Environmental Implications of Reuse and Recycling of Packaging

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Abstract A major issue confronting the community and government is waste disposal. A considerable amount of waste is generated when consumers procure and use products. The disposal of waste has become a serious problem due to the increase in the number of consumers and high waste generation. According to the Manual on Municipal Solid Waste Management, Ministry of Urban Development, Government of India (2000), approximately 0.1 million tons of municipal solid waste was generated in India every day leading to almost 36.5 million tons/y. Many manufacturers and retailers are earnest in promoting their brands by the use of excessive packaging without regard to real human needs or environmental concerns. This has resulted in an enormous amount of waste, which calls for numerous waste-management policies. Reduce, reuse, and recycle are tools to minimize the negative implications of manufacturing and retailing on the environment. Design experts today create packaging solutions that consider the optimum use of raw materials and techniques as well as the use of recycled materials in inventory, which can in turn be reused, recycled, composted, or become a source of energy recovery. This chapter presents an overview of the impact of the industrial packaging supply chain on environment, the challenges facing environmentally conscious manufacturing, concepts underlying reuse and recycling of packaging, and the trends in green packaging. The environmental implications of the reuse and recycling of packaging were shown to be beneficial in case studies in terms of raw material, resources, cost, and reduction in landfills. Challenges regarding waste may be different in different countries, but the path to addressing the problems of the waste sector may be common. Evidence from case studies proves that

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ecologically sustainable concepts lead to savings in resources and have a positive effect on the environment giving a competitive advantage to firms. Prevention and reduction of waste at the source and circular global economy will be of primary importance for all countries to bring about radical changes toward greening the waste sector.

Keywords Environment conscious manufacturing · Reuse and Recycling · Green packaging

1 Impact of Industrial Packaging Supply Chain on Environment

1.1 Introduction

Packaging of products has become an area of concern because it occupies an important position in the supply chain with the growing necessity of cost minimization, reduction of environmental impact, and increase in electronic operations. The main purpose of a supply chain is the production, transportation, and distribution of products to consumers. The different levels in the supply chain from supplier to consumer are linked with the movement of packed products, which has a bearing on the design-and-manufacturing process, improved layout, and increased efficiency. The fundamental role of packaging along the supply chain requires connectivity with logistics, marketing, production, and environmental aspects. Logistics calls for easy handling of the packages until it reaches the consumer, whereas marketing demands good appearance and right size of the product to inspire the customer to use it. The production department calculates the minimization of time and cost for the packaging of products, and looks for recyclable packaging and least use of raw materials.

While analyzing environmental issues regarding packaging, sustainable packaging is a main frame that should be considered. To enhance the sustainability factor in packaging, manufacturers should look into the primary details such as whether the product actually needs to be packed and the minimum amount of packaging needed to retain its appearance and quality. The package design process evaluates the mass and volume of packages and determines the optimal use of raw materials. Returnable packages encourage closed-loop logistics, and recycling lays the emphasis on the recovery of primary parts of packages. Packaging waste can be used as refuse-derived fuel and allows for a waste-to-energy principle. In some cases, materials must be disposed of and may end up being incinerated or dumped in a landfill. Many manufacturers have started using recyclable materials, such as plastics, cardboard, and paper, and reusing secondary packaging materials for future shipments.

1.2 Impact of Packaging Raw Materials on the Environment

A wide range of raw materials are used for packaging to serve functions such as protection, sales appeal, product identity and information, consumer convenience, and safety. They are usually applied in three broad categories, namely, (1) primary packaging, which forms part of the basic or first packaging of goods; (2) secondary packaging, which covers larger packs and (3) tertiary packaging, which is the outermost wrappings thus facilitating easy transport. Secondary and tertiary packaging materials are most often similar and can be reused or recyclable. The primary packaging materials usually vary and are damaged thereby making it difficult to reuse or recycle.

The American Society of Testing Materials, ASTM D 996-95 (E01) (Terminology of Packaging and Distribution), defines industrial packaging (tertiary packaging) as a package used for the transportation or storage of commodities, the contents of which are not meant for retail sale without being repackaged. The society also defines transport packaging (secondary packaging) as "packaging intended to contain one or more articles or packages or bulk materials for the purposes of handling and or distribution" (Reusable Industrial Packaging Association (RIPA) 2011). Packaging waste statistics show that on average, every citizen in the 27 European Union member states generated 159 kg of packaging waste in 2011, and this quantity varied between 43 and 216 kg per capita across European countries (Eurostat 2013).

Packaging materials commonly used are a wide range of oil-based polymers, which are nonbiodegradable and difficult to recycle or reuse. The most common types of packaging materials used for primary packaging are paper- and pulp-based materials, glass, and metals such as aluminum or steel and plastics. Approximately 36 % of the total Australian packaging market constitutes paper and cardboard packaging, 30 % plastics, 20 % metals, 10 % glass, with the remaining being other types of packaging. In 2002 to 2003, Australia used 4 million tons of printing, writing and packaging paper and cardboard, and 83 % of the waste paper recycled was used for making packaging and industrial paper. In addition, more than 1 billion milk and juice cartons are used each year in Australia, and >2300 tons of liquid paperboard is recovered through recycling for the use of office paper (Tuckerman 2005).

Paper and cardboard are widely used consumer materials derived from wood, a valuable natural resource. Both chemical and mechanical processes are involved in the conversion of raw materials to paper consuming large amounts of energy and water. It has been estimated that 1 ton of paper consumes 20 fully grown trees, and in 2003 to 2004, Australia used 3,863,000 tons of wood for paper manufacturing, which accounts for an approximate 6.9 % increase from 2002 to 2003. Moreover, approximately 1.9 million tons of paper is sent to landfills each year, which could be recycled instead (Clean up 2009). Approximately 50 % of waste material reaching landfills could be recycled or reused, thus saving natural resources and reducing greenhouse gas emissions. Glass is made from natural materials, namely, sand, soda ash, and limestone with dolomite and feldspar and heated in blast furnaces at temperatures >1500–2730 °F before the glass is cooled. It has been estimated that 2 tons of CO_2 is emitted for manufacturing 1 ton of glass (Hugger 2004). Sand mining, heavy consumption of heat energy, and huge volumes of gas emissions mark the production of glass. Glass is recyclable, and scrap glass called "cullet" is added in different percentages (45–100 %) to the raw material as per the needs and requirements of the end product.

The major global environmental issues with relevance to the plastic industry are numerous. Plastic production uses large amounts of fossil fuel energy and raw material resources with the release of greenhouse gases such as CO_2, N_2O, CFCs, and CH_4 into the atmosphere. Depletion of the ozone layer due to the release of CFCs can cause higher levels of UV-B radiation, thus creating problems with human health and changes in agricultural and marine ecosystems. Gases released by the burning of fossil fuels cause acidification of the environment resulting in impairment of fertility of agricultural soil and damage to crops, forests, and inland fisheries. Urban litter is another problem due to the improper disposal of plastic and paper packaging, thus leading to problems for animals, birds, and marine life.

