CASE STUDIES

Plastic Recycling

Alistair Cook

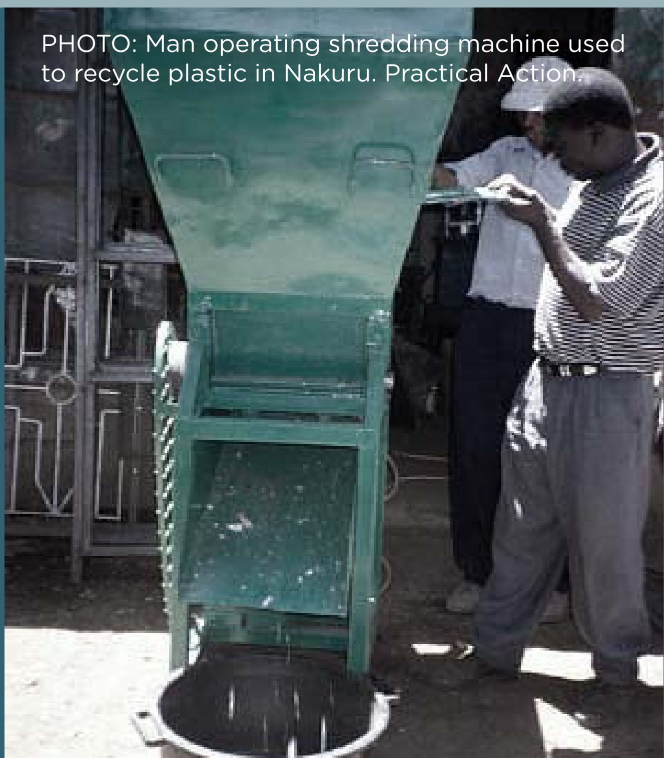


PHOTO: Man operating shredding machine used to recycle plastic in Nakuru. Practical Action.

GDEE GLOBAL DIMENSION IN ENGINEERING EDUCATION

CASE STUDIES **Plastic Recycling**

EDITED BY
Global Dimension in Engineering Education

COORDINATED BY
Agustí Pérez-Foguet, Enric Velo, Pol Arranz, Ricard Giné
and **Boris Lazzarini** *(Universitat Politècnica de Catalunya)*
Manuel Sierra *(Universidad Politécnica de Madrid)*
Alejandra Boni and **Jordi Peris** *(Universitat Politècnica de València)*
Guido Zolezzi and **Gabriella Trombino** *(Università degli Studi di Trento)*
Rhoda Trimingham *(Loughborough University)*
Valentín Villarroel *(ONGAWA)*
Neil Nobles and Meadhbh Bolger *(Practical Action)*
Francesco Mongera *(Training Center for International Cooperation)*
Katie Cresswell-Maynard *(Engineering Without Border UK)*

DL B 10735-2015
ISBN 978-84-606-7546-4

Citation: Cook, A. (2015) 'Plastic Recycling', in *Case studies for developing globally responsible engineers*,
GDEE (eds.), Global Dimension in Engineering Education, Barcelona. Available from: http://gdee.eu/index.php/resources.html

PLASTIC RECYCLING

Alistair Cook: MBA candidate Global Social Sustainable Enterprise, Colorado State University

INDEX

1. Introduction

The Global Dimension in Engineering Education (GDEE) is a European Union funded initiative involving the collaboration of development NGOs and Universities, with an aim to integrate sustainable human development as a regular part of all technical University courses. Part of the initiative is the development of a set of case studies based on real field experiences of development projects. The case studies cover a broad range of topics directly linked to those studied in engineering, science and other technology/environment/development-related courses. They give a background to the topic, a look into the real life project, and offer students hands on learning by various class and homework activities.

