Status of Plastics Waste in Circular Economy in the USA

Serpil Guran, Ronald L. Mersky and Sannidhya K. Ghosh

Abstract Circular economy, an economic system where waste is utilized as an economic input, is currently the subject of much interest. Methods to incorporate all wastes into circular economy have not been developed. This paper discusses the current status and options for including plastics wastes in circular economy in the USA. Utilizing some plastics wastes as fuel is the most feasible path to doing so at present. Completely closed-loop circular economy for plastics would require fundamental changes in how plastics-based products are designed and manufactured.

Keywords Circular economy · Recycling · Plastics waste

1 Introduction

The term *circular economy* has become popular in recent years (Kok et al. 2013), but the concept is not new. The basic definition of circular economy is simply an economic system based on what is traditionally defined as *waste* being redefined as an economic input, as opposed to a *linear economy* (Fig. 1) in which materials are extracted, used, and disposed of (Hoomweg and Kennedy 2013). Some definitions of circular economy also include reduction of nonrecoverable pollutants and increased durability of products (lengthening of the circle) (Lahti et al. 2018). Circular economy can therefore in practice be considered essentially synonymous with the term *zero waste economy*.

Waste is something that is considered to be of negative value and therefore is designated for removal, by its owner (Michelini et al. 2017). Historically, waste

S. Guran (✉)
The EcoComplex, Rutgers University, Rutgers, The State University of New Jersey, New Brunswick, USA
e-mail: sg795@njaes.rutgers.edu

R. L. Mersky
Department of Civil Engineering, Widener University, Chester, USA

S. K. Ghosh
Structural Engineering and Structural Mechanics, Department of Civil, Environmental and Architectural Engineering, University of Colorado Boulder, Boulder, USA

S. K. Ghosh (ed.), *Circular Economy: Global Perspective*,
https://doi.org/10.1007/978-981-15-1052-6_21

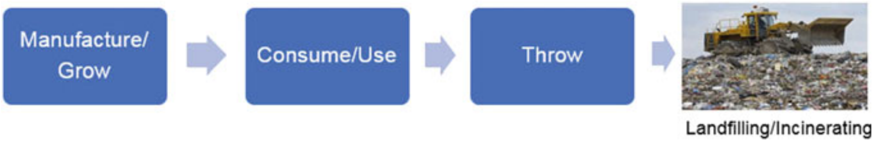

Fig. 1 Linear economy resource management approach

management has been performed for the purposes of sanitation, health, and esthetics (Michelini et al. 2017). As such, waste was managed by disposal, except in cases where the waste was economically and functionally competitive with virgin materials. More recently, secondary (waste) materials use (more popularly referred to as *recycling*—a term that, like circular economy, indicates the cyclic nature of the process) has been encouraged or mandated for perceived environmental benefits, rather than only free-market reasons. Circular economy is an expansion of encouraged or mandated recycling—it is an economy *requiring* a cyclical materials system. To achieve such implies not just materials recovery, but also that the cyclical use of materials be incorporated in all aspects of the economy—including product design, manufacture, and use.

Plastics materials are an increasingly large quantity and percentage in the US waste stream. From Table 1, it is noted that total plastics in the USA MSW increased from 390,000 US tons in 1960 to 34,500,000 in 2015—an increase of almost 90 times (2015 data are the most recent published by the US EPA). From Table 2, it is seen that at the same time, period plastics increased from 0.4% to 13.1% of the USA MSW. No other single waste material has had nearly that rate of growth.

A significant reason for this quantity and percentage increase is substitution of plastics (a newer material) for older materials (glass, metals, and paper) in existing products. Tables 1 and 2 indicate a slowing of plastics wastes' quantity and percentage increases (as plastics become mature materials) but the increase still continues.

Given the large, and still increasing, portion of plastics in the USA MSW, it is critical for the USA economy to incorporate plastics wastes into production of new products if a circular economy is to be achieved.