Raw material for the production of primary aluminum is bauxite, and secondary aluminum comes from aluminum scrap. Molten aluminum is converted into different shapes called "ingots." It is then made into sheets or foils during the semimanufacturing stage, after which the final product is fabricated. Aluminum is a strong metal that can be used as a future resource. The environmental impact of aluminum production is red-mud generation and land use in bauxite mining. Aluminum-associated toxicity through air, water, and soil emissions and wastes from the plant are some of the environmental impacts that cause problems to humans and the environment. The greenhouse gas emissions generated during different stages of aluminum production are given in Table 1. Aluminum toxicity affects approximately 40 % of agricultural soils in the world (Flaten et al. 1996) and has led to fish species extinction due to acid rains. Chronic renal failure, anemia, encephalopathy, and osteomalacia are some of the toxicity effects of aluminum in humans.

The production of steel is accompanied by unwanted products—such as scrap, slag, and scale—that are used by cement and recycling industries; air emissions such as CO_2, CO, SO_x, NO_x; and dust and water emissions, e.g., oil, grease, chemicals, and suspended solids. The impact of steel production is assessed in terms of global warming potential (467 $kgCO_2e$), ecotoxicity (57.3 $PAFm^2y$), fossil fuel (478.4 Mj), carcinogen (DALY 1.2×10^{-5}), and respiratory inorganic (DALY 8.0×10^{-4}) (Tongpool et al. 2010). After aluminum and glass cans, steel cans have a moderate impact on the environment. They are not compostable, but they are recyclable, and are designed for disassembly because they can be taken apart after their end of life for reuse or recycling. Since steel cans are recyclable, they can contribute to reduced resource use.

Table 1 Range of GHG emissions during the different stages of aluminum production (Liu and Muller 2012)

Sl. No.	Production stages	kg CO_2-eq/kg output				Typical range
		Place/year	Minimum	Place/year	Maximum	
1.	Primary aluminum	Greenfield smelter, Iceland	5.92	Middle East, 2000	41.10	9.7–18.3
2.	Secondary aluminum	Scrap remelting, Europe, 2005	0.32	China	0.74	0.3–0.6
3.	Rolling	82 % yield ratio, US, 1995	0.20	Foil production, Europe, 2005	1.35	0.6–0.9
4.	Extrusion	69 % yield ratio, US, 1995	0.28	International Aluminum Institute, London, 1998	0.74	0.3–0.7
5.	Shape casting	45 % yield ratio, 1995	0.48	International Aluminum Institute, London 1998	0.62	0.5–0.6

1.3 Case Study of the Impact of Packaging Materials on the Environment

A multidimensional environmental evaluation of packaging materials was performed using three methods, namely life-cycle assessment (LCA), analytic hierarchy process (AHP), and cluster analysis (CA) (Huang and Ma 2004). All material requirements, e.g., energy consumed, emissions, waste, and environmental impacts associated with product, process, and service, were quantified. Functional units for the packaging materials and system boundaries were identified. Four stages of the life cycle of the packaging materials were considered: resource extraction, manufacture, use, and waste disposal. SimaPro 4.0 was the software used for computing the LCA. The nine environmental issues considered were ozone-layer depletion, heavy metals, carcinogenic substances, summer smog, winter smog, pesticides, greenhouse effect, acidification, and eutrophication. Under the analytic hierarchy process, seven evaluation factors were considered from ISO 14021 to assess environmental friendliness, and objectives were set. Every packaging material is weighted according to each evaluation factor, and the material is scored using associated evaluation factors; a total score is obtained by summing scores. The cluster-analysis technique used the LCA points and the AHP scores to describe the character of the material and also showed the homogeneity or heterogeneity of the materials.

Table 2 Results of the AHP scores, LCA points, and cluster-analysis grouping of packaging materials (Huang and Ma 2004)

Sl. No.	Packaging materials	AHP scores[a]	Assigned order[b]	LCA points[c]	Assigned order[b]	Cluster-analysis grouping[a]
1.	PET containers	1.32	1	7.75E-04	4	1
2.	PP containers	1.32	1	3.50E-04	3	1
3.	HDPE containers	1.27	3	2.66E-04	1	1
4.	PS containers	1.02	4	8.95E-04	6	1
5.	Steel cans	0.73	5	9.53E-04	7	2
6.	Glass containers	0.63	6	2.69E-04	8	3
7.	Cardboard boxes	0.61	7	5.13E-04	4	2
8.	Liquid paperboards	0.61	7	9.53E-04	2	2
9.	Aluminum cans	0.49	9	2.83E-04	9	3

[a]Higher scores have less environmental impact
[b]In environmentally friendly order
[c]Higher points have more environmental impact

The results of LCA indicated that aluminum cans and glass containers had the greatest impact on the environment when the whole life cycle was taken into account because aluminum cans emit more carcinogens and glass containers emit more heavy metals during the manufacturing stage. LCA also showed that the worst environmental impact (>90 %) was incurred during the manufacturing phase. The LCA scores, which showed higher points, had greater environmental impact. The data for evaluation is given in Table 2. The results of AHP showed that PET, HDPE, and PP containers are better in terms of environmental impact compared with cardboard boxes, liquid paperboards, and aluminum cans. This may be due to the fact that the factor weight assigned for each parameter yielded higher scores e.g., "reduce resource use" had a factor weight of 0.20, and "recovered energy" had a factor weight of 0.13. The higher the scores, the lesser was the impact in the AHP analysis. The cluster analysis formed three groups. Group 1 included all types of plastics because they have low environmental impact and have similar characteristics. Group 2 are cardboard boxes, liquid paperboards, and steel cans because they are "moderate" in terms of environmental damage. Group 3 included aluminum cans and glass containers because they have the worst impact on environment. In the three groups, AHP and LCA scores yielded the same directions in terms of results.

This study provided a holistic approach to analyzing the environmental impact of packaging materials on the environment taking the quantitative (LCA) and qualitative (AHP) methods, as well as the impact on all phases of the life cycle, into account. Materials commonly used in the market were considered, but this study can be extended to other materials.

1.4 Effect of Packaging Supply Chain on the Environment

The packaging supply chain is increasingly complex and involves the active participation of producers of the raw materials using in packaging, the retailers who sell the packed goods, the customers, and the companies who manage end-of-life of packaging. Each member of the supply chain must collaborate and support each other to achieve the best environmental sustainability. The quantity of packaging materials that fill the dustbins show that optimum packaging has not yet been achieved and that redesign of packaging to save raw material and energy is essential.

Optimal packaging design reduces the excessive use of raw material and reduces environmental impacts right from source, manufacture, distribution, and delivery. Communication among all of the partners of the supply chain, as well as the adoption of new innovative technologies, can reduce costs for packaging and distribution, thereby reducing environmental impacts. The packaging supply chain can lower costs by reducing distance and transportation costs, production waste and costs, and unplanned activities to shrink the environmental footprint. Other issues, such as social elements, are also taken into account. The most fitting example would be the interaction of economic consideration with social and environmental issues such as noise pollution, congestion, and CO_2 emissions in packaging and logistics, and their role in retailers' sensitivity to sustainable issues in the supply chain.