This case study looks into plastic recycling in the Global South. The world's production of plastic materials has been increasing at a rate of nearly 5% per annum over the past 20 years (UNEP, n.d.). In many economically poorer countries, the increase in use of plastics has been higher than the world average and waste plastics are becoming a major waste stream. They are often found as litter across cities; they are burned, buried or disposed of in open dumps along with other waste. The high quantities being generated and the lack of efficient end-of-life management means plastics are now posing serious threats to the environment and human health. Awareness is growing of the need to reduce plastic use, and to deal effectively with plastic waste by recycling, reusing or upcycling. Many viable plastic recycling businesses have been set up in the Global South with the double result of reducing hazards of plastics, and providing a livelihood.

The process of recycling plastics and setting up a viable business contains many challenges, including technical challenges such as questions of efficient energy usage and machinery, and management challenges such as organisational structure and collection systems. Understanding the process of recycling for plastic is an important consideration in design, as designers and engineers strive to achieve 'closed loop' cycles, where waste is reduced or eliminated, and products are designed for re-use.

1.1. Disciplines covered

- Product Design Engineering
- Chemical / Process Engineering
- Mechanical Engineering
- Environmental Engineering
- Engineering Business Management (or similar)

1.2. Learning outcomes

- Understand the importance of recycling plastics and the real life complications in doing so, particularly in the context of countries in the Global South
- Understand the stages and processes of recycling plastic
- Learn how to do a basic life cycle assessment of a material or product and use the tool to compare options
- Develop a basic understanding of business economics

1.3. Activities

There are three activities attached to this case study, which can be run as discrete activities or joined into a project;

1. Consider and research the cradle to cradle life of a household plastic object. Compare the use of new or recycled plastic as a manufacturing material
2. Complete a Life Cycle Analysis for a new and recycled plastic product and compare the results
3. Develop a basic business plan for a recycling company in Kenya or Uganda

These activities require access to a computer and the internet, as students will be required to download and utilise an open source LCA program.

2. Description of the context

2.1. Introduction to Recycling Plastics and Relevance in the Global South

Plastics are inexpensive, lightweight and durable materials, which can be easily manufactured into lots of products that are used throughout the world. Because of this, the production of plastics has increased markedly over the last 60 years. A major portion of plastic produced each year is used to make disposable items of packaging or other short-lived products that are discarded within a year of manufacture. These current levels of usage and disposal are not sustainable and generate many environmental and health problems. For example, producing plastics account for around 7-8% of world oil and gas use, both as feedstock for plastics and to provide energy for their manufacture (Hopewell, et al., 2009), contributing to global warming; substantial quantities of discarded plastics accumulate as debris in landfills and in natural habitats worldwide causing methane leakage, starvation of marine mammals due to plastic consumption, and contamination of groundwater supplies due to chemical seepage. In order to mitigate these effects, reducing our consumption of plastic, and thus the creation of plastic, is key; not using plastic needlessly, using recycled /

bio-degradable packaging if we must, supporting campaigns which encourage businesses, workplaces, factories etc. to reduce their use. Of course, large-scale behavioural change does not happen overnight. This is where waste management strategies come into play, such as plastic recycling, reduction in material use through down gauging or product reuse, and the use of alternative biodegradable materials and energy recovery as fuel. Here, we will talk about plastic recycling.

In addition to the advantages of reducing the environmental and health impacts stated above, the process of plastic recycling provides livelihoods for millions of people and communities in the Global South, either in the form of formal employment or informal economic activities. The collecting, sorting and recycling plastic waste is a viable activity to generate income. There is a wide scope for recycling in these countries due to several factors:

- In many countries there is an existing culture of reuse and recycling, with the associated system of collection, sorting, cleaning and reuse of ‘waste’ or used materials.
- There is often an ‘informal sector’ which is ideally suited to taking on small-scale recycling activities. Such opportunities to earn a small income are rarely missed by members of the urban poor.
- There are fewer laws to control the standards of recycled materials. (This is not to say that standards can be low – the consumer will always demand a certain level of quality).
- Innovative use of scrap machinery often leads to low entry costs for processing or manufacture.