2 Governmental Involvement in MSW

Nationwide US waste management laws began in 1965 with the "Solid Waste Disposal Act" (Fig. 2). This was followed by the Resource Conservation and Recovery Act (RCRA) of 1976. The RCRA program, implemented by the US EPA and its partner states, tribes, and local governments, protects communities and the environment from the improper management of solid and hazardous waste, cleans land and water, conserves resources, and empowers citizens by delivering information and opportunities that enable communities to participate in decision-making processes.

Table 1 Materials generated[a] in the municipal waste stream, 1960–2015 (thousands of tons) (5)

Paper and paperboard	29,990	44,310	55,160	72,730	87,740	84,840	71,310	68,610	68,050
Glass	6720	12,740	15,130	13,100	12,770	12,540	11,520	11,480	11,470
Metals									
Ferrous	10,300	12,360	12,620	12,640	14,150	15,210	16,920	17,880	18,170
Aluminum	340	800	1730	2810	3190	3330	3510	3530	3610
Other nonferrous	180	670	1160	1100	1600	1860	2020	2230	2220
Total metals	*10,820*	*13,830*	*15,510*	*16,550*	*18,940*	*20,400*	22,450	23,640	24,000
Plastics	390	2900	6830	17,130	25,550	29,380	31,400	33,390	34,500
Rubber and leather	1840	2970	4200	5790	6670	7290	7750	8210	8480
Textiles	1760	2040	2530	5810	9480	11,510	13,220	15,240	16,030
Wood	3030	3720	7010	12,210	13,570	14,790	15,710	16,120	16,300
Other[b]	70	770	2520	3190	4000	4290	4710	5120	5160
Total materials in products	*54,620*	*83,280*	*108,890*	*146,510*	*178,720*	*185,040*	*178,070*	*181,810*	*183,990*
Other wastes									
Food	12,200	12,800	13,000	23,860	30,700	32,930	35,740	38,670	39,730
Yard trimmings	20,000	23,200	27,500	35,000	30,530	32,070	33,400	34,500	34,720
Miscellaneous Inorganic Wastes	1300	1780	2250	2900	3500	3690	3840	3970	3990
Total other wastes	33,500	37,780	42,750	61,760	64,730	68,690	72,980	77,140	78,440
Total MSW generated—weight	88,120	121,060	151,640	208,270	243,450	253,730	251,050	258,950	262,430

[a]Generation before materials recycling, composting, combustion with energy recovery, or landfilling. Does not include construction and demolition debris, industrial process wastes or certain other wastes. Details may not add to totals due to rounding
[b]Includes electrolytes in batteries and fluff pulp, feces and urine in disposable diapers

Table 2 Materials Generated[a] in the Municipal Waste Stream, 1960 to 2015 (percent of total generation) (5)

Paper and paperboard	34.0%	36.6%	36.4%	34.9%	36.0%	33.4%	28.4%	26.5%	25.9%
Glass	7.6%	10.5%	10.0%	6.3%	5.2%	4.9%	4.6%	4.4%	4.4%
Metals									
Ferrous	11.7%	10.2%	8.3%	6.1%	5.8%	6.0%	6.7%	6.9%	6.9%
Aluminum	0.4%	0.7%	1.1%	1.3%	1.3%	1.3%	1.4%	1.4%	1.4%
Other nonferrous	0.2%	0.6%	0.8%	0.5%	0.7%	0.7%	0.8%	0.8%	0.8%
Total metals	*12.3%*	*11.4%*	*10.2%*	*7.9%*	*7.8%*	*8.0%*	*8.9%*	*9.1%*	9.1%
Plastics	0.4%	2.4%	4.5%	8.2%	10.5%	11.6%	12.5%	12.9%	13.1%
Rubber and leather	2.1%	2.5%	2.8%	2.8%	2.7%	2.9%	3.1%	3.2%	3.2%
Textiles	2.0%	1.7%	1.7%	2.8%	3.9%	4.5%	5.3%	5.9%	6.1%
Wood	3.4%	3.1%	4.6%	5.9%	5.6%	5.8%	6.3%	6.2%	6.2%
Other[b]	0.1%	0.6%	1.7%	1.5%	1.6%	1.7%	1.9%	2.0%	2.1%
Total materials in products	62.0%	68.8%	71.8%	70.3%	73.4%	72.9%	70.9%	70.2%	70.1%
Other wastes									
Food	13.8%	10.6%	8.6%	11.5%	12.6%	13.0%	14.2%	14.9%	15.1%
Yard trimmings	22.7%	19.2%	18.1%	16.8%	12.5%	12.6%	13.3%	13.3%	13.3%
Miscellaneous Inorganic wastes	1.5%	1.5%	1.5%	1.4%	1.4%	1.5%	1.5%	1.5%	1.5%
Total other wastes	38.0%	31.2%	28.2%	29.7%	26.6%	27.1%	29.1%	29.8%	29.9%
Total MSW generated—%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