The integration of sustainability concepts into legislation will change the environment in which firms work and the nature of competition. This calls for supply-chain managers to address new issues such as reverse supply chain, responsibility for pollution, extent of recycling and reuse, and end-of-life product management. This line of thought will produce changes in existing practices to create new production and management systems.

Our imagined future will call for new renewable resources for packaging and distribution, level of negative impact on the environment, market force and consumerism, attitudinal and lifestyle changes, and policies necessary to achieve sustainability along the entire supply chain. Research focus should be directed toward critical operational and sustainability issues such as decentralization in collection and processing of end-of-life products, better use of used products, and life-cycle analysis interlinked with statistical packages. The closed-loop nature of sustainable supply-chain management will alter the policies and strategies of firms and the competitive environment. Economics will look at total environmental cost, which includes effects on resource depletion and the generation of byproducts such as pollution and waste. Strategy and planning must include sustainability issues, and organizations must go beyond the normal limits to work for a sustainable supply chain, of which packaging and logistics form an important part. Case-study analysis, hypothesis testing, and multiple case-model development are some of the tools that could be used for bringing about awareness in all areas of supply-chain management.

2 Issues in Environmentally Conscious Manufacturing and Product Recovery

A new era of human experience began during the industrial revolution when a shift from hand-made to machine-made products resulted in increased productivity and flow of income; during this period, a higher standard of living transformed the life of the individual and society as a whole. However, industrial production was unplanned and unaccountable, and there were many flaws in the production-and-consumption process leading to indiscriminate use of resources, energy, and materials. Intentional careless approaches in production and consumption have lead to pollution of air, water, and soil and an increasing amount of garbage. During the last decade, environmentally conscious manufacturing and product recovery (ECMPRO) has become the most popular move to safeguard the environment for future generations. Environmentally conscious manufacturing is concerned with manufacturing new products with the utmost care in terms of conceptual design to final delivery and end-of-life disposal of the product such that it matches the specifications prescribed to satisfy environmental standards and requirements. Product recovery, in contrast, is dedicated to minimizing the amount of waste going to landfills through disassembly, reuse, and recycling.

The life-cycle analysis of a product should be well understood to design environmentally friendly products. Life-cycle analysis covers the design development, manufacturing, use, and disposal phases of a product, and ecofriendly decisions are essential at all stages of the product life cycle. "Design for recycling," "design for environment," and "design for disassembly" are some important terms in design development. The end-of-life management of products is crucial and can be achieved by disassembly and recycling. Some meaningful terms regarding environmentally conscious manufacturing are given here (Olson and Sutherland 1994).

Demanufacturing is a process of reducing and retrieving usable components from a product successively through assemblies for major parts; subassemblies for minor parts; and materials for use.

Disassembly is the reduction of a product to its assemblies and subordinate parts. Disassembly is seen as a cost-adding step to demanufacturing.

Rebuilding returns a product to an as-was condition. It implies that the product is minimally refurbished where essential worn parts are replaced.

Recycling is a process of extracting useful materials from waste by sorting, mechanical, or chemical operations.

Many environmental regulations have been passed by countries around the globe for extending the responsibility of product end-of-life management to manufacturers. This requires considerable focus in understanding how the energy and material flow is affected by product changes and how to plan desirable changes in the industrial ecosystems. These changes will have an impact on material choices, energy use, market and consumer response, waste management, and policy changes. Current environmental regulation is centered on environmental health and safety, but it can extend to other criteria such as social and humanitarian grounds. This creates a great number of challenges to manufacturers and retailers who strive hard to sustain their position in the competitive global market.

2.1 Challenges Facing Environmentally Conscious Manufacturing

2.1.1 Manufacturing Challenge

New laws have been created to give a basis to define labels that state “clean,” “green,” “ecofriendly,” etc. Manufacturers must meet these changing definitions and choose materials that have less impact on environment, minimize materials for packaging and other uses, and develop efficient recycling schemes. Environmental regulatory compliance is seen as the minimum standard of performance, and consumers today are asking for more far-reaching benefits. It is best to integrate environmental considerations into corporate culture and business planning. The main goal of the manufacturer should be reduction of negative environmental impact in all subsystems to achieve an overall rating of the system as “ecofriendly.” Many organizations have reported savings by minimizing packaging and type of raw material used. Firms have switched from white to brown boxes saving material cost as well decreasing the bleaching of paper in the process sequence. Similarly, environmental impacts must be identified in all areas of manufacture and distribution to improve their environmental performance.

2.1.2 Role of the Consumer

The consumer is very important and meeting his or her needs is the primary aim of the manufacturer. The performance, quality, and cost of the product must suit the customer’s needs as well as satisfy environmental compliance guidelines. The attitudes and values of consumers has changed over the years, and they have become aware of their role in reducing the environmental impact. A study reports that in 1989, 67 % Americans were willing to pay 5–10 % more for green products; by 1991, environmentally conscious people were willing to pay 15–20 % more for ecofriendly products. A survey in 1994 showed that 79 % of female consumers surveyed in the United Kingdom were willing to pay 40 % more for a product that has been proven to be green (Laroche et al. 2001). The attitudes of the consumer is changing: They want authentic certifications for products that have been developed from recycled materials or for the use of recycled materials in their packaging. Consumer forums have publicly criticized Walmart and Procter & Gamble for putting a green label on their brand of paper towels that were chlorine bleached and made of virgin material and packaged in plastic; the claim made by the manufacturers were that the inner tube for the towels was made from recycled paper. An effort made by McDonalds to eliminate polystyrene clamshell packaging was commended as progressive and exemplary in corporate practices regarding environment. This clearly shows that consumers refuse to be influenced by false environmental claims.

2.1.3 Design Consideration

The potential impact of the life cycle of a product should be minimized. Green quality function deployment (QFD) considers product quality requirements, environmental impact, and production costs. Further developments in green designing also include life-cycle analysis, life-cycle costing, and analytic hierarchy process. Life-cycle engineering is an LCA-assisted method where the product life cycle is designed by making choices on product concept, structure, materials, and processes (Ilgin and Gupta 2010). Material selection covers factors such as weight, processability, and cost; material selection charts integrate environmental concerns, green material cost analysis recommends materials that cause less pollution. The recyclability of selected materials is an important factor, and the recyclability index is a tool for evaluating the material recovery. Another important concern is reverse and closed-loop supply chains, which are involved in the collection and recovery or disposal of used products. While designing products, uncertain characteristics should be included to prevent design problems and to allocate alternatives for the foreseen problems in the design. Design evaluation by simulation techniques serves to examine the impact of the design on long-term basis of a closed-loop supply chain with recycling activities.

The end-of-life option for a product must be determined in the design stage. Recovery and disposal are the options, but the basis of selection is based on environmental impact, legislation, quality, and cost. The next problem is marketing of developed products, and the issues include pricing manufactured and remanufactured products, competition involved in remanufacturing, and determining the return policy. Product design plays a crucial role in terms of environmental impact, and care must be taken to spell out all consequences at the designing stage. Henry Ford highlights the importance of optimal design by the following words.

> Waste is not something which comes after the fact… Picking up and reclaiming the scrap left over after production is a public service, but planning so that there will be no scrap is a higher public service.

