The Evolving Role of Packaging in the Circular Economy

Donna L Visioli E I DuPont de Nemours, Wilmington, DE, USA

Karlheinz Hausmann and Sarah Perreard, DuPont de Nemours International, Geneva, Switzerland

Abstract

Packaging contributes to sustainability in many ways including: reduced package weight; recyclable materials; reduced food waste; and reduced packaging waste. Flexible packaging adds unique challenges, including low bulk density and, in some cases, complex multilayer structures. These challenges are described, along with examples of approaches to meet the challenges.

Introduction

The public perception of the environmental impact of plastics, particularly flexible packaging, can be negative, in part due to less than optimal end of life strategies. More than 70% of the total plastic ever produced is now in waste streams, sent largely to landfill. Packaging accounts for 42% of the non-fiber production (1). Packaging is typically used for less than a year and makes up 54% of the plastic discarded in 2015 (2). Much flexible packaging waste just litters the wider environment, including the oceans. More than 50% of this ocean plastic comes from five developing countries due to their inadequate or improperly managed waste management systems (3). Nonetheless, concern with flexible packaging waste has led to a number of legislative efforts to ban or restrict plastics, such as the recent UN conference on the health of the oceans which called for reduction of single-use plastics and plastic bags (4). These concerns can influence the ongoing growth of the plastics packaging industry.

In the US, Municipal solid waste (MSW) typically consists of items commonly discarded, including food scraps, yard trimmings, and durable items such as refrigerators and computers as well as packaging. Legislative and regulatory efforts to control packaging are based on the mistaken perception that packaging is the largest component of MSW. The US Environmental Protection Agency found that only approximately 31% of the MSW generated in 2005 was from packaging-related materials; this percentage has remained relatively constant since the 1990s despite an increase in the total amount of MSW. Non-packaging sources such as newsprint, telephone books, and office communications generate more than twice as much MSW (5, 6). Materials recovery facilities (MRF) accepts recyclable materials from municipal solid waste and separates and prepares these materials for marketing to end use manufacturer. Flexible packaging films present unique challenges in the MRF because it films can tangle in sortation equipment and contaminate paper fiber separation (7). Polyethylene film (such as bags and wraps) can be sorted and used in lumber or sheet applications (8). Recycling of multilayer films required use of a compatibilizer for good performance (9).

The concept of the circular economy can provide a framework to reduce waste, capture greater value from resources, provide increased economic and social value, and optimizing the environmental performance of product-packaging systems across their lifecycles (10). The advantages of plastic packaging in reducing both food waste and package weight, combined with robust end of life strategies for the package, are valuable components in this framework.

