time, constant renewal and updating of these devices leads to many becoming obsolete while they are still functional. The high turnover of products creates a continuous demand for raw materials. During 2015, 49 million tonnes of plastic was produced in Europe alone, of which 5.8 per cent went to the electrical and electronic sector.[1] However, of the 41.8 million tonnes of waste electrical and electronic equipment (WEEE) generated worldwide in 2014, only 6.5 million tonnes was reported to be treated by national take-back programmes and schemes.[2]

Although increasing emphasis is being placed on recovering metals from WEEE, a high percentage of the composition is plastic, due to electronic devices being enclosed in plastic casings. These are made from a mixture of polycarbonate and acrylonitrile butadiene styrene (ABS), both of which have a negative environmental impact if they are allowed to accumulate in ecosystems. Moreover, the production of

Supported by
eit Climate-KIC

Climate-KIC is supported by the EIT, a body of the European Union

1 tonne of ABS virgin plastic releases approximately 4,800 kg of CO_2.[3] However, ABS from WEEE can be reused by converting it into recycled plastic filaments for the additive manufacturing industry. This closes two important material loops: a) diverting waste from the electrical and electronics sector; and b) recycling plastic within the additive manufacturing sector itself. This *Insight* presents research by the Instituto Tecnológico de la Energía (ITE), a Spanish Climate-KIC partner, into the challenges associated with recycling ABS plastic casings into plastic filaments.

The additive manufacturing sector

The additive manufacturing sector has grown rapidly over the past decade, with the number of 3D printers increasing from an estimated 1,000 units in 2009 to 280,000 in 2016.[4] These 3D printers are used for developing prototypes, creating models with complex structures and mechanisms, and manufacturing customised components. Although the technology has numerous advantages, its main disadvantage is its dependency on plastic filament. While 3D printers use a wide variety of filament types, ABS is one of those used most commonly and hence recycling ABS is the focus of the research and this *Insight*.

Between 2016 and 2020, the additive manufacturing sector is predicted to consume approximately 250 million tonnes of virgin plastic worldwide.[5] Based on this data, if only 25 per cent of this plastic was recycled, it would displace 62.5 million tonnes of virgin plastic, avoiding 300 million tonnes of CO_2 emissions[3] and saving around 3.3 billion megajoules of energy.[6]

Important health benefits are also associated with recycling plastics, since plastics decompose very slowly, up to five centuries in some instances.[7] This slow rate of decomposition is problematic, particularly since plastics tend to contain toxic chemical additives, such as brominated flame retardants (BFR), which, if ingested in large quantities by marine fauna, will contaminate our food chains. Toxins like BFR accumulate in body tissues and may have carcinogenic and mutagenic effects.[8]

However, if suitable processes can be developed to recycle plastics into recovered filaments, there will be significant opportunities to recycle waste ABS plastic for 3D printing. This would also reduce contamination of food chains by plastic waste. In other words, recovering 25 per cent of plastic waste would contribute significant benefits to society and the environment in terms of health improvement, mitigating climate change and preserving natural resources.

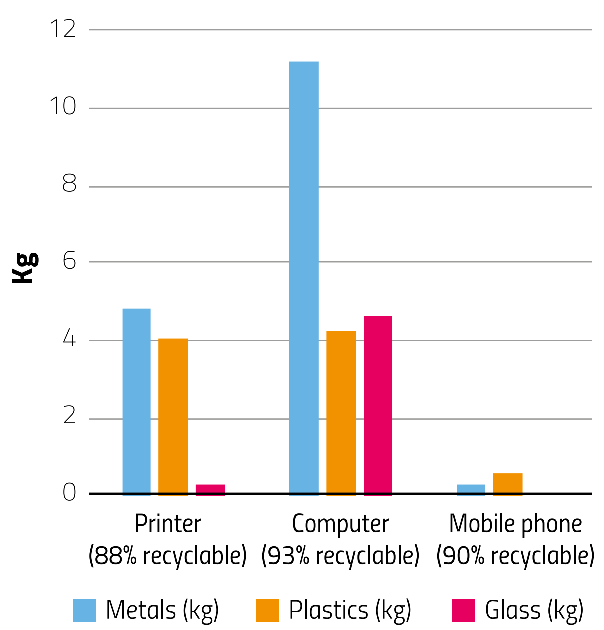
Substituting virgin plastic filaments in 3D printing