2.1.4 Evaluation of Environmental Impact

Measurement of environmental impact is highly associated with life-cycle analysis. In earlier days product designers and chemical-process designers were primarily concerned with the life cycle from raw material selection to the manufacturing and product-completion stage, but currently there is environmental concern at all stages of the product life cycle. Process engineers must clearly understand their product process sequence, as well as the byproducts that may be formed, and find solutions for the use or disposal of the same, i.e., the manufacture of vinyl chloride is associated with the byproduct generation of hydrochloric acid, which can be used for steel or semiconductor manufacturing (Allen and Shonnard 2001). The environmental impact of different processes is taken into consideration, and the best route is usually selected as shown in Table 3.

Table 3 shows two alternative synthesis routes for the production of methyl methacrylate and their environmental implications. In this case, the health and safety issue associated with sulphuric acid is the major concern and hence the isobutylene route is preferred. Although more data are available for the two processes, the required information is taken according to the needs of the industry.

Table 3 Stoichiometric, persistence, toxicity and bioaccumulation data for two synthesis routes for methyl methacrylate (Allen and Shonnard 2001)

Compound	Lb (kg) produced or required per lb of methyl methacrylate[a]	Atmospheric half-life/aquatic half-life[b]	l/TLV[d] $(ppm)^{-1}$	Bioconcentration factor[e] (concentration in lipids/water)
Acetone-cyanohydrin route				
Acetone	−0.68 (−0.31)	52 days/week	1/750	3.2
Hydrogen cyanide	−0.32 (−0.15)	1 year/week	1/10	3.2
Methanol	−0.37 (−0.168)	17 days/days	1/200	3.2
Sulphuric acid[c]	−1.63 (−0.74)	–	1/2 (est.)	
Methyl methacrylate	1.00 (0.45)	7 h/week	1/100	2.3
Isobutylene route				
Isobutylene	−1.12 (−0.51)	2.5 h/week	1/200	12.6
Methanol	−0.38 (−0.172)	17 days/days	1/200	3.2
Pentane	−0.03 (−0.014)	2.6 days/days	1/600	81
Sulphuric acid[c]	−0.01 (−0.005)		1/2 (est.)	
Methyl methacrylate	1.00 (0.45)	7 h/week	1/100	2.3

[a]A (−) stoichoimetric index indicates material is consumed, whereas a (+) index indicates a product of reaction
[b]Atmospheric half-life based on hydroxyl radical reaction; aquatic half-life calculated by way of biodegradation based on expert estimates
[c]Lifetime of H_2SO_4 in atmosphere is short due to reactions with ammonia
[d]TLV is the threshold limit value, and the inverse is a measure of inhalation toxicity potential for a chemical
[e]Bioconcentration factor is the chemical's potential to accumulate through the food chain

LCA analysis has several shortcomings. A LCA is data- and resource-intensive and tends to include everything, which may result in false impressions: (1) It is complex in nature in both methodological and analytical terms; (2) it takes a limited input/output approach and neglects qualitative or nonquantifiable variables and uses inadequate substitutes for environmental impacts; (3) it is directive in nature and cannot provide concrete measure for the greenness of a product; and (4) it is sometimes very confusing with the methods and data available; experienced personnel and collective analysis are necessary to avoid any improper decisions. Studies on the need of reusable versus disposable nappies are still under analysis due to different conclusions. Designers, product engineers, and process engineers are being asked to develop environmentally friendly products without guidance on what is "environmentally preferable" in practical terms, how they can be identified, what are the upper and lower limits, impact on ecofriendly choices on the other parts of the industrial systems, and the entire supply chain.

Further several LCA methods are available, and the choice of the right life-cycle impact analysis (LCIA) can lead to differences in final conclusions. The impacts from emission depends on the quantity of the substance emitted, the properties of the substance, and the characteristics of the emitting source and the receiving environment (Finnveden et al. 2009). A global default procedure is followed in LCIA and will cater to the first two aspects of the impacts per the emissions assessment. However, the situations can be different in terms of locality or region, and hence the same emission quantity may lead to different levels of impact. Therefore, site-dependant characterization is essential. Resources may be of two types—abiotic and biotic—and most of the environmental impacts have been devised to measure biotic resource depletion; similarly land use, water use, and toxicity in indoor and outdoor air require a great degree of differentiation and technical limitations such as mid-value, end-value, etc., to compute the impact of the product, process, or service. The uncertainties of LCIA can be in data (e.g., variability, specification mistakes, incomplete and irrelevant information), in choices (may be inconsistent with the goal and scope of analysis or across alternatives), or in relationships (directions of relations may be wrong, incomplete, hasty, and implemented inaccurately).

To study the environmental impact of products and services, organizations use various tools for evaluation to prevent any flaws in the approach. A research report highlights the use of environmentally conscious business practices such as Design for the Environment (DFE), life-cycle analysis (LCA), total quality environmental management (TQEM), green supply-chain management (GSC), and ISO 14000 EMS requirements. The subcomponents of each of the above are specified in Table 4. Analytical network process (ANP) or analytic hierarchy process (AHP) are models used for the decision-making framework.

Another study describes three tools, namely, life-cycle assessment (LCA), quality function deployment for environment (QFDE), and theory of inventive problem solving (TRIZ) (Sakao 2007). This combined strategy helps product designers in

Table 4 Components and subcomponents of major environmentally conscious business practices (Sarkis 1998)

Sl. No.	Environment conscious business practices	
	Components	Subcomponents
1.	Design for Environment (DFE)	Design for recyclability (RECY) Design for reuse (REUSE) Design for remanufacturability (REMAN) Design for disassembly (DISASS) Design for disposal (DISP)
2.	Life-cycle analysis (LCA)	Inventory analysis (INVAN) Life-cycle costing (LCC) Impact analysis (IMPAN) Improvement analysis (IMPVAN)
3.	Total quality environmental management (TQEM)	Leadership (LEADER) Strategic environmental quality planning (SEQP) Environmental quality–management systems (EQMS) Human resource development (HRD) Stakeholder emphasis (STAKE) Environmental measurements (EMEAS) Environmental quality assurance (EQA)
4.	Green supply-chain management (GSC)	Inbound logistics/procurement (INBD) Materials managaement (MTMAN) Outbound logistics/transportation (OUTBD) Packaging (PACK) Reverse logistics (REVLOG)
5.	ISO 14000 EMS requirements	Environmental policy (EP) Planning (PLAN) Implementation and operation (IO) Checking and corrective action (CCA) Management review (MREV)

a multifold manner, e.g., the designers could use the LCA results to identify that the product had high impact on global warming through energy consumption; this could be remedied by defining a requirement in QDFE to reduce energy consumption; TRIZ allows designers to generate four solutions for improvement of which one is used based on the requirement. This methodology has more benefits than the independent use of the three tools.

