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REVERSE LOGISTICS PROCESSES IN PLASTICS SUPPLY CHAINS

Abstract: The role of reverse logistics in creating added value for producers of plastics is presented here. The premise is the choice of reverse logistics for plastics on the one hand, considering their versatile applications, such as in the packaging, construction and automotive industries. On the other hand, an extremely important issue is that their production is characterized by high dynamics, has a significant impact on the environment, contributing significantly to the use of the valuable resource that is oil. This paper will focus on the economical and environmental optimization of reverse logistics processes in production enterprises. The presented article is part of a research project on developing application methods for the settlement of environmental-economic support for reverse logistics processes aimed at reducing consumption of energy and raw materials by plastics manufacturers, which ultimately translates into added value in terms of so-called environmental benefits.

Keywords: logistics, reverse logistics, recovery, plastics.

1. Introduction

The process of waste disposal can be significantly boosted by logistics, and especially by the logistics of recovery, which is "fixed" in traditional logistics and yet is representative of the ecological orientation of logistics and therefore very well suited to the imperative of sustainable development. Reverse logistics enables the realization of the idea of a circular economy, which is a departure from the linear model of raw material flow, to a model of closed material-energy cycles, which significantly reduces the high entropy of the modern economy while enhancing the overall utility rate.

This objective meets the assumptions of Integrated Product Policy (IPP) developed by the European Commission in 2003, whose basic tenet is to think in categories of life cycle (Life Cycle Thinking). The introduction of this principle to business practice requires such an integrated approach to waste management issues and dissemination of the flow of reverse logistics processes.

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Logistics systems activities require the assurance of adequate economical and environmental efficiency levels on the demands of sustainable development [1]. Reverse logistics – because of the complexity and increasing importance in logistics processes – has become one of the most important areas of the eco-efficiency rise. New system solutions are observed as essential to increasing the eco-efficiency level of reverse management.

Current thinking about supply chains is focused primarily on logistics flows from raw materials to finished products, and therefore those processes which primarily lead to interest in creating and developing supply chains.

The global market, technology improvement and sustainability development has involved new models of supply chain. A new trend in logistics is observed [12]. In recent years, in the context of sustainable resource management, there is a new concept, that of reverse logistics, for which there are synonymous terms such as: reverse logistics, Ecologistics, logistics in the field of recycling, or waste logistics. The problems of waste management are increasingly falling into the field of logistics – this is reflected in the growth of reverse logistics.

Sustainable development, as defined by the EU, stands for meeting the development needs of present generations without jeopardizing the ability of future generations to meet their own development needs. Sustainable development does not focus solely on environmental issues, but broadly captures the different dimensions of development. Traditionally, sustainable development is conceptually considered in terms of three main pillars:

– environmental sustainability,
– economic sustainability,
– social sustainability.

Environmental sustainability is defined as the ability of the environment to continue to function properly indefinitely. The goal of environmental sustainability is to minimize environmental degradation and to stop and reverse the process that leads to environmental degradation.

Economic sustainability is defined as the way to achieving economic growth whilst respecting environmental limits, finding ways to minimise damage to the natural world and making use of the earth's resources in a sustainable way.

The social pillar of sustainable development is defined as a compilation of actions and efforts to promote development that does not deplete the stock of social and human resources but rather contributes to the enhancement of their potential. The social pillar also refers to the concept of "building sustainable and harmonious communities".

There is obvious to maximising the environmental, social and economic benefits of human activities, while minimising the negative impacts, as far as possible.

The implementation of the concept of sustainable development into business practice and the need to meet the challenges of the twenty-first century, at the root of which lies the widespread awareness of the profound global ecological crisis, are now causing particular attention to be given to issues related to environmental quality and cost-effective exploitation of resources [13].

The assumptions of sustainable development clearly indicate that the search for new solutions to technical, technological and logistical resources, and rationalization of the economy, energy and waste should be a priority for all business sectors and services [10].