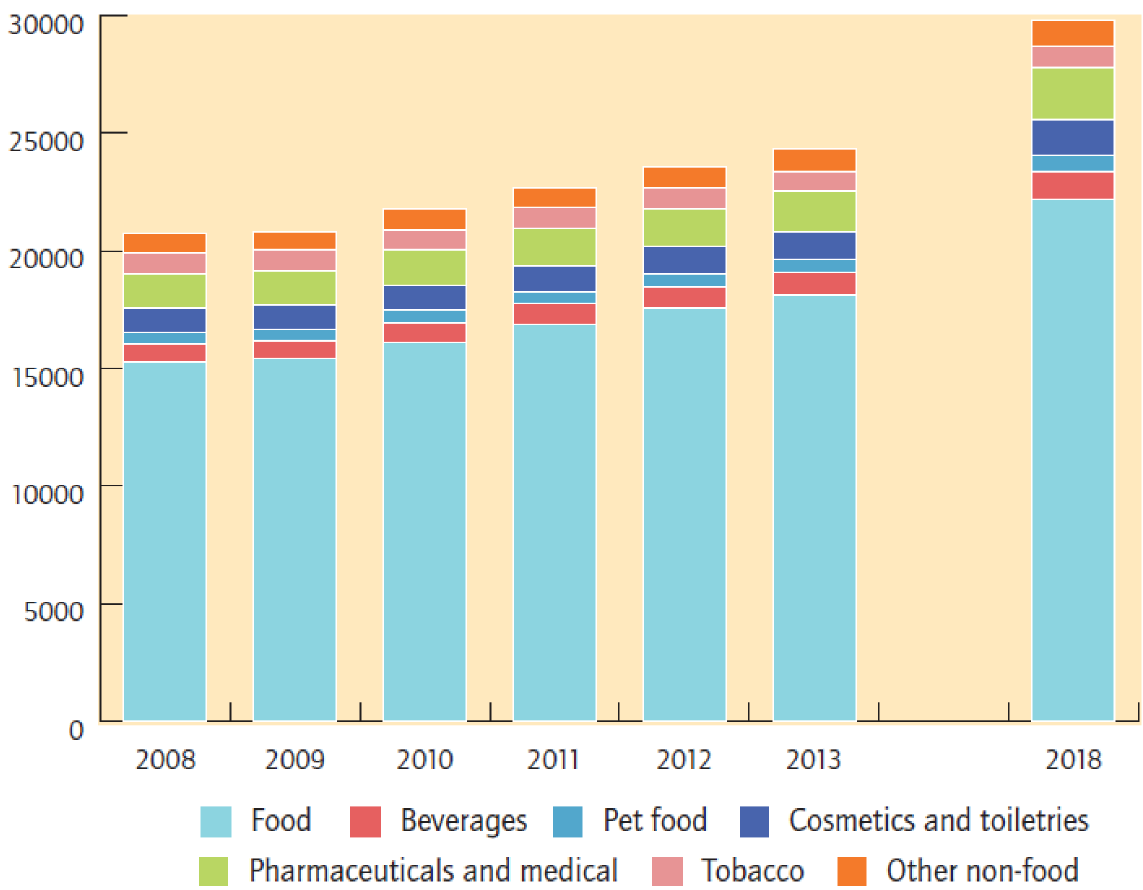
Background: The Flexible Packaging Market

The flexible packaging market, estimated to be $195 Billion in 2013, is growing at an annual rate of 3.5%. This is higher than expected global GDP growth, and is driven primarily by the growth of the consumer class in developing counties in Asia-Pacific, Latin America, and eastern Europe (11)

PE is the most widely used substrate in flexible packaging by weight, followed by BOPP, paper, and aluminum foil. The forecast growth rates are highest for higher barrier materials including BOPET, EVOH, and PA.

For flexible packaging, food packaging is the dominant end use.

Global forecast: consumer flexible packaging consumption by end use 2008 – 2018 ('000 tons)



The environmental advantages of flexible packaging, including light weighting, high package to product ratio, and transportation savings, have been well documented (12):

Packaging to Product Ratio of Various Raisins Packaging

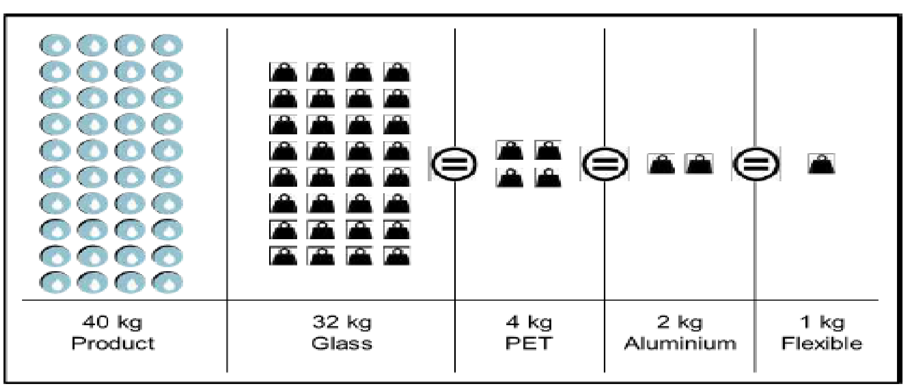
Packaging type	Folding carton with inner plastic bag	Round paperboard canister with Plastic Lid	Stand-up flexible pouch
Packaging Weight (g)	22.68	39.69	11.34
Product Weight (g)	340	680	680
Packaging to Product Ratio	1:15	1:17	1:60