Figure 1 illustrates that plastic is a major part of electrical and electronic equipment (EEE), since it represents 44 per cent of the materials in a printer, 21 per cent of those in a personal computer and 71 per cent of those in a mobile phone. Specifically, ABS plastic represents 45 per cent of the different polymers that are found in televisions and computer screen casings.[9] The figure also shows that a high percentage of WEEE is potentially recyclable, therefore recycling plastic into filaments could contribute to addressing the problems associated with the large amount of ABS waste. Moreover, recycled filaments could have different characteristics from those of virgin plastics; for example, the potential to embed piezoelectric pressure sensors, which would be advantageous for applying 3D printing in such sectors as toys and sport shoes. This is a novel research area being explored by ITE.

Limitations of existing recycling processes

For most WEEE that is processed in official waste management collection systems, the first step is to dismantle all product components, clean them and identify any toxic materials. Following dismantling, the components containing plastics are crushed. Then, any small particles of metals, glass or paper remaining in the crushed mixture are removed. Recovering ABS plastics

Figure 1. Amount of recyclable material in WEEE (kg per product)



Source: Ambiental, Recyclia and Recybérica (2014)[10] from the remaining mixture is achieved by mechanical, thermodynamic or energy recovery recycling processes.

Mechanical recycling is appropriate when product components contain no dangerous or toxic substances, such as BFR. Once the plastics have been crushed, the resulting granules can be used to create recycled plastic, which in turn can be re-introduced into manufacturing processes as material inputs. Thermodynamic recycling and energy recovery by combustion are used when dangerous substances, such as BFR, are likely to be present or complex composite materials cannot be separated through mechanical recycling. These processes break down the plastics into their molecular components, which can then be used to create raw materials for new products.

However, it is extremely difficult to identify ABS plastics and internal additives like BFR within WEEE. As a result, most plastic waste is thermodynamically recycled because waste management companies lack accurate information regarding the material composition of products or components. Figure 2 illustrates the different plastic recycling processes.