2. Reverse logistics, recycling and recovery

The problems of waste management are increasingly falling into the field of logistics – this is reflected in the growth of reverse logistics.

Recovery means any operation the principal result of chich is waste serving a useful purpose by replacing other materials which would otherwise have been used to fulfil a particular function, or waste being prepared to fulfil that function, in the plant or in the wider economy. Recycling means any recovery operation by which waste materials are reprocessed into products, materials or substances whether for the original or other purposes. It includes the reprocessing of organic material but does not include energy recovery and the reprocessing into materials that are to be used as fuels or for backfilling operations.

Logistics covers the planning, coordination and control both in the aspect of time and pace, the course of actual processes in the realization of which organization is a participant, for the purpose of efficient and effective goal achievement by an organization [3, 4, 11]. It particularly concerns spatial and timely arrangement (where?), state (how much and in what configuration?) and flow (where from, where to and by what means of transmission?) of goods constituting the components of these processes, i.e. people, material goods, information and funds [14].

Reverse logistics is defined as the process of planning, implementing, and controlling the efficient, cost effective flow of raw materials, in-process inventory, finished goods and related information from the point of consumption to the point of origin for the purpose of recapturing value or proper disposal [2]. More precisely, reverse logistics is the process of moving goods from their typical final destination for the purpose of capturing value, or proper disposal.

Remanufacturing and refurbishing activities also may be included in the definition of reverse logistics. Reverse logistics is more than reusing containers and recycling packaging materials. Redesigning packaging to use less material, or reducing the energy and pollution from transportation are important activities, but they might be better placed in the realm of "green" logistics. If no goods or materials are being sent "backward," the activity is probably not a reverse logistics activity.

Reverse logistics also includes processing returned merchandise due to damage, seasonal inventory, restock, salvage, recalls, and excess inventory. It also includes recycling programs, hazardous material programs, obsolete equipment disposition, and asset recovery [6].

In recent years a marked increase in interest in the optimization of logistic processes in support of various types of recovery value of the products in the phase of postconsumer waste, including through reuse, regeneration, recycling and processing can be noted. In the wake of the emergence of new areas of logistics: recovery logistics and/or recycling logistics (reverse logistics).

Defining these new areas requires a reference to the classification of the types of recovery process assigned to the various stages of integrated supply chain, which is presented by Thierry et al. (see Figure 1).

There are 8 types of recovery/disposal options. Direct reuse/resale, repair, refurbishing, remanufacturing, cannibalization, recycling, incineration, and landfilling. Each of the product recovery options involves the collection of used products and components, reprocessing and redistribution. The main difference between the options is in reprocessing. Repair, refurbishing, and remanufacturing upgrade the product. What they differ in is the degree of upgrading [9].

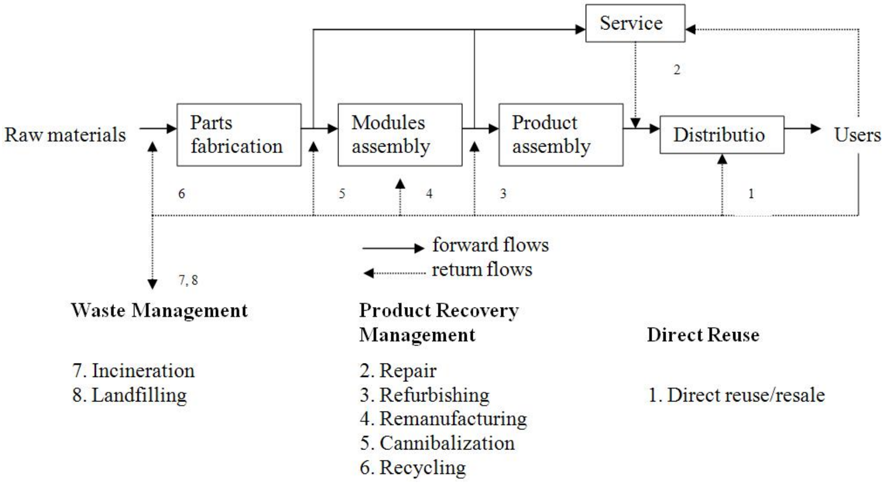

Fig. 1. *Different kinds of recovery in integrated supply-chain [9]*

The aim of **repairing** is to return the used products to working order. Quality of the repaired products is more likely less than the original. It requires limited disassembly and remanufacturing. This operation can be performed anywhere. Durable product manufacturers (e.g., IBM, DEC, and Philips).