Properties and Types of Plastics

Type of plastic	Identification	General properties	Common uses
Polyethylene terephthalate (PET/PETE)	1 PET	• Clear • Hard • Tough • Barrier to gas and water • Resistance to heat • Resistance to grease/oil	• Mineral water bottles • 2 litre soda bottles • Cooking oil bottles • Powder detergent jars • Fibre for clothing • Fibre for carpets • Strapping • Peanut butter jars
High density polyethylene (HDPE)	2 HDPE	• Barrier to water • Chemical resistance • Hard to semi-flexible • Strong • Soft waxy surface • Low cost • Permeable to gas • Natural milky white colour	• Jerry cans • “Crinkly” shopping bags • Film • Milk packaging • Toys • Buckets • Rigid pipes • Crates • Bottle caps
Polyvinyl chloride (PVC)	3 PVC	• Transparent • Hard, rigid (flexible when plasticised) • Good chemical resistance • Long term stability • Electrical insulation • Low gas permeability	• Pipes and fittings • Carpet backing • Window frames • Water, shampoo and vegetable oil bottles • Credit cards • Wire and cable sheathing • Floor coverings • Shoe soles and uppers
Low density polyethylene (LDPE)	4 LDPE	• Tough • Flexible • Waxy surface • Soft - scratches easily • Good transparency • Low melting point • Stable electrical properties • Moisture barrier	• Agricultural films • Refuse sacks • Packaging films • Foams • Bubble wrap • Flexible bottles • Wire and cable applications

Poly propylene (PP)	5 PP	• Excellent chemical resistance • High melting point • Hard, but flexible • Waxy surface • Translucent • Strong	• Yoghurt containers • Potato crisp bags • Drinking straws • Medicine bottles • crates, • plant pots • Car battery cases • Heavy gauge woven bags
Polystyrene (PS)	6 PS	• Clear to opaque • Glassy surface • Rigid • Hard • Brittle • High clarity • Affected by fats and solvents	• Packaging pellets • Yoghurt containers • Fast food trays • disposable cutlery • Coat hangers
Other plastics	7 OTHER		• Mostly not available in sufficient quantities for recycling

Table 1 *Properties of Plastics* (Berg, 2009)

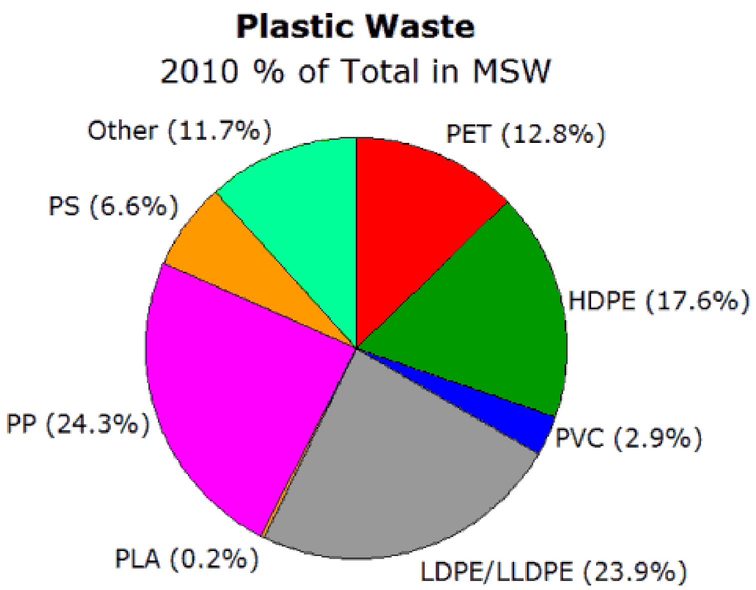


Figure 1 *Types of Plastic Waste*

2.2. Identifying Waste Plastics

To differentiate between the types of plastics above in order to discern if they can be recycled, it is now common for plastic containers to have the polymer identification code on them, as seen in section 2.2. Unfortunately, not all plastic applications carry such identifiers. However, there are several simple tests that can be used to distinguish between the common types of polymers so that they may be separated for processing (other types are more difficult to identify and require experience):

Water test - After adding a few drops of liquid detergent to some water put in a small piece of plastic and see if it floats.