[a]Generation before materials recycling, composting, combustion with energy recovery or landfilling. Does not include construction and demolition debris, industrial process wastes or certain other wastes. Details may not add to totals due to rounding

[b]Includes electrolytes in batteries and fluff pulp, feces and urine in disposable diapers

Fig. 2 The evolution of significant RCRA legislation Adapted from RCRA's Critical Mission and the Path Forward, 2014 (USEPA 2014)

RCRA also serves as a legislative basis for EPA's Sustainable Materials Management (SMM) program, which is a systemic approach for promoting using and reusing materials over their life cycle. The program has four primary goals: to decrease the disposal rate; reduce environmental impacts; increase socioeconomic benefits; and increase the capacity of communities to adopt SMM practices. The SMM program set three strategic priorities as follows:

– The built environment
– Sustainable food management
– Sustainable packaging.

3 Plastics Recycling

Table 3 shows the US recycling rates for MSW component materials, 1960–2015. It is notable that plastics wastes have the lowest recycling rates of all MSW categories except food (which, as a wet waste, has only recently been subject to significant organized source separation in the USA).

There are multiple reasons to explain the low plastics recycling rate, including:

Collection/transport/separation

- some plastics (i.e., EPS) are of very low density, making transport per weight expensive and energy inefficient.
- plastics are often strongly attached to other plastics or nonplastic materials (i.e., multi-polymer packaging, appliances) making separation into pure polymers expensive if not feasibly impossible.
- some plastics waste (i.e., agricultural) are produced in remote areas.
- contamination (most likely the result of single-stream recycling practices).

Technological

- Thermoset plastics cannot be remelted and reformed, significantly limiting their input into new products.
- Depolymerization is not yet commercialized.

Table 3 Materials recycled and composted[a] in municipal solid waste, 1960–2015 (percent of generation of each material)