The aim of **refurbishing** is to bring used product to a specified quality level. Quality is less rigorous compared to the new products. It consists of fixing the improper modules and replacing them with working or technological ones. Military aircraft are examples of refurbished products.

The aim of **remanufacturing** is to bring the products to the quality level of new products, that is, to make them "as new". Used products are completely disassembled to the parts level. All parts are extensively tested. Worn-out or outdated parts are replaced with the new ones. Repairable parts are extensively tested. Approved parts are subassembled to the module level, and approved modules are subassembled to product. BMW has been remanufacturing for a number of years.

Cannibalization. In the past three options, the identity of the used product was preserved. In this case, only a small amount of used products, which are recoverable, is taken out of the old product and reused. This is sometimes called selective disassembly. Those parts are used in repairing, refurbishing and remanufacturing activities. Quality of cannibalized parts depends on the process in which they will be used. Aurora, a US Company, is engaged in cannibalizing integrated circuits.

As opposed to the previous activities, in **recycling** neither product nor part identity is preserved. The aim is to reuse the materials from used products. Quality required depends on the process in which the recycled material will be used. 75% percent of the metals from discarded parts are recycled in European countries, such as Germany, U.K.[9]

3. Characteristics of the plastics industry

Plastics are a crucial part of 21st century life. Not only do they provide us with useful, lightweight and durable products, but they play a key role in the sustainable development of our world. Every activity in modern life is influenced by plastics and many depend entirely on plastics products. It would be hard to produce cars without synthetic bumper, dashboards, steering wheels and switches. It would almost impossible to exist medicine without plastic hypodermic syringes and artificial hip joints. The same is in telecommunications, dependent on plastic telephones, circuit boards and cable insulation. Our entertainment and leisure relies on the unique combination of characteristics offered by plastics in sports equipment and clothing, CDs, video and audio tape, television and cinema.

Plastic is the general common term for a wide range of synthetic or semi-synthetic materials used in a huge, and growing, range of applications from packaging to buildings; from cars to medical devices, toys, clothes etc. The term ''plastic" is derived from the Greek word "plastikos" meaning fit for moulding, and "plastos" meaning moulded. It refers to the material's malleability, or plasticity during manufacture, that allows it to be cast, pressed, or extruded into a variety of shapes – such as films, fibres, plates, tubes, bottles, boxes, and much more.

Only 4% of global oil production is used for plastics. 87% is used for transport, energy and heating and simply burnt and lost (see Figure 2).

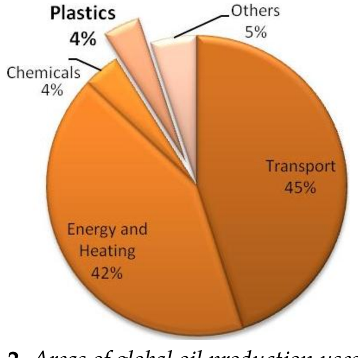

Fig. 2. *Areas of global oil production uses [5]*

Plastics applications can be found in almost all areas of everyday living due to their versatility. Plastics enable the eco-efficient manufacture of products including packaging and electronic devices. Lighter plastic components enable safety and resource efficiency solutions for cars and aircraft. And plastics help to insulate buildings and save lives in healthcare applications.