Packaging to Product Ratio of Various Food and Beverage Items

	Packaging	Packaging to Product Ratio
Butter (Büsser, 2009) Block of 250 grams	Wrapper: Aluminium foil/ synthetic wax/ paper	1:17
Coffee (FPA, 2013)	Flexible "brick pack"	1:29
Beverage (FPA, 2013)	Aluminium foil laminated plastic pouch	1:35
Rotisserie Chicken(FPA, 2013)	Plastic pouch	1:76
Soup (FPA, 2013)	Plastic pouch, large size for food service	1:108

Because flexible package enables light weighting, it reduces transport weight of packaged food:

Transport Weight



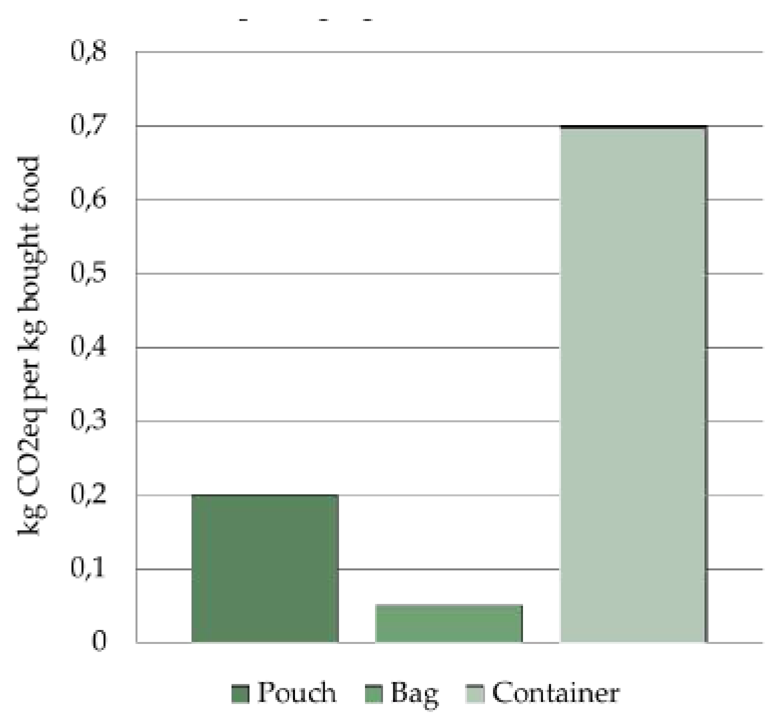
The Role of Packaging in Reducing Food Waste

Food waste is a global issue. It has been estimated that 1/3 of food produced is never eaten; since 1/9 of the world population is starving, the impact of this waste on world hunger is obvious. Food sent to landfill releases methane, which is a potent greenhouse gas. Resources wasted annually by producing food which goes to waste include 25% of all fresh water,300 MM barrels of oil; 25 million acres of land are unnecessarily deforested annually to grow food even though enough food is actually produced to feed the world (13).

Flexible packaging can offer a reduction in global warming potential of packaged food (12):

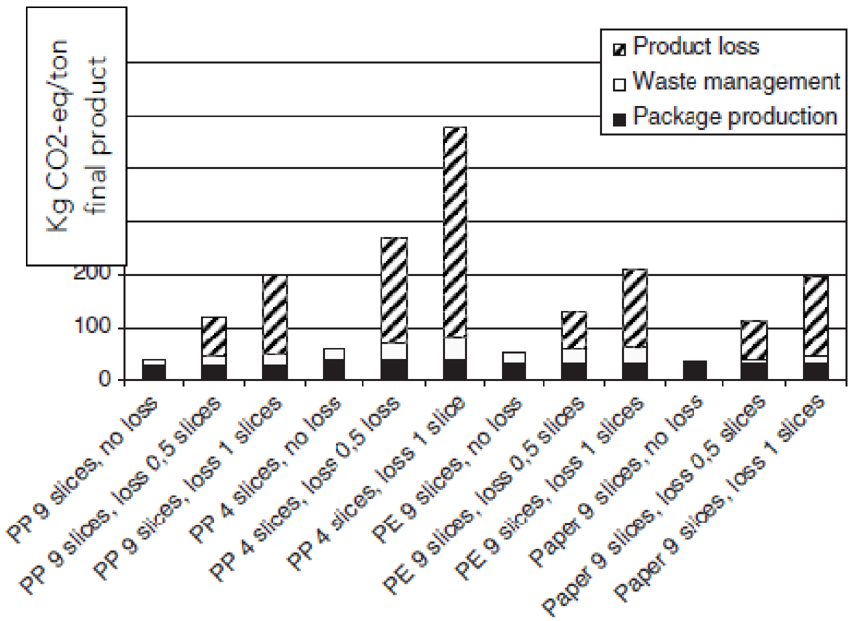
Global Warming Potential of Three Packaging Solutions for Rice