Industrial demonstration pilots

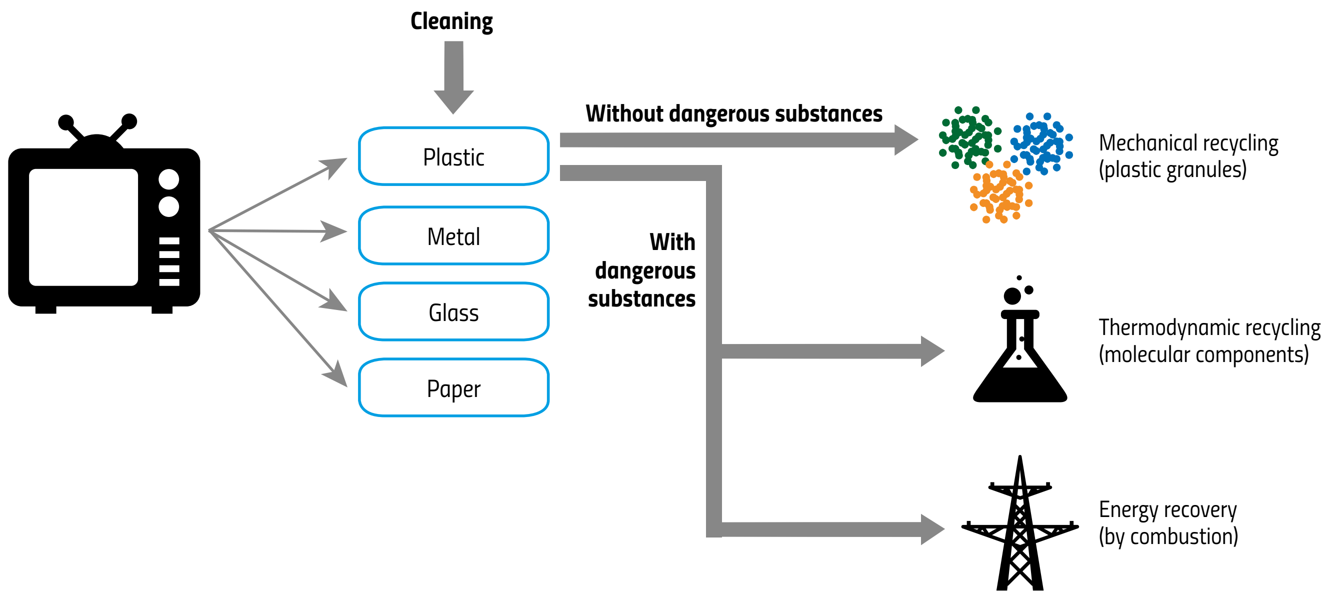
Considering an estimated 500,000 tonnes of ABS plastic was used in the manufacture of EEE in 2015,[1] a significant opportunity is presented by improved recycling processes that facilitate the recovery of plastic from WEEE suitable for producing new parts with the same properties. While there are technologies that facilitate the recycling of plastics at domestic level, for example converting plastic bottles into filaments, the challenge is to achieve adequate and efficient industrial processes for recycling plastic from WEEE and revaluing it to the additive manufacturing sector.

This suggests that investment is required to develop and deploy demonstration industrial pilots to prove that recycling ABS can be achieved through dismantling, sorting, separation (including BFR removal) and reprocessing into new materials that can be used as inputs for new products. Industrial demonstration pilots are required to illustrate technical and performance limitations, economic feasibility related to achievable rates of material recovery, energy input requirements and associated costs, and rates of material loss or degradation.

Implications for plastic filament value chain actors

Improving the recovery and recycling of plastic from WEEE could represent a significant opportunity for different actors within recycled plastic filament value chains. Recycling companies are likely to have the most to gain from developing new business models associated with diversifying the types of plastics they recycle, particularly since recycled ABS is an attractive substitute, costing manufacturers only around €800–1,000 per tonne, compared with virgin plastic at around €1,400–1,600 per tonne.[3]

Figure 2. Plastic recycling processes



Source: ITE

For manufacturers, the introduction of recycled plastic filament lowers the cost associated with printing prototypes using 3D printers. Engineering companies may also benefit, since their expertise is required to design and build appropriate industrial pilots for reprocessing plastics from WEEE. Creating regional circular plastic filament value chains may also have a positive influence on the local economy because the recycled materials can be used in local markets, close to places of recovery.

Regulatory opportunities and recommendations for further research

The recycling of WEEE is regulated by Directive 2012/19/EU of the European Parliament, which sets minimum recovery targets based on an average amount of WEEE introduced into the market in a specific country during the previous three years. These targets are set to guarantee the proper treatment of collected WEEE, but the recovery rates of each material are not specified. Hence, to date, the emphasis has been on the separation and capture of metals. However, this situation creates an opportunity for additive manufacturing because most WEEE plastic is not yet recycled.

While there is an opportunity to transform plastics (particularly ABS) into recycled filaments for 3D printing, appropriate regulation is currently lacking. It would be beneficial to limit the percentage of toxic additives (e.g. BFR), establish a minimum recycled ABS content in products that contain ABS plastic and develop standardised material passport or labelling systems so material contents are more easily identifiable in subsequent cycles. Investing in demonstration pilots would also help the development of efficient industrial processes for recycling plastics from WEEE.

Numerous climate, environmental, economic and co-benefits are associated with developing industrial-scale processes for WEEE plastics recycling. Achieving industrial-scale recycling of ABS plastics from WEEE for use in the additive manufacturing sector would contribute to important health benefits associated with avoiding plastic decomposition and related bio-accumulation of toxins in food chains.