2.1.5 Product Recovery

Product recovery is an integral part of converting waste into resource. The cooperative effort of consumers, retailers, and manufacturers is essential to manage the end-of-life essentials of a product. Many people consider waste as inferior, but waste could also serve as a resource if handled efficiently, e.g., (Richards 1994) a waste stream of acetonitrile was cleaned by British Petroleum and serves as a feedstock for the production of insulin. Instead of disposal of waste, minimizing waste and the reuse of waste could yield efficient results. Similarly Dow Chemicals formed a new business group, Advanced Cleaning Systems, in 1990. The organization was threatened by regulations on ozone-depleting chemicals and the control of toxic air emissions. Apart from developing alternative chemicals and processes, they offer new packs to their customers with a take-back policy of the used chemicals in reusable containers.

Product disposal considerations require efficient end-of-life management. Omission of toxic materials would be ideal for a product that is to be discarded; material diversity should be avoided if the product is to be recycled. Identification marks in different components to show that they are made of the same material would help in the recycling process. Modular compartments can be planned in products that can be easily changed to make them as good as new. System-performance improvements would yield better economics than dealing only with product performance. The challenge for the managerial side would be to ensure that all of the players of the supply chain are environmentally conscious and require managing risk and customer satisfaction at all levels.

3 Reuse and Recycling of Packaging

Delivering products to consumers by preserving their integrity and usefulness is the primary role of packaging. The environmental impacts of packaging have increased considerably and litter ends up in landfills through the municipal waste system. However, the regulating legislations issued by different governments of developed and developing countries have created awareness among manufacturers and consumers to take into account the environmental footprint of products. Raw materials cost has increased, and the impact of packaging on the total cost is very high; this calls for sustainable packaging management. Retailers are imposing certain requirements on suppliers to manage environmental impacts. Walmart has established a comprehensive packaging score card on which suppliers are evaluated. Preconsumer and postconsumer packaging chains are analyzed and designed in such a way that recycling or reuse has the lowest environmental impact or the waste is brought back and recycled to prevent waste from being sent to landfills.

Many life-cycle assessments are being performed to assess the environmental impacts of packaging; the effect of reuse and recycling are also assessed to find the best solution for decision making in terms of design and product development. LCA can be performed as cradle-to-grave, cradle-to-gate, or gate-to gate, but environmental legislations calls for assessments along the entire life cycle of the product until it is reused or recycled with minimal environmental effects. The circular economy has been recommended for good results. It has two characteristics, namely, the biological flow designed to safely re-enter the biosphere and the technical flow, that are designed to circulate at high quality without entering the biosphere. This is not the same as with the current linear economy, which uses natural resources and materials without any concern for the ensuing environmental impacts. In the circular economy, there is no waste because all of the biological and technical components are designed to fit back into the natural cycle. Long-lasting products, diverse and versatile components, and products that can be upgraded or repaired should be the primary focus in product manufacturing. Obtaining energy from renewable sources and thinking in terms of systems are important for reducing the environmental impact.

3.1 Concepts Underlying Environmental Impact Reduction

The reduction of environmental effects can be addressed by using the principles of reduce, renew, reuse, and recycle. Reduction of the use of materials can be achieved in containers and packaging by reducing product weight, making the walls of the container thinner, achieving compactness in design of the product pack or container, and downsizing products. Attempts in introducing renewable packaging, such as polyactide or biopolyethylene, instead of petroleum-based products are important. Reuse can call for the development of refills and replacement products so that the original packs or containers can be reused. Recycling initiatives involve the use of recycled materials such as recycled paper or recycled resin. It also recommends the after-the end-of-life product should be recyclable or biodegradable with minimal impact on environment.

3.2 Implications of Reuse

Reuse and recycling are the focus, and this has brought a new insight and awareness of the amount of waste that is generated during product production and consumption. During the European week for waste reduction, 79 reuse centers in 5 EU countries collected 709 tons of goods, of which 129 tons have been reused (Reuse 2014); otherwise it would have gone into the waste cycle. Reuse targets are to become an important part of the waste legislation in the EU. The KAO group in Japan (KAO 2014) undertook a design transformation in their laundry detergent bottle by reducing the amount of resin per bottle, making the walls thinner by 29 % leading to reductions in environmental impact by approximately 2800 intones of CO_2/y and a reduction in costs by approximately 350 million yen. The company also used 10 % biopolyethylene for shampoo refill packs and reduced CO_2 emissions by 12 %; a shrink film containing 50 % polylactide was used for their green tea packs resulting in a 38 % reduction, and they are also aiming at changing the packaging for other products as well.

In earlier days, the reuse of postconsumer packaging, such as glass bottles and jars, was common. In cases where production was in a central facility and distribution and collection points were far, leading to transport expenditure, reuse was the principle used. Refillable bottles are stronger and can be reused, thereby generating less packaging waste than single-use containers. It has been estimated that 46 kg of aluminum is necessary to fill 1000 l of beer, whereas the same amount of beer needs 26 kg of glass, thereby reducing the use of resources by 43 % (Mehr 2015). Furthermore, glass bottles can be reused. Curbside-collection schemes under the Green Dot systems show lower collection rates and recycling rates and percentage compared with the deposit schemes. In deposit schemes, as in reverse vending machines or incentives for waste returns, 99 % of materials are recycled, and here bottle-to-bottle recycling can be performed (PricewaterhouseCoopers 2011). Refilling and take-back schemes are available but only as activities performed by local businesses rather than as large-scale activities. The trend is moving back to reuse for environmental concerns where reusable bags are slowly replacing single-use carrier bags, and levies and bans on lightweight carrier bags seem to turn the attention of the consumer toward reuse.

3.3 Issues Related to Recycling

Recycling is always associated with recovery, and waste management is very important for recycling to achieve viable solutions. PET is the most recycled plastic material in Europe, and it was estimated that approximately 65 billion bottles were recycled in 2013 (PETCORE 2014). Another report states that huge investments are being directed toward the development of PET-reclamation plants to increase recycled content in new bottles. PET-reclamation capacity is expected to increase by 50.3 % in the next 3 years (Powell 2011), and 12 of the current 20 PET-reclamation plants in the United States and Canada produce RPET for the manufacture of new containers. The ability of PET to be recycled and reused for different end uses is helping in achieving a circular economy. Any waste can pass through multiple stages, such as manufacture into a reusable container, enter into the waste stream, recover for energy, and recycle into a durable application.

Landfill: Space for landfills is becoming less, and it is advisable to use this option as the last stage in waste management. Well-managed landfill sites can result in limited environmental harm apart from collection and transport; the long-term risks of waste are the contamination of soil and groundwater due to the breakdown of substances in the waste to become pollutants. Once a waste material reaches the landfill, it has passed all stages of reuse and recycling and cannot be recovered, thus showing that the material flow in landfills is linear. Diversion of waste from landfills are the primary concern, and many governments have passed tough legislation to prevent waste from reaching landfills.

Incineration and energy recovery: Energy recovery is the main concern in many countries that incinerate plastic waste, which can lead to the release of hazardous substances into the atmosphere. In countries such as Denmark and Sweden, the infrastructure for incineration is extensive, and this technique is used to deal with municipal solid waste. The energy recovery may be varied because it can be used for electricity generation, combined with heat and power, or used as solid refuse fuel used in blast furnaces and cement kilns.