Rice packaging, incineration, no food



Food shelf life can be enhanced using flexible packaging. Because the environmental impact of flexible packaging is less than that of food waste, preventing food waste reduces greenhouse gas emissions (12), as seen below:

Carbon Footprint of Bread Waste versus its Packaging, and Contributions of their Waste Management (Recovery)



This effect is especially magnified for meat packaging because of the environmental footprint of meat production. A study done by Denkstatt shows that it takes substantially more (up to 1000x and more) greenhouse gas emissions are created in producing meat than in packaging it, depending on the type of package, the location of meat production and the type of meat, beef being the most resource efficient product(14). In a later study, Denkstatt collaborated with the Austrian packaging Recycling Association(ARA) to quantify how packaging contributes to food waste prevention (15). This study, based on collection of data at retailers (not including food wasted at home), showed that changing packaging reduced waste for a variety of food types. By preventing spoilage and increasing shelf life, in-store waste of beef steak was reduced from 34% to 18%; cheese was reduced for 5% to 0.14%; waste of bakery product was reduced from 11% to 0.8%; fresh leafy green vegetable waste was reduced from 42% to 3.4%; and waste of cucumbers was reduced for 9.4% to 4.6% (15).

Approaches to Reducing Packaging Waste

Multiple end of life strategies are possible for packaging waste, including recycling and energy recovery. The design to recycle approach can provide a way to reduce waste.

Despite ongoing efforts to facilitate recycling of plastics, only a small fraction of plastic waste is recycled. In 2008, only 13.3% of plastic packaging was recycled in the US (16). Plastic (PET) soft drink bottles and PE milk jugs have a high value in recycling, since they are single material, but in the US, only 27 % of these are recycled (16). An additional 11% of waste plastic is used for energy recovery; most of the remainder is landfilled (17).

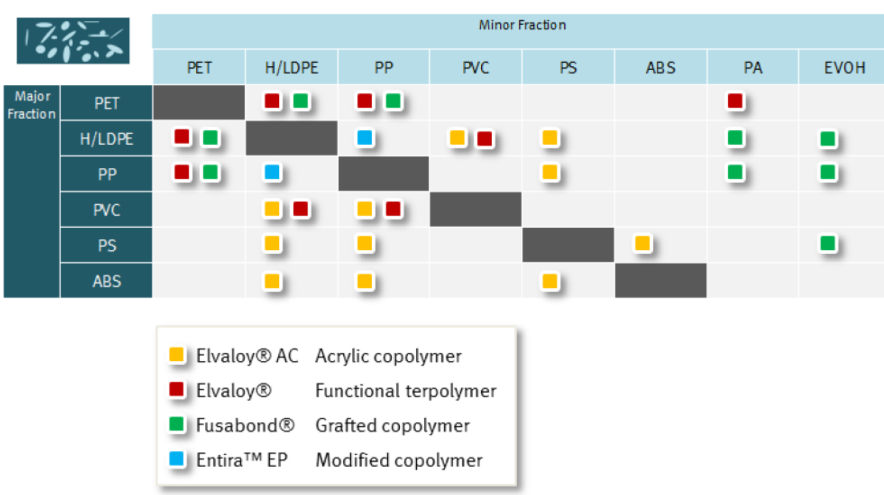
Successful plastic recycling depends on both the disposal and collection of the plastic waste, and the chemistry and consistency of the mixed polymer steam chemistry. These factors interact and often success depends on integrating them. This can involve collaboration between different players in eh value chain.