	Percent of generation of each material								
	1960	1970	1980	1990	2000	2005	2010	2014	2015
Paper and paperboard	16.9%	15.3%	21.3%	27.8%	42.8%	49.5%	62.5%	64.7%	66.6%
Glass	1.5%	1.3%	5.0%	20.1%	22.6%	20.7%	27.2%	26.0%	26.4%
Metals									
Ferrous	0.5%	1.2%	2.9%	17.6%	33.1%	33.0%	34.3%	33.4%	33.4%
Aluminum	Neg.	1.3%	17.9%	35.9%	27.0%	20.7%	19.4%	20.1%	18.6%
Other nonferrous	Neg.	47.8%	46.6%	66.4%	66.3%	68.8%	71.3%	69.5%	67.6%
Total metals	*0.5%*	*3.5%*	*7.9%*	*24.0%*	*34.8%*	*34.3%*	35.3%	*34.8%*	*34.3%*
Plastics	Neg.	Neg.	0.3%	2.2%	5.8%	6.1%	8.0%	9.6%	9.1%
Rubber and leather	17.9%	8.4%	3.1%	6.4%	12.3%	14.4%	18.6%	17.5%	17.8%
Textiles	2.8%	2.9%	6.3%	11.4%	13.9%	15.9%	15.5%	14.8%	15.3%
Wood	Neg.	Neg.	Neg.	1.1%	10.1%	12.4%	14.5%	15.9%	16.3%
Other[b]	Neg.	39.0%	19.8%	21.3%	24.5%	28.2%	29.1%	28.7%	27.7%
Total materials in products	10.3%	9.6%	13.3%	19.8%	29.7%	32.0%	36.6%	36.6%	36.8%
Other wastes									
Food[c]	Neg.	Neg.	Neg.	Neg.	2.2%	2.1%	2.7%	5.0%	5.3%
Yard trimmings	Neg.	Neg.	Neg.	12.0%	51.7%	61.9%	57.5%	61.1%	61.3%
Miscellaneous Inorganic wastes	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.
Total other wastes	Neg.	Neg.	Neg.	6.8%	25.4%	29.9%	27.6%	29.8%	29.8%
Total MSW recycled and composted—%	6.4%	6.6%	9.6%	16.0%	28.5%	31.4%	34.0%	34.6%	34.7%

[a]Recycling and composting of postconsumer wastes; does not include converting/fabrication scrap. Details may not add to totals due to rounding
[b]Collection of electrolytes in batteries; probably not recycled. Neg = Less than 5000 tons or 0.05%
[c]Includes collection of other MSW organics for composting

4 Legislative and Industrial Initiatives

Most USA governmental actions aimed at managing plastics wastes have occurred at the local level. Some municipal governments have banned or restricted the use of specific plastics products that are perceived as being particularly problematic (single-use bags, straws). Such actions may reduce plastics wastes but do not provide for reintroduction of wastes into circular economy.

Some states have taken actions. California, for example, has passed a regulation requiring that some disposable food service items be reusable, recyclable, or compostable by 2021 (Rajbanshi 2019; California Legislative Information 2018). However the regulation is limited to certain items at certain state facilities, so its scope is not broad. Also, rather than causing plastics items to be reintroduced into circular economy, the result could instead be substitution for non-plastics items.

At the federal level, legislation has been proposed to introduce extended producer responsibility to manufacturers of plastics packaging (Product Stewardship Institute 2019). However the proposal also calls for bans or disincentives for some plastic products and container deposits. Also it is unclear if this will become law and, if so, in what form.

Overall, there is not significant law to encourage plastics in circular economy.

The plastics industry has been willing for decades to find uses for some plastics collected in recycling programs. However the overall USA plastics recycling rate, as of 2015, is 9.1% (USEPA 2019) (although some specific products have much higher rates). This indicates that industry has not yet found much circular economy pathway for plastics.

5 Options for Plastics in Circular Economy

There is currently not any indication that the mentioned obstacles will be overcome in the near future. Therefore, it appears that, if the USA is to move toward a circular economy (Fig. 3), fundamental changes in plastics wastes are needed. This would include replacing some current polymers in products, redesign of many products, and elimination of some products. This runs contrary to usual free-market economics and would have many secondary consequences. It is not feasible.

For plastics in the USA, utilizing some plastics wastes as fuel appears to be the most feasible current method for plastics to be a part of movement toward circular economy.