Considering the expected growth of the additive manufacturing sector and taking into account the increase in WEEE generated, ITE intends to investigate the use of such waste for the production of plastic parts. The aim is to reduce the use of virgin plastic while developing products with electrical qualities, for example piezoelectric pressure sensors. Achieving this process would have a positive impact simultaneously on the properties of the final product, the environment and the economy.

Endnotes

1. Plastics Europe's Market Research and Statistics Group (2016) *Plastics – The Facts. An analysis of European plastics production, demand and waste data*, Brussels, Belgium: Plastics Europe.
2. Baldé, C.P. et al. (2015) *The Global E-waste Monitor 2014*, New York, USA: United Nations University.
3. Hestin, M. et al. (2014) *Increased EU Plastics Recycling Targets: Environmental, Economic and Social Impact Assesment, Final Report*, prepared for Plastic Recyclers Europe, Bio by Deloitte (http://www.plasticsrecyclers.eu/sites/default/files/BIO_Deloitte_PRE_Plastics%20Recycling%20Impact_Assesment_Final%20Report.pdf).
4. Wohlers Associates (2016) *3D Printing and Additive Manufacturing - State of the Industry*, Wohler Report 2016.
5. Eco-Circular (online) *Economia Circular, Proyecto de Exito: 3D Impact* (http://eco-circular.com/2016/07/21/economia-circular-proyecto-de-exito-3d-impact/).
6. Schindler, A. et al. (2014) *Styrene Acrylonitrile (SAN) and Acrylonitrile Butadiene Styrene (ABS)*, Brussels, Belgium: Plastics Europe.
7. Wurpel, G. et al. (2011) *Plastics do not belong in the ocean. Towards a roadmap for a clean North Sea*, Amsterdam, Netherlands: Imsa.
8. European Commission (2013) *Green Paper: A European Strategy on Plastic Waste in the Environment*, Brussels, Belgium: European Commission.
9. Devesa Albeza, F. (2008) *Estudio de la compatibilidad de residuos plásticos procedentes de aparatos eléctricos y electrónicos*, Valencia, Spain: Universidad Politécnica de Valencia.
10. Ambiental, Recyclia and Recybérica (2014) 17 de Mayo DÍA MUNDIAL DEL RECICLAJE (http://www.recyclia.es/notas/140514.pdf).

Climate Innovation Insights is a platform for reflection and discussion on the lessons, challenges and opportunities of addressing climate change through innovation. It brings together key insights, informed opinion, best practice and methodological approaches to understand how research, education, business and government can, together, accelerate the transition to a zero-carbon economy. The series is developed and published by Climate-KIC, Europe's largest public–private partnership focused on climate innovation. We would like to thank the Series Editor, Dr Geraldine Brennan and the two external reviewers, Dr Carmen Ruiz Puente and Dr Inês dos Santos Costa.

About Climate-KIC

Climate-KIC is Europe's largest public–private partnership addressing climate change through innovation. With a focus on sustainable production systems, Climate-KIC is building a new foundation for industry in Europe – developing climate-friendly and economically viable circular models of manufacturing for a zero-carbon economy. Climate-KIC is supported by the European Institute of Innovation and Technology (EIT), a body of the European Union.

Contact details:

@ClimateKIC
www.climate-kic.org
www.climate-kic.org/sps

About ITE

Instituto Tecnológico de la Energía (ITE), based in Valencia, Spain, supports energy sector companies to convert their innovative ideas into business opportunities and launch innovative products and services.

Photo credits: page 1: Additive manufacturing – Sergi Lopez Roig/Shutterstock.com
Editing, design, and layout: Green Ink (www.greenink.co.uk)

Supported by

Climate-KIC

ITE INSTITUTO TECNOLÓGICO DE LA ENERGÍA

Climate-KIC is supported by the EIT, a body of the European Union