Disposal and collection of plastic waste can be enabled by public education and outreach, as documented in the REACH study in the US in 2011 (18). The consistency of the polymer stream and understanding its chemistry is critical for enabling use of recycled mixed plastics for higher value applications. To facilitate developing these applications, it is critically important for governments/municipalities to put into place effective waste collection systems. Without such waste collection systems, valuable waste streams which are worth recycling cannot be developed. Eventually developing a consistent polymer stream is especially problematic for flexible packaging, because packaging films increasingly are multilayer and contain multiple components in barrier, adhesive, and structural layers.

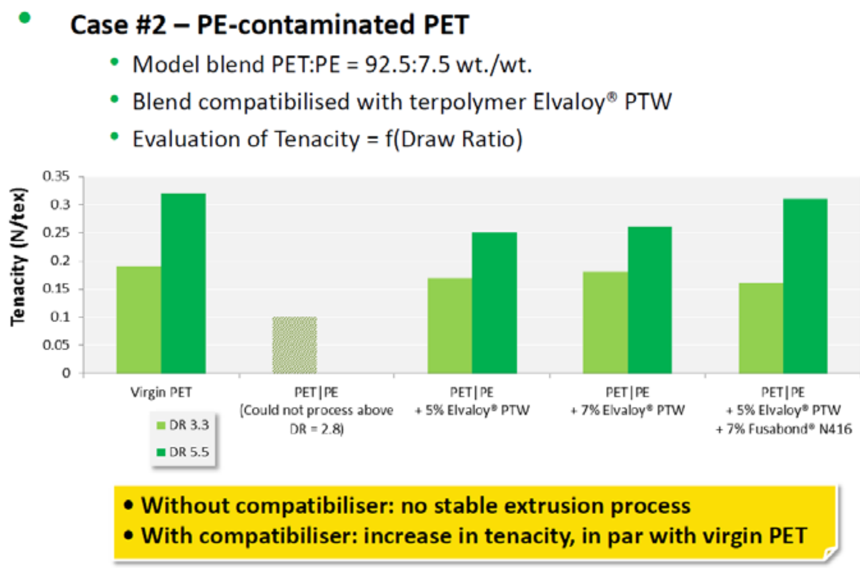
Properties of polymers from mixed-stream recycle can be enhanced by using impact modifiers, compatibilizer, and coupling agents.   Coupling agents can couple inorganic or organic contaminants in recycling streams, resulting in better mixing and compatibility, which can improve impact resistance. For incompatible blends, compatibilizers can improve mechanical properties either by simply improving the dispersion of the minor phase in the major phase; or if the compatibilizer contains reactive comonomer such as glycidyl methacrylate or maleic anhydride, it can react with either or both phases. DuPont's portfolio of recycling compatibilizers is shown below:

Selected portfolio of solutions for incompatible blends

- PET and conventional polyolefins represent the large majority of post consumer plastics (table is not strictly symmetrical)



Improvement in performance for PE-contaminated PET is exemplified below (19). This example involved production of textile fibers from PE-contaminated PET; because developing a stable fiber spinning process is inherently sensitive to contaminants, this result so an especially good demonstration of the property improvement due to compatibilizers.



Design to recycle is an approach to encourage reuse of materials. It is most advanced in Europe for durable goods; European "Take-Back Law" requires automobile (and other) manufacturers to take back all vehicles (and other products) which were ever sold in that country (20). In the EU, Extended Producer Responsibility (EPR) for packaging is a policy approach that extends the producer's responsibility for a product beyond their current scope – for worker health and safety, consumer safety and production costs – to also include the management of their product's packaging after the product has been used by consumers. EPR policies generally shift the waste management cost or physical collection partially or fully from local governments to producers. Policies can also involve incentives for producers to take environmental considerations into account when designing their products (21). For packaging, design to recycle may involve use of monomaterial films, simplified multilayer films (eliminating paper, metallization, solvent-based adhesives, and carbon black) and/or integrating compatibilizers into multilayer films. These are challenging goals if advances in lightweighting and shelf life improvement are to be maintained (22).