Downguaging: Many manufacturers use the required material for a given application. However, for the sake of aesthetics, convenience, and marketing benefits, an overuse of packaging results. Existing investment in tooling and production processes can also result in the excessive packaging of some products. The principle of reduction in the amount of packaging per unit will help in reduce waste volumes.

Levels of Recycling: Recycling may be performed as four levels: primary, secondary, tertiary, and quaternary. Mechanical reprocessing of a product into a one with similar properties is primary recycling, also known as closed-loop recycling. In secondary recycling, there is mechanical reprocessing of a product into a product with lower-grade properties. Recovery of chemical constituents is tertiary recycling, also described as chemical or feed stock recycling, e.g., depolymerization of a polymer into its chemical constituents. Quaternary recycling is energy recovery, energy from waste, or production of energy from the decomposition of waste as biogas or by biological treatment with anaerobic digestion. A report (EGF 2015) states that 2000 tons of waste produce energy to supply 150 thousand inhabitants. After treatment, the bottom ashes may be used for civil construction, public works, and landscape recovery. Many ferrous and nonferrous metals are recovered from the combustion process and sent to recycling industries.

Reuse can save raw materials and energy, but care must be taken to see that the packaging materials are fit to be reusable. Primary packaging may not be reusable, but all other types can be reused in areas where the multiple layers are wrapped before being put into the outermost packaging. Tertiary packaging can be used for secondary packaging and so on. It is in the mindset of the organization to use packaging materials effectively to bring savings in cost, raw materials, energy, and transport. The trend of reuse is more common in developing countries than in developed nations. The material is reused until it becomes unfit for reuse, at which point it is sent for recycling. When reusing materials, this should be performed so smartly that one must be unable to recognize that the packaging has been reused. The cost-effectiveness of refills also encourage the reuse of packaging. Recycling is the last stage after reuse when the packaging is considered as waste to be developed into a raw material for a new product. Recycling attempts are developing into large industries with huge investments and will serve to encourage manufacturers to use recycled materials. The range of materials obtained from recycling activities include energy, ashes for landfill, organic compost, recycled raw materials, and refused derived fuel. Apart from environmental benefits, recycling and waste management can offer employment opportunities for many ranging from grassroots-level personnel to researchers and ecodesigners. Consumers today are ecoconscious and tend to purchase products with recycling labels and recycled content. The environmental safety trend has begun and will tend to protect the environment for the future.

4 Trends in Green Packaging

In this age of INTERNET marketing, sustainable packaging is a yardstick of competitive stature. Ecofriendly packaging puts manufacturers in a better marketing position and showcases their product as a quality and environmentally conscious product. Sustainable packaging has become a part of day-to-day activities and is just another requirement such as product performance, service, and pricing. Governments, producers, retailers, and consumers have started realizing the importance of green packaging and its importance on our environment, yet there is no organizational framework that can be adopted by all manufacturers. The projected market for sustainable packaging will be $244 billion by 2018. Companies who are progressive in their approach will use the concept of sustainability in packaging to surpass their competitors and differentiate themselves from other manufacturers in the marketplace.

Green packaging is of great importance to humans and their environment. Packaging production has always used fossil fuels, which adds millions of metric tons of carbon dioxide and methane into the atmosphere, whereas discarded packaging ends up in landfills and oceans causing soil, water, and plant contamination, which then pollutes the food chain. Sustainable packaging can eliminate these contaminants by lowering packaging content, formulation of recyclable or biodegradable packaging, and use of wind, solar and biofuels for the production and transport of packaging. It can be anticipated that packaging is the main source driving the green market and is one of the most important contributors to the demand of going green. There are various trends surrounding green packaging, and a few have been discussed here.

4.1 Green Consumers

The primary motives that drive a consumer in terms of regarding environmental impact and sustainability are helpful to know when creating new product positions. Consumers have been classified (Iyer and Banerjee 1993) as “planet passionates” who want to preserve their planet by recycling bottles, cans, and newspapers; the second group is “health fanatics” with the motive of preserving personal health through the use of safe food and organic products only; the third group is “animal lovers” with the motive of preserving animal life by becoming members of humane societies, buying cruelty-free cosmetics, and boycotting fur coats and leather goods. The growth of green products is based on such studies, and this motivates green consumers to buy/avoid such products. It has also been found that green advertising is centered on planet preservation and environmental issues and is generally focused on the producer and production toward sustainability.

4.2 Sustainability Measures

The latest trend is the shift from petroleum-derived to plant-based plastics. Leading manufacturers and retailers look out for biobased raw materials, and they tell their consumers about the savings in fossil fuels due to the use of ecofriendly packaging materials. Many global brands have jointly established a Bioplastic Feedstock Alliance (BFA) to increase awareness and set standards for the wider use of plant-based plastics.

Paper and board has been estimated to increase to 6 % by 2017, which will amount to >30 million tons with an approximate value of $70 billion (Lifshitz 2014a, b). Brands will seek out for new barrier technologies that are renewably sourced, recyclable, and biodegradable. Bioplastics and water-based coatings are some of the barrier technologies that will exist in the near future.

4.3 Lightweight Packaging

Lightweight small-sized packaging with little input of raw materials and environmentally friendly rigid packaging is a central theme. The evolution of a light weight packaging standard, known as “packaging-efficiency model,” provides a holistic approach covering the packaging life cycle. The prime concerns are resources used, protection of product, efficiency in transport and delivery, and provision of a positive customer experience. Problems associated with opening of packaging will be addressed by providing frustration-free packaging where packaging can be easily opened without tools.

4.4 Consumer Information

In the United Kingdom, it has been estimated that 5.91 million tons of packaging waste (Wadhwani 2014) accumulates every year. Consumers want answers as to the source of the packaging material, the materials used for packaging, and the possibility to recycle the package. Traceability is both an environmental and ethical issue. Today brands are communicating their sourcing details and supply-chain traceability to assure their consumers that their packaging is from legal and sustainably managed production cycle.

A universal on-the-pack label should be made mandatory for the consumer to understand sustainability information without confusion regarding the level of sustainability in the product. Regarding recycling labels, the method of recycling should be clearly given to enable the customer to understand the method adopted for recycling and its impact.

Reusability and secondary use in packaging also attracts the consumer's interest. In 2011, Pizza Hut introduced a special Green Box (Lifshitz 2014a, b) that could be broken down into four plates and a small box for leftovers. These endeavors create a strong impression on the minds of the consumers, and they become willing to pay more for such innovative sustainable ideas.

4.5 Consumer Attitudes

The boom of the health and wellness sector has become a key factor in the packaging trend showing a wide public desire to purchase what is environmentally sound and sustainable. Health credentials are to be displayed on food-related packaging. The special features of the product in terms of natural-ingredient formulations, innovative methods of preservation of fresh food, and communicative labeling will help in both short- and long-term success of the product and its manufacturer.

Another important tool for brand managers is advertisement about the product. Advertising on packaging increases the awareness of credibility and authenticity and reassures the customer about the truthfulness and high quality of the product. The brand owner can further capture the attention of the consumer by communicating the carbon-footprint benefits of using a local brand because transportation and packaging will be reduced.