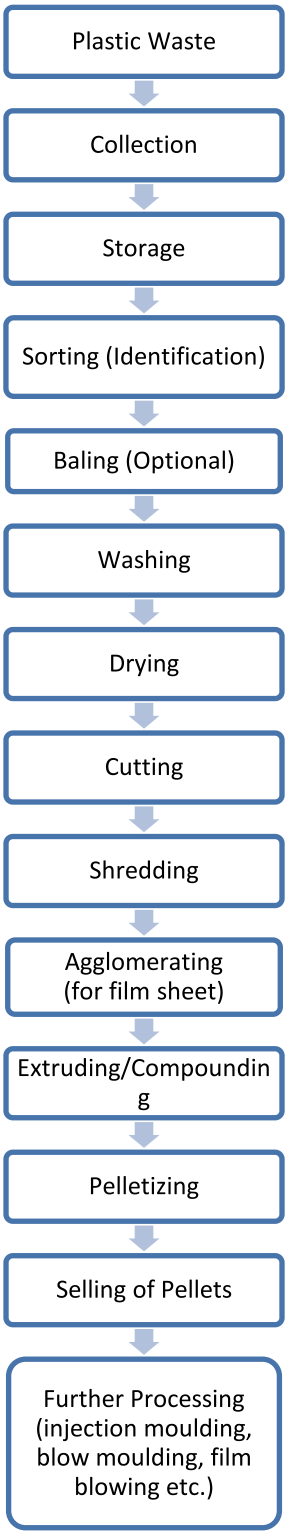
Burning test - Hold a piece of the plastic in a tweezers or on the back of a knife and apply a flame. Dose the plastic burn? If so, what colour?

Fingernail test - Can a sample of the plastic be scratched with a fingernail?

Test	Type of Plastic			
	PE	PP	PS	PVC*
Water	Floats	Floats	Sinks	Sinks
Burning	Blue flame with yellow tip, melts and drips	Yellow flame with blue base.	Yellow, sooty flame – drips	Yellow, sooty smoke. Does not continue to burn if flame is removed
Smell after burning	Like Candle Wax	Like candle wax - less strong than PE	Sweet	Hydrochloric acid
Scratch	Yes	No	No	No

Table 2 *Plastic testing identification matrix* (Berg, 2009)

2.3. Processing Waste Plastic



Steps to process waste plastic are as follows (summarised in table to left):

Collection - in starting a plastic recycling business, setting up an efficient collection system of waste plastic is key. A constant supply of raw material to the factory is of utmost importance for the existence of the business. Collection of waste plastic may already happen through the activities of scavengers, middlemen and traders. It is possible to integrate in this system by letting them know that the factory is willing to buy plastic waste material. Another option is to cooperate with the municipality to get involved in collection schemes accompanied with a public awareness campaign. In this way the public can be informed about the advantages of plastic recycling.

Storage - the plastic recycling enterprise needs quite a large storage space in order to store all collected waste items, processed materials and finessed products. Plastic waste items, especially bottles, have a large volume and therefore a large storage place is necessary.

Sorting and identification - plastics sorting operations may be carried out manually or automatically, using appropriate means of identification. The more accurate and efficient the means of identification, sorting and separation, the better the quality of the recovered product obtained.

Baling - after collecting and sorting the plastic material, the option exists to sell the material to (other) processing units. If so, it is important to compact the waste to improve handling and save costs during transport, especially when transporting distances are considerable.

Washing and Drying – if not sold on, the next step is to clean the plastic if dirty. The main cleaning steps are:

- Draining of remaining fluids from plastic containers/bottles.
- Rough cleaning of plastic containers and other pieces of plastic.
- Removing of paper, plastic or metal stickers.
- In the case of PET bottles removing of caps and etiquettes.
- Intensive washing in cold or hot water with addition of detergents or caustic soda.
- The waste water can be reused by installing a simple waste water treatment system like a sedimentation basin

Cutting - this is usually carried out for initial size reduction of large objects. It can be carried out with scissors, shears, saw, machine etc.