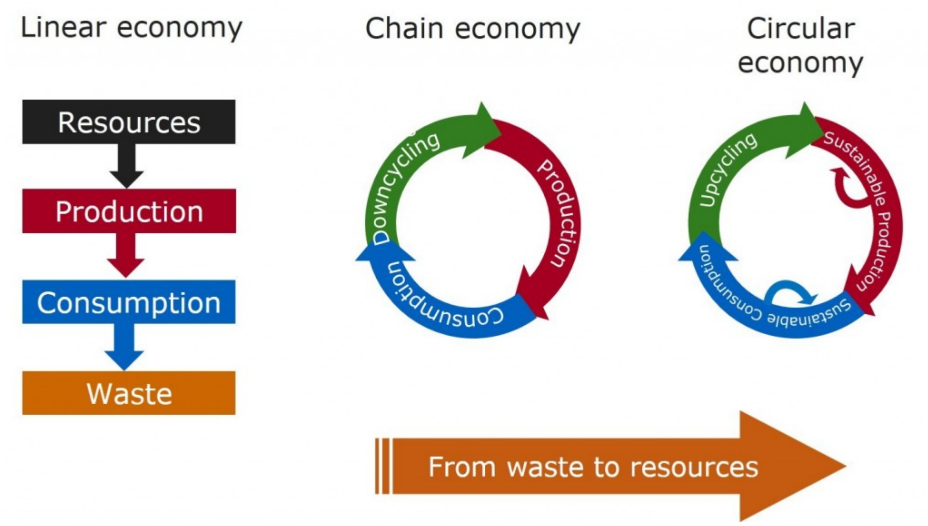
DuPont is participating in various working groups and initiatives, including CEFLEX (A Circular Economy for Flexible Packaging), PCEP (Plastics Europe), the Ellen MacArthur Foundation, NPEC (the New Plastics Economy) and others helping the industry to define rules for improved design guidelines for flexible packaging and designs for recyclability in order to eventually reduce littering and landfill.

Energy recovery can be accomplished by several approaches, including plastic to oil, engineered fuel, and gasification (23). Plastics to oil is a catalytic cracking process used to recover the hydrocarbon content of the plastic. Engineered fuels are an amalgam of densified plastic and paper, maybe including a binding agent. In the gasification process, waste is pyrolyzed to produce char which reacts with steam to produce carbon monoxide and hydrogen; this 'syngas' can be converted to methanol, ethanol, and subsequently olefins and polymers.

Consumer education is critically important to improving recycling rates. To encourage diversion of plastic which cannot or are not recycled from landfills, Dow has developed an 'EnergyBag' program which involved municipalities and industry partners to encourage collection of non-recycled items for energy recovery (24). Similarly, the How2Recycle™ program sponsored by the Sustainable Packaging Coalition (25) provides labeling for consumer product packaging which enhances the information available in the resin identification codes introduce by the Society of the Plastics Industry (SPI) in 1988 (26).

The Circular Economy in Practice: Adding Value to Recycled Materials

The fundamental principle of the circular economy is to keep resources in use for as long as possible. This can be shown schematically (27):



Successful implementation of these principles will require identification of end-use markets for the recycled resins. The US EPA has developed Sustainable Materials Management Plan which partners with stakeholders across the value chain. This Plan focuses on increasing the quantity and quality of reused and recycled materials from MSW, by including public and private sector collection and processing infrastructure and end markets, promoting the productive and sustainable use of materials across their entire life cycle (28).

DuPont has developed the 'virtuous circle' model of value chain collaboration to reduce the circular economy model to practice (29). In South Africa, DuPont coordinates with partners along the value chain so that multilayer flexible pouches filled with nutritious liquid meal replacements pouches used to feed children and then collected after use and recycled into plastic lumber used to fabricate school desks. Agrochemical packaging, which is primarily rigid containers, offers a similar challenge in that they are multilayer structures. In Brazil, DuPont has worked across the value chain to collect agrochemical bottles and blend them with compatibilizers to produce high value products from the recyclate such as piping and conduit (30).

These Virtuous Circle projects highlight some important factors affecting use of compatibilizers in mixed stream recycled packaging. In technical terms, the compatibilization process is simplified and most effective if the recycle stream does not contain aluminum bound to film, paper combined with plastic, or carbon black inks. Replacing cross-linked adhesives with tie layers made from coextrudable thermoplastics can really make a difference in the quality (and hence the value) of the recycled plastic.