Plastics have a positive effect on climate protection. 12% to 15% of a modern car is made of plastic to help to reduce weight, save fuel and reduce emissions. Plastic components positively impact fuel efficiency, saving approximately 2.5 litres of fuel per kg used (equivalent to 6 kg of CO_2 emissions) over the lifetime of the vehicle. High performance plastic composites in today's aircraft similarly reduce weight and fuel consumption. Lightweight plastic packaging reduces the weight of transported goods and the amount of waste created – both of which reduce greenhouse gas emissions. If all plastics used in packaging were substituted with alternative materials it would be equivalent to adding another 25 million cars to European roads.

Nearly 40% of all energy consumed is used in buildings. Plastic insulation helps our homes to stay warm or cool in a sustainable, eco-efficient way. Results from PlasticsEurope's report from Denkstatt AG (The impact of plastics on life-cycle energy consumption and greenhouse gas emissions in Europe, June 2010), confirm that without plastic packaging it is estimated that the tonnage of alternative packaging would increase by a factor of almost four. Greenhouse gas emissions would rise by 61% and energy consumption by 57% [7].

All these plastics products are made from the essential polymer mixed with a complex blend of materials known collectively as additives. Without additives, plastics would not work, but with them they can be made safer, cleaner, tougher and more colourful. Additives cost money, of course, but by reducing production costs and making products last longer, they help us to save money and conserve the world's precious raw material reserves. In fact, our world today would be a lot less safe, a lot more expensive without the additives that turn basic polymers in to useful plastics.

The plastics industry has grown continuously for over 60 years. Production increased from 1.5 million tonnes in 1950 to 230 million tonnes in 2009. This growth is around 9% a year on average (See Figure 3)

Plastics have a very good environmental profile. Only 4% of the world's oil production is used for plastics and much less energy is used to produce it compared to other materials. Plastics are durable yet lightweight and thus save weight in cars, aircraft, packaging and pipework.

Demand from European converters fell back 7.2% from 2008 to 45 million tonnes in 2009. The market share of end use applications remained stable with packaging the largest segment representing 40.1% of overall demand. This is followed by Building and Construction (20.4%), Automotive (7%) and Electrical and Electronic equipment (5.6%). Others include different small segments like sport, leisure, agriculture, machinery engineering etc. (See Figure 4).

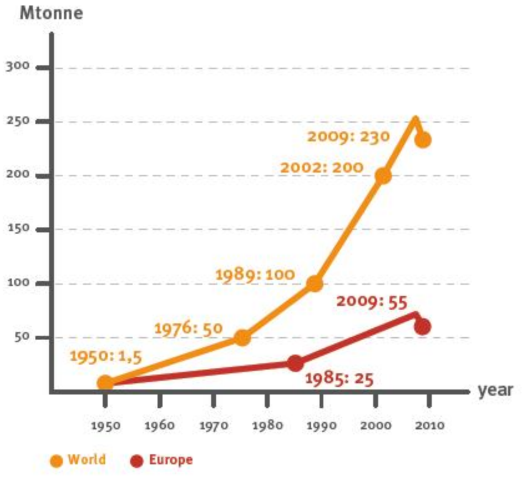

Fig. 3. *World Plastics Production 1950–2009 [7]*

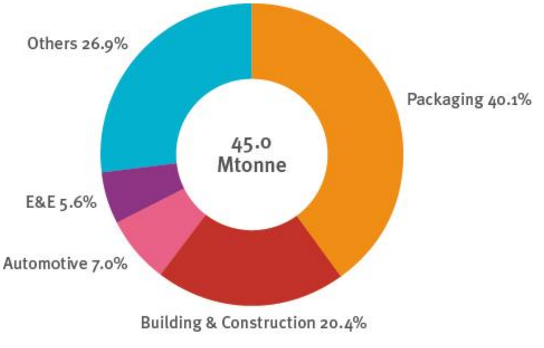

Fig. 4. *Europe Plastics Demand by Segments in 2009 [7]*

Europe is one of the biggest produce and export region of the plastics in the world. Table 1 shows demand for plastics by countries. Years 2005, 2007 and 2009 were there compared. Despite high growth rates, per capita consumption in Asia and Central Europe is significantly below the levels of mature industrial regions. Mature industrial regions are also expected to see growth rates slightly above GDP. Thus there is room for further growth.