Shredding - shredding is suitable for smaller pieces. A typical shredder has a series of rotating blades driven by an electric motor, some form of grid for size grading and a collection bin. Materials are fed into the shredder via a hopper which is sited above the blade rotor. The product of shredding is a pile of coarse irregularly shaped plastic flakes which can then be further processed.

Agglomeration - clean film sheet is processed in an agglomerator. The agglomerator consists of a vertical drum with a set of fast moving blades in the bottom. The agglomerator chops the sheets into thin film flakes. Due to the cutting and friction energy of the process, the flakes are heated until they start to melt and form crumbs or agglomerate. This will increase the bulk density of the material which is now fit to be feed directly into the extruder.

Pelletizing - for many purposes it is recommended to convert plastic flakes or agglomerate (crumbs) into pellets before processing. The plastic pieces are fed into the extruder, are heated and then forced through a die to form a plastic spaghetti which can then be cooled in a water bath before being chopped into pellets.

Further processing

Extrusion **–** the extrusion process used for manufacturing new products is similar to that outlined above except that the product is usually in the form of a continuous 'tube' of plastic such as piping or hose. The main components of the extrusion machine are shown in Figure 1.

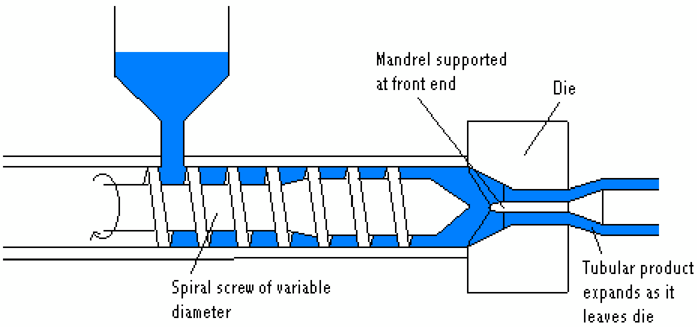


Figure 1 Plastic Extrusion *(Berg, 2009)*

The reclaimed plastic is forced along the heated tube by an Archimedes screw and the plastic polymer is shaped around a die. The die is designed to give the required dimensions to the product and can be interchanged.

Injection moulding – the first stage of this manufacturing process is identical to that of extrusion, but then the plastic polymer emerges through a nozzle into a split mould. The quantity of polymer being forced out is carefully controlled, usually by moving the screw forward in the heated barrel. A series of moulds would be used to allow continual production while cooling takes place. This type of production technique is used to produce moulded products such as plates, bowls, buckets, etc.

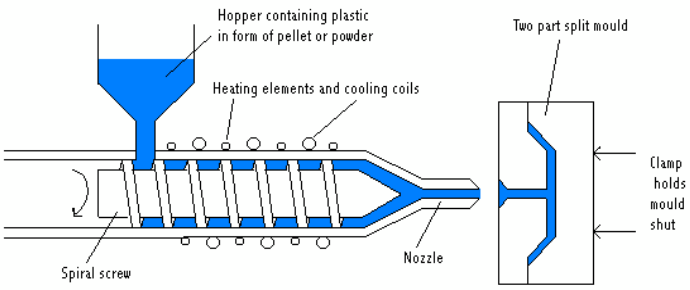


Figure 2 Plastic Injection Moulding *(Berg, 2009)*

Blow moulding – again the spiral screw forces the plasticised polymer through a die. A short piece of tube, or 'parison' is then enclosed between a split die - which is the final shape of the product - and compressed air is used to expand the parison until it fills the mould and achieves its required shape. This manufacturing technique is used for manufacturing closed vessels such as bottles and other containers.