Although consumers are willing to pay more for sustainable products, it is the responsibility of the manufacturer or retailer to offer the best cost-effective price because cost is the first consideration in buying decisions. Buying in excess and stocking has disappeared, and consumers today are looking for sustainable reusable packages for consumption options.

4.6 Package Design and Brand Imagery

Package design is an important aspect in creating a brand image. Packaging assists consumers to select among many of products offered on a retail shelf. "Badge products"—such as cigarettes—use packaging as an advertising tool. The packaging has a high degree of social visibility and is constantly taken out and left out for public display. These products also have the highest brand loyalty and show the association of the consumer with the brand image. Health warnings are discreetly incorporated into the packaging design to minimize their intrusiveness and preserve the look of the packaged product. Although cigarettes are injurious to health, package design plays an important role in serving as a social status symbol for the user.

4.7 Green Product Innovation

Product innovation in terms of sustainability is moving toward higher goals for recycled content and recyclability in sustainable packaging. Starbucks recently announced a new goal to have 100 % recyclable or reusable cups, and Hewlett-Packard cut packaging on a few products by 97 % (Maria and Pujari 2010). Water is being sold in a 100 % recyclable paper carton instead of the traditional glass bottle and has the label "Boxed Water is Better for Earth" (Nobel et al. 2009). Form, fill, and seal is used for the manufacture of this product given that the main marketability of the product is due to the recyclability of the container.

Earlier manufacturing worked on the principle that solutions to malfunctions or breakdowns were replacement of the entire assembly or subassembly. Manufacturers are developing designs that avoid hazardous components and bring savings by the concept of reuse. Modular designs help in principles of remanufacturing, automated remedies for problems and repair, or replacement by subvendors or manufacturers. Careful material planning may result in losses upstream, which could be compensated by savings downstream and in recycling. In the United States, disposal costs have reached $50 billion (Kleindorfer et al. 2005) with no clear solution of how costs can be covered. Waste can also contain toxic parts; disassembly can help to remove the toxic parts, and the rest could be sent to the landfill. Promoting environmental care, mitigating environmental health, and the safety impacts of a company are the basics of socially responsible good business.

Green-product innovation starts with the integration of environmental concerns and conventional product attributes at an economical price. Usually development and manufacturing costs are high, thus making the price noncompetitive, which slows down the introduction of new products. Another challenge is the lack of awareness about green products among consumers, but this can be rectified by the use of ecolabeling and third-party certification. Organizational and managerial issues are important when dealing with third-party certification and require environmental specialists to work in the product design and developmental process. An understanding of a green-product portfolio will enlighten how companies invest in the green-product technologies platform to bring new green products to markets.

4.8 Design-Based Research

Design experiments combine design focus and assessment of critical design elements. Qualitative measures assess the performance of the design in practice and determine how social and contextual variables affect cognitive variables. Design-based research is essential to produce green designs with a special focus on environment. This calls for creative thinking and problem-solving approaches. Successful implementation of designs call for many experiments in the practical context. The egg-drop experiment (Dede 2005) is part of a research activity where the researchers are given raw eggs and a few basic materials. The researchers are asked to create packaging that will cushion the egg from breakage when dropped from a considerable height. Similarly, research in design is required for environmental solutions, and manufacturers must identify the most optimal green design with end-of-life management that will give the least impact to environment. Thus, researchers will be able to identify the best solutions, and when these strategies are implemented they will not be met with impractical failures.

4.9 Sustainable Product-Design Tools

The design phase of any product is attributed to 5–7 % cost, but the decisions made in terms of product design will cover 70–80 % of the total product cost. In the early design phase, a high level of uncertainty prevails regarding the working ability and sustainability of the given product or process. Novel methods and tools are necessary to help designers ascertain this aspect. DFE enables environmental consideration coupled with business opportunities, and the standard should be set by the organization for the level of DFE to be implemented by the company. Ecodesign tools may be based on checklists, life-cycle assessments (LAC), or quality function deployment (QFD). Check lists are tools with many questions to be answered and are suitable for small- and medium-sized industries. They are subjective in nature and require great knowledge, skill, and experience to interpret the results. The LCA is an objective method of assessment that calculates the environmental impact of the product throughout is life cycle. LCA is not design-oriented, but it is designed to analyze certain structures and components as well as the greenness of concept description. Tools based on QFD convert customer needs into engineering characteristics and conduct a correlation analysis between customer needs and product quality characteristics. The common problem in this method is that correlation analysis is based on the traditional environmental-engineering regulations without considering the whole product life-cycle. The tools are used in combination to enable decision makers to pursue sustainable product-design activities on a holistic basis.

4.10 Sustainable Materials

The use of locally available materials and labor can reduce the environmental costs of shipping, fuel consumption, and CO_2 emissions generated from transportation. Reclaimed and recycled materials can be used for new-product development. Water recycling systems, such as rain-water harvesting and the reuse of "grey water" from households and off-grid homes—which harness energy from active (solar power, biomass, wind turbines, and geothermal energy) or passive (bioclimatic buildings, green roof designs) energy systems—are some of the applications of systems leading to eco materials. Ecodesigners can take an environmentally conscious approach, from the choice of materials to the type of materials being consumed to the disposal of waste, to obtain maximum benefit out of the materials.

The term "green" signifies various meanings, and in the context of sustainability there is no limit to achieving better prospects for the environment. Sustainable packaging must promote the healthy coexistence of humanity and nature, designers accepting responsibility for the consequences of design, the creation of safe products of long-term value, and an understanding of the limitations of design to seek continuous improvement in terms of environmental implications and sustainable concepts. Understanding green-packaging trends, as well as integrating elements such as packaging sustainability with convenience, will increase brand loyalty, enhance product reputation, and bring improvement in business.

5 Roadmap for Green-Packaging Solutions

The roadmap for green packaging solutions and better waste management is given in Fig. 1. It shows the forces that have compelled a change in product and manufacturing systems to work with great concern to reduce the negative impacts on the environment. Waste is being produced at an alarming rate causing massive damage to the ecosystems in the environment. The main statistical findings by Eurostat shows that in 2013, municipal waste generation ranged from 272 kg/capita in Romania to 747 kg/capita in Denmark (Eurostat 2015). Environmental and human health hazards resulted in changes in the global level leading to regulations and laws to reduce waste and to make manufacturing industries and retailers accountable for the waste produced. Many leading brands have used sustainability and ecofriendliness as a tool to gain competitive advantage over other brands, thus driving consumer demand for more green products made from materials that have a low impact on environment. These driving forces have brought a wave of change across the globe to work for green solutions to achieve zero waste throughout the life cycle of the product.