Conclusions

Although flexible plastic packaging has been in use for less than a century, it has had an enormous impact on packaged goods as well as on waste proliferation. The advantages of plastic packaging in reducing both food waste and package weight, combined with robust end of life strategies for the package, are valuable contributors to the packaging market. Managing packaging materials as valuable resources economy enables meeting consumer desires and environmental standards and managing public perception of their benefits. Collaboration throughout in the framework of the circular economy in a format like the Virtuous Circle benefits all players in the value chain. In terms of how best to collect waste and ensure sustainability, the Virtuous Circle projects demonstrate the importance of appropriate collection schemes: unless these are in place, whether or not the material is recyclable or not is a moot point.

References

1. https://www.nytimes.com/2017/07/19/climate/plastic-pollution-study-science-advances.html?smprod=nytcore-iphone&smid=nytcore-iphone-share
2. http://advances.sciencemag.org/content/3/7/e1700782
3. https://www.worldwildlife.org/magazine/issues/fall-2016/articles/stemming-the-tide-of-plastics-in-our-oceans
4. http://www.plasticsnews.com/article/20170612/NEWS/170619986/acc-un-forum-too-focused-on-plastic-bans-not-enough-on-waste-management
5. https://www.epa.gov/sites/production/files/2015-08/documents/reducing_wasted_food_pkg_tool.pdf
6. http://advances.sciencemag.org/content/3/7/e1700782.full
7. http://www.plasticsnews.com/article/20170321/NEWS/170329972/plastic-film-recycling-research-group-seeking-mrf-help
8. https://plastics.americanchemistry.com/Education-Resources/Publications/2014-National-Postconsumer-Plastic-Bag-Film-Recycling-Report.pdf

9. UEHARA, Gabriel Abreu; FRANCA, Marcos Pini and CANEVAROLO JUNIOR, Sebastiao Vicente. Recycling assessment of multilayer flexible packaging films using design of experiments. *Polímeros* [online]. 2015, vol.25, n.4 [cited 2017-08-01], pp.371-381. Available from: <http://www.scielo.br/scielo.php?script=sci_arttext&pid=S0104-14282015000400371&lng=en&nrm=iso>. ISSN 0104-1428. http://dx.doi.org/10.1590/0104-1428.1965
10. http://www.ameripen.org/wp-content/uploads/2017/07/Maximizing-the-Benefits-of-CE-SMM-Models-AMERIPEN.pdf
11. Smithers Pira, 'The future of Flexible Packaging to 2018'
12. https://ceflex.eu/public_downloads/FIACE-Final-report-version-24-4-2017-non-confidential-version-Final.pdf
13. http://www.fao.org/food-loss-and-food-waste/en/
14. Denkstatt, "The Impact of Plastic Packaging on Life Cycle Energy Consumption and Greenhouse Gas Emissions in Europe", 2011
15. Denkstatt, "How Packaging Contributes to Food Waste Prevention", 2014
16. http://www.mrcpolymers.com/PlasticRecyclingFacts.php
17. http://advances.sciencemag.org/content/3/7/e1700782
18. https://plastics.americanchemistry.com/National-Reach-Study/
19. http://www.centexbel.be/files/publication-pdf/Supertex_ChemicalFibersInternational.pdf
20. https://engineering.dartmouth.edu/~d30345d/courses/engs171/DfRecycling.pdf
21. http://www.europen-packaging.eu/policy/9-extended-producer-responsibility.html
22. https://www.grontpunkt.no/files/dmfile/Report-GPN---Design-for-Recycling---07.04.174.pdf
23. https://plastics.americanchemistry.com/Energy-Recovery/
24. http://www.dow.com/en-us/packaging/sustainability/energy-recovery
25. http://www.sustainablepackaging.org/content/?type=5&id=labeling-for-recovery
26. https://plastics.americanchemistry.com/Plastic-Resin-Codes-PDF/
27. http:/www.circular-europe-network.eu/about/what-is-circular-economy
28. http://greenblueorg.s3.amazonaws.com/smm/wp-content/uploads/2015/11/SMM-Strategic-Plan_October-2015.pdf
29. http://thevirtuouscircle.co.za/partners/dupont
30. http://www.dupont.com/products-and-services/packaging-materials-solutions/sustainable-packaging/articles/recyclable-packaging.html