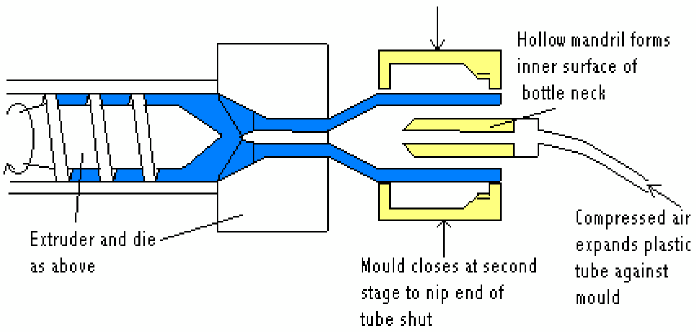


Figure 3 Plastic Blow Moulding *(Berg, 2009)*

Film blowing – film blowing is a process used to manufacture such items as garbage bags. It is a technically more complex process than the others described in this brief and requires high quality raw material input. The process involves blowing compressed air into a thin tube of polymer to expand it to the point where it becomes a thin film tube. One end can then be sealed and the bag or sack is formed. Sheet plastic can also be manufactured using a variation of the process described.

2.4. Cradle to cradle and life cycle assessment

‘Cradle to Cradle: Remaking the Way We Make Things’ is a book by German chemist Michael Braungart and U.S. architect William McDonough on their work with full cycle design and life cycle analysis, and is the basis behind much of the thinking and application of these processes today. The book looks at how products can be designed from the outset so that after their useful lives, they will provide nourishment for something new – continually circulating as pure and viable materials within a 'cradle to cradle' model (think reincarnation of a product!). No matter if you have a technical product like a smart phone, derived from many minerals and fossil fuels, or a biological product like washing detergent, derived from factory-made chemicals, there is great value in designing them so that they can be recycled back into the system, not disposed of, creating waste which harms the planet.

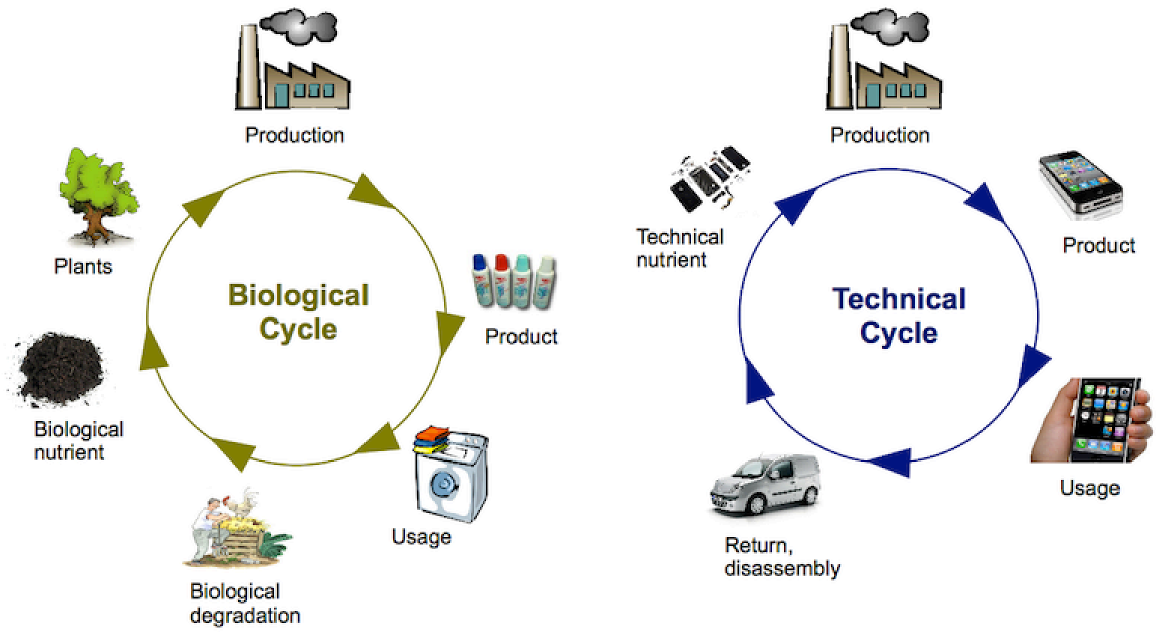


Figure 4 (INNOCHEM Wasser GmbH, 2014)