Table 1. *Europe Plastics Demand by Countries (kt)*

Country	2005	2007	2009
Austria	880	990	939
Belgium and Luxemburg	2480	2570	2099
Bulgaria	310	415	343
Cyprus	10	10	13
Czech Republic	810	1095	975
Denmark	630	640	484
Estonia	40	140	109
Finland	600	625	497
France	5300	5350	4541
Germany	11150	12250	10730
Greece	740	865	716
Hungary	800	880	755
Ireland	320	330	240
Italy	7870	8315	7042
Latvia	50	190	135
Lithuania	110	240	182
Malta	10	10	13
Nederland	1850	2010	1659
Poland	1890	2350	2481
Portugal	770	825	787
Romania	350	645	571
Slovakia	290	365	366
Slovenia	130	210	219
Spain	4520	4785	3769
Sweden	860	880	800
UK	4300	4350	3578
Norway	230	275	213
Switzerland	850	890	789

Source: self study on basis [7]

When plastics have completed their use phase, whether as a car bumper or a bottle, they can either be recycled or if this is not economic or environmentally beneficial the calorific value of the plastic can be recovered through energy from waste incineration to provide a much source of home-grown power. As a consequence plastics can be viewed as 'borrowing' the oil.

The Futurologist Ray Hammond in his book "The World in 2030" predicts that oil in the future will not be burnt away and wasted in energy and transport but reserved for "high value processes and products such as plastics manufacturing . . . and energy trapped within the plastics can either be recycled or recovered and used for heat generation" [5].

4. Supply chain of plastics

All plastics can be recycled, however the extent to which they are recycled depends upon both economic and logistic factors. As a valuable and finite resource, the optimum use for most plastic after its first use is to be recycled, preferably into a product that can be recycled again.

Used plastics can be recycled up to six times. If it doesn't make economic or environmental sense to recycle, then the energy can be recovered through Energy from Waste (EfW) incineration. Used plastics have a higher calorific value than coal and at a time of high energy prices unrecyclable materials can, through EfW provide a much needed local energy supply.

Plastics products which have undergone a full service life and have then been reclaimed for further use are termed, post-use material, and can arise from industrial, commercial and domestic sources. Recent years have seen a growth in post-consumer plastics recycling.

Most of the plastics recycled are from the commercial and industrial sectors, with bottles being recovered from domestic sources. This pattern is because the main requirements for effective recycling of post-use plastics are [5]:

- resource efficient reclamation of the post-use products;
- facilities to sort and compact the reclaimed products;
- end use applications for the recycled plastics materials and these conditions are more easily met from commercial post-use waste.

In addition, heavily contaminated plastic waste requires special washing and drying facilities. Figure 5 shows the lifecycle of plastics – from converter demand to finally recovery and disposal.