Efforts are to be directed right from the grassroots level to the highest level to achieve maximum benefit. The roadmap highlights the involvement of all stakeholders starting from the consumer, industry, nation, and globe. Attitudinal and behavioral change on the part of the consumer to make environmentally conscious choices and to look for quality and function rather than aesthetics would serve to force manufacturers work toward the goal of sustainability. On one hand, today's consumers look for products with sustainable materials and increased recycled components to help reduce the negative impact on environment. On the other

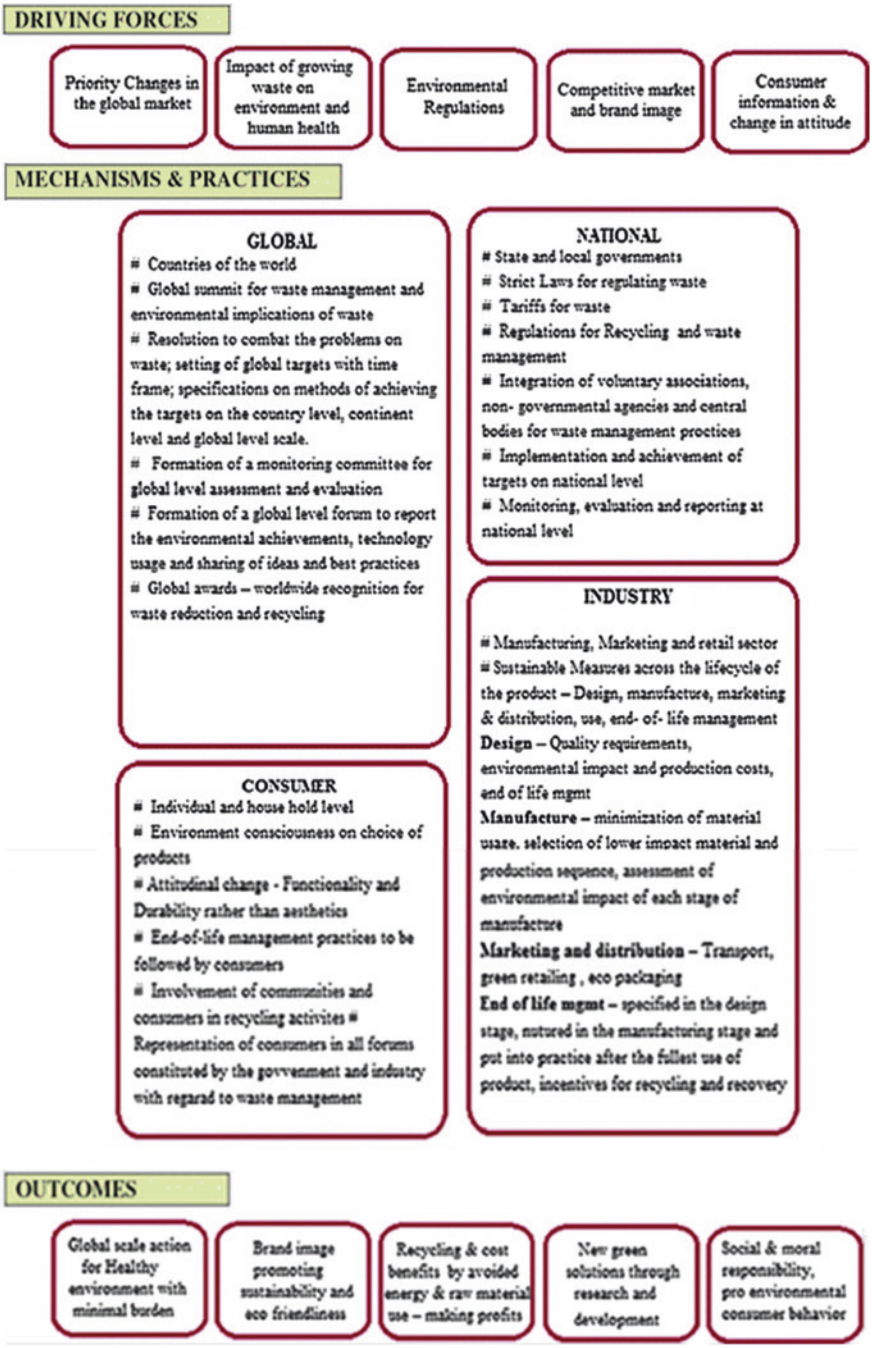

Fig. 1 Roadmap for green-packaging solutions

hand, the packaging industry is working toward ecofriendliness from the design stage to end-of-life management. Reuse and recycling has become very important to showcase the green brand image. To quote a few examples—

1. Leftover sound-absorbing material from the production of cars and sedans has been used to insulate coats that are transformed into sleeping bags for many homeless people. This effort prevented 212,500 pounds of waste going to landfills (General motors 2012).
2. General motors has used oil-soaked booms for under-the-hood car parts and recycled >100,000 pounds of plastic resin along with the use of resources, such as oil and water from the booms, thus saving 29,000 gallons of water and oil and eliminating 212,500 pounds of waste and 149 tons of CO_2 emissions (Price 2010; General Motors 2011).
3. General Motors donated 100 steel crates used for shipping engines and 250 crates from other departments for the conversion of vacant parking lots in Detroit into urban gardens involving the community residents and volunteers to water and maintain the gardens for free vegetables and herbs (General Motors 2013).

These efforts, and many others adopting reuse and recycling, have fetched General Motors the Top Project of the Year Award in the Environmental Leader Product and the Projects Award for driving a global movement for zero waste (Fast Lane 2014).

The movement toward sustainability and green packaging has been further enhanced by the role played by countries and nations around the globe. Several laws and regulations—such as the PlasTax in Ireland, the German Packaging Ordinance, the ban on plastic bags in Africa, and the fee for the use of plastic bags in supermarkets in Hong Kong—have led to a reduction in the use of plastic bags. Targets and time frames for the reduction of waste can be set at national and global levels, and monitoring and evaluation committees could record the progress toward the goal of zero waste. Achievements and savings, best practices, and technologies could be transferred by forums for others to follow the path of sustainability and to show that such measures are feasible. Conscious efforts and policies will slowly lead to a healthy environment where reuse and recycling are performed to create zero waste, thus leading to savings in energy, raw material use, and reduction in emissions resulting in healthy profits. Recycling and reuse could open the doors to innumerous research projects, and new solutions could be developed. Social and moral responsibility on the part of industry and consumers would result in a safe environment where brand image is established based on the extent of product sustainability.

6 Concluding Remarks

Manufacturers and retailers ought to look for functional products with good quality and assign less importance to aesthetics, packaging, and finishing. Intelligent packaging solutions are far more serviceable and sustainable than ones that contribute to pollution of the environment. More involvement is required from all stakeholders, along with active participation of consumers, to take responsibility for waste. The aim of ecodesigners is to focus on the goal of zero waste to achieve the best results; when minor quantities of waste occur, it must be reused or recycled to form the closed-loop system. Efforts to clean up the environment have begun, and awareness for green-product design and process will pave the way to control the generation of waste. Whatever waste is generated will be reused or recycled to produce a circular economy with growth and development. Waste is no longer rubbish but a means for recovery and recycling for new product development. The attitude of the people requires a positive change toward nature and the environment, and the technological march toward sustainability will blossom into a greener environment. To conclude with the words of Evo Morales 'Sooner or later, we will have to recognize that the Earth has rights, too, to live without pollution. What mankind must know is that human beings cannot live without Mother Earth, but the planet can live without humans.'

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