Life Cycle Assessment (LCA) is a technique to assess environmental impacts associated with all the stages of a product's life, from cradle to grave. This includes steps such as raw material extraction, materials processing, manufacture, distribution, use, repair and maintenance, and disposal or recycling of the material. LCAs can help designers understand the full environmental impact of their product by:

- Compiling an inventory of relevant energy and material inputs and environmental releases
- Evaluating the potential impacts associated with identified inputs and releases
- Interpreting the results to help make a more informed decision e.g. where they can reduce environmental impact

A product designed with these issues in mind will drastically increase the financial and physical viability of recycling a product at its end of life, making a recycling business more viable. This is particularly relevant to poorer communities, as reducing the costs and technical complications will enable them to set up their own small-scale businesses and make a living from it, whist also mitigating the environmental and health impacts of their communities from plastic waste.

2.5. Case Studies of Plastic Recycling

Sustainable Management of Plastic Waste, Practical Action - Kibera, Kenya

Each day, hundreds of plastic bags can be seen blowing across the Nairobi slum of Kibera (the largest urban slum in Africa), clogging up doorways and pit latrines. But these are now being turned into a thriving business through communities' hard work.

The international development NGO, Practical Action, has helped to introduce a plastic factory for residents and has trained members on running a business and how to use the plastic washing machines effectively. Residents sell their waste plastic to community members who have formed a Recyclers Co-operative Savings and Credit Society at 5ksh (£0.035) per kilogram, which has so far collected more than 30 tons of plastic bags.

The plastics' washing machine, a manual and motorized machine, is specially designed to wash plastic bags before they are sold on for commercial recycling where plastic pellets can be turned into new produces.

As well as recycling plastic bags, the machines can be used to wash other plastics which can then be used to make items such as fence posts. It costs as little as 13pence to process 1,000 plastic bags in the recycling factory and £1.22 to recycle plastics for the fences.

Through training sessions held by Practical Action, community members have now been trained on business development and also how to use the new technology in the form of the washing machines. At its launch, community members and stakeholders showed products made from the recycling scheme to show to others how waste could be recycling into improving livelihoods and therefore sustain a better quality of life. Acting as a blue print for other communities, the group hopes this will show how utilising the excessive surplus of waste plastic and contribute to sustainable development, help to alleviate poverty and environmental degradation. *Reproduced with permission* (Practical Action, 2014)

Collection of PET bottles – PRI, Kampala, Uganda

In December 2006, Plastic Recycling Industries (PRI) Uganda installed a new production line for the shredding and washing of PE and PET. As a reliable input of raw material is of the utmost importance for the existence of the factory, at the same time PRI set up a very successful collection system for Kampala. Several different activities were executed to achieve this:

- Execution of a public information campaign using posters, spots on local radio and TV, articles and commercials in newspapers.
- Training of NGO’s and other organisations involved in the collection of plastic waste material.
- Setting up several collection points in the city.

In this way a simple and reliable collection system exists now in Kampala. In this, communication is a key factor. The message you want to promote must be clear: What types of plastics is the factory buying? How clean and sorted must the plastic waste be to be accepted? How much does the factory pay? Etc.

As a result of this intensive marketing and promotional campaign, more than 100 contracts were established with suppliers of plastic waste materials like hotels, restaurants, schools, NGO’s, garbage collectors, petrol stations and supermarkets. Apart from these agreements, many small companies started collecting and selling plastic waste material to PRI.