The USA can transform current stalled inefficient plastics recycling operations and create innovative solutions. Creating an effective infrastructure is a key to achieve transformation and the solutions can be listed as follows (Bara and Leonard 2018):

– Producing plastics from nonfossil feedstocks
– Displacing fossil energy by renewable energy during the production and distribution of plastics

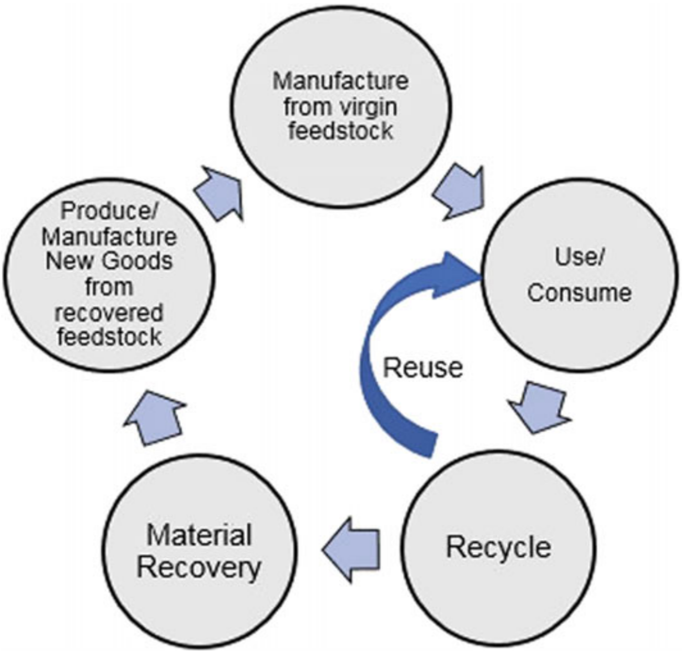

Fig. 3 Closing the loop for circular economy

- Market transformation through technological innovation: Researching and developing new production processes to achieve longevity, reusability, and reduce the waste
- Considering plastic waste as a resource
- Developing new sustainable business models
- Market-based incentives
- Development of new institutional infrastructure
- Supportive regulations
- Collaboration between researchers, businesses, consumers, and decision makers
- A systems approach to identify the opportunities and creating an ecosystem that strategies and policies can impact each other efficiently.

References

Bara, R., & Leonard, S. A. (2018). Plastics and the circular economy. A STAP document.

California Legislative Information. (2018). https://leginfo.legislature.ca.gov/faces/billCompareClient.xhtml?bill_id=201720180SB1335.

Hoomweg, D., Bhada-Tata. P., & Kennedy, C. (2013). Waste production must peak this century. *Nature, 502*, 615–617.

Kok, L., Wurpel, G., & Ten Wolde, A. (2013). *Unleashing the power of circular economy*. Amsterdam, Netherlands: IMSA and Circle Economy.

Lahti, T., Wincent, J., & Parida, N. (2018). A definition and theoretical review of circular economy, value creation, and sustainable business models: Where are we now and where should research move in the future? *Sustainability, 10,* 2799–2817. https://doi.org/10.3390/su10082799.

Michelini, G., Moraes, R. N., Cunha, R. N., Costa, J. M. H., & Ometto, A. R. (2017). From linear to circular economy: PSS conducting the transition. *Procedia CIRP*, 2–6. https://doi.org/10.1016/j.procir.2017.03.012.

Product Stewardship Institute. (19 July, 2019). *Waste Advantage Magazine*. https://wasteadvantagemag.com/extended-producer-responsibility-epr-proposal-for-packaging-hits-the-national-stage/.

Rajbanshi, R. (19 July, 2019). Upcoming California law could set stage for recycling definition debate. *Waste Dive.*. https://www.wastedive.com/news/upcoming-california-law-could-set-stage-for-recycling-definition-debate/559078/.

USEPA. (2014). Protecting communities-restoring land-conserving resources: RCRA's Critical Mission & The Path Forward. https://www.epa.gov/sites/production/files/2015-09/documents/rcras_critical_mission_and_the_path_forward.pdf.

USEPA. (2018). Advancing sustainable materials management: 2015 fact sheet-assessing trends in material generation, recycling, composting, combustion with energy recovery and landfilling in the United States.

USEPA. (2019). Plastics: Material-Specific Data. https://www.epa.gov/facts-and-figures-about-materials-waste-and-recycling/plastics-material-specific-data.