The impact of these activities is enormous, next to the creation of hundreds of jobs in the collection and transportation of plastic waste, also a great impact on environment is noticeable. Plastic waste lying around in streets is less and it is also noticed that the burning of plastic has decreased in many areas of the city. *Reproduced with permission* (Berg, 2009)

3. Class activity

The first activity will be to map out 'cradle to cradle' lifespan of a common product or plastic material used in the individual student's home. The student should select two alternatives: the product as if made from new material and the product as if it is made from recycled material (processing the plastic, from oil or recycled waste, should be included) including all the steps and processes along the way, this will underpin the following LCA exercise. Students should also explain how or if they can think of ways to reduce the impact by changes in design or process that may remove or reduce the impact of the processes the item being investigated.

An example of how this process can be carried out is at http://www.openlca.org/documentation/index.php/Case_study:_Beer_Bottle – a case study of how to compare an aluminium can with a PET bottle.

The second activity will be to conduct a simple lifecycle assessment of the two options utilising open source online tools – an LCA program, available from http://www.openlca.org/download_page, and data sets for their required processes and materials at https://nexus.openlca.org/searchds/plastic. The tutor will need to spend some time learning from the tutorials how these tools operate. These results can then be compared and discussed to assess if using new grade or recycled grade plastic is the more sustainable option, depending on the different products the students have chosen to assess. This is either an individual exercise with a group discussion component, or a group exercise. It should be kept in mind that there is no absolute answer generated, as the numbers will depend on the level of detail and assumptions the students make. There should however be a clear difference, of at least a 50-70% reduction in impact by the use of recycled materials.

For the exercises, it is suggested that the item chosen for examination by the student is simple, with only one or two plastics and processes (such as a plastic water bottle) as LCA's, in particular, can be very complex.

3.1. Solution and evaluation criteria

There are no absolute answers for the above activities as the purpose is for students to understand the complexities and subtleties of measuring environmental impact. Thus, grading can be based on how well the students engaged with, and used, the tools and processes to produce a detailed comprehensive response and analyses.

4. HOMEWORK ACTIVITY

Based on one of the two case studies in Kenya or Uganda, create a basic business plan using the separate word template and excel documents attached. This is a simplified business plan with financial projections for two years – for the sake of simplicity, financing complications have been removed.

It will be particularly important for students to research and justify their hypothesis, for example;

- Salaries in the city chosen
- Amount of recycling collected per day
- Delivery methods
- Capital (equipment) costs to start the business.

5. BIBLIOGRAPHY

Berg, S. v. d., 2009. *Technical Brief - Recycling Plastics,* Rugby: Practical Action.

Hopewell, J., Dvorak, R. & Kosior, E., 2009. Plastics recycling: challenges and opportunities. *Plastics, the environment and human health*, 14 06.

INNOCHEM Wasser GmbH, 2014. *About Us - Cradle to Cradle.* [Online]
Available at: http://www.innochem-online.de/en/about-us/cradle-to-cradle/

Practical Action, 2014. *Plastic Recycling.* [Online]
Available at: http://practicalaction.org/plastics-recycling
[Accessed 14 08 2014].

The Economist, 2007. The truth about recycling. *Technology Quarterly.*

UNEP, n.d. *IETC - Project converting waste plastic into fuel.* [Online]
Available at:
http://www.unep.org/ietc/ourwork/wastemanagement/projects/wasteplasticsproject/tabid/79203/default.aspx
[Accessed 14 07 2014].

Vest, H., 2000. *Small Scale Recycling of Plastic Waste,* s.l.: Gate Informtation Service.

GDEE
GLOBAL DIMENSION IN ENGINEERING EDUCATION

http://www.gdee.eu

UNIVERSITAT POLITÈCNICA DE CATALUNYA BARCELONATECH

UNIVERSITY OF TRENTO - Italy

UNIVERSITAT POLITÈCNICA DE VALÈNCIA

POLITÉCNICA CAMPUS DE EXCELENCIA INTERNACIONAL

Loughborough University

ONGAWA INGENIERÍA PARA EL DESARROLLO HUMANO

Centro per la Formazione alla Solidarietà Internazionale
Training Centre for International Cooperation

PRACTICAL ACTION

engineers without borders uk

This project is funded by