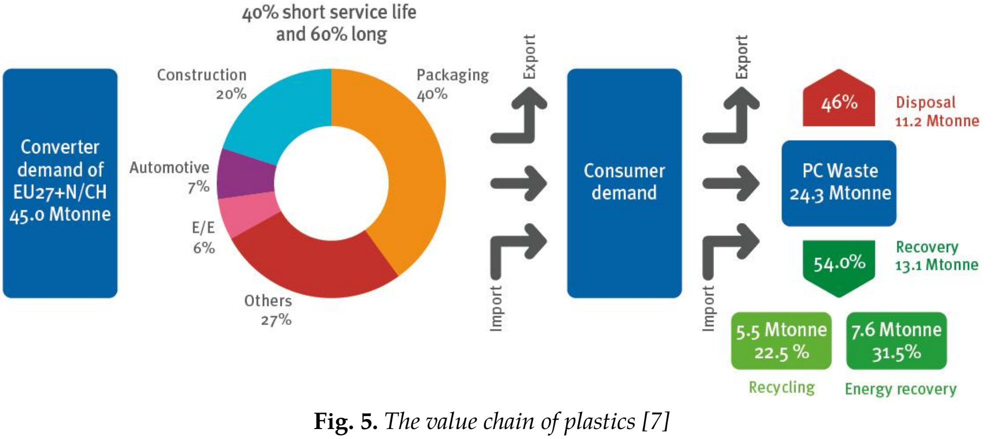

Fig. 5. *The value chain of plastics [7]*

As it is highlighted, the plastic's converter demand is 45 m tonnes, but only little more than half of this currently ends up each year as waste (24.4 m tonnes). 2009 was the first year when the generation of plastics waste fell from the previous year.

The drop was smaller than the reduction in plastics demand at 2%. The progress in capturing the value from plastics waste is, on average, slow. The recovery rate increase is approximately +2 percentage points per year. Many EU member states need to make greater efforts, to bring their recovery rate to 80% and more by 2020 [7].

The revised Waste Framework Directive (WFD) provides a framework to drive waste management practices in the EU. Underpinning this is the recognition of the 5 step waste hierarchy as a priority order to be applied flexibly using life cycle thinking to allow each waste stream to be handled in the best environmental way, considering economic viability and technical feasibility. The hierarchy for improving resource efficiency is (in descending priority order) [6]: 1) reduce, 2) reuse, 3) recycle, 4) recover, and 5) disposal.

The most resource-efficient approach is not to generate the waste in the first place, or to create as little as possible. The next option is reuse (using an article over- and again). If reuse is not feasible then products should be recycled, provided that this is more eco-efficient from a lifecycle perspective than recovery. The last resort is disposal, which should be minimised.

Nine countries (Table 2) with best recovery results have very strict boundaries on waste disposal, implementing a total or partial embargo on plastic waste disposal. Countries with high recovery rates do well on both recycling and energy recovery. A complete resource management strategy needs to address both, as no country will be able to recycle all post-consumer waste.

Seven of the EU Member States plus Norway and Switzerland recover more than 84% of their used plastics. The EU Member States plus Norway and Switzerland treated 24.3 million tonnes of post consumer waste in 2009. This results in an overall recovery rate from post-consumer plastic waste of 54%, up 2.7 percentage points compared to 2008.

The mechanical recycling rate up 1.2 percentage point to 22.2% and the energy recovery rate is up by 1.5 percentage points to 31.5% and landfill rate is down by 2.7 percentage points to 45.8% [7]. There are two primary methods to recycle plastics, mechanical recycling and feedstock recycling [5]:

- Mechanical recycling is the simplest method. Mechanical recycling is where the plastics, which soften on heating, are, reformed into moulding granules to make new products. The process involves collection, sorting, baling then size reduction into flake (film and sheet) or granules which may then need washing and drying. This is then re-compounded with additives and/or more virgin raw material, extruded and chopped into pellets ready for reuse.
- Feedstock recycling involves breaking down polymers into their constituent parts through the use of heat or pressure. In turn these parts can be used to make new plastics and chemicals. Feedstock recycling provides benefits when the materials are being recycled are mixed or contaminated.

An alternative to recycling is to recover plastics thermal content through energy from waste incineration, providing an alternative source of energy. The average value for polymers is 38 mega joules per kilogram (MJ/kg), which compares favourably to

Table 2. *Europe Plastics Demand by Countries (kt)*

	Recycling	**Energy recovery**	**Total recovery**
Switzerland	24.5%	75.2%	**99.7%**
Germany	33.9%	62.8%	**96.7%**
Denmark	21.2%	75.4%	**96.6%**
Sweden	33.0%	62.9%	**95.9%**
Austria	28.3%	67.4%	**95.7%**
Belgium	29.3%	63.8%	**93.1%**
Netherlands	24.9%	64.3%	**89.2%**
Norway	25.6%	62.7%	**88.3%**
Luxembourg	16.4%	67.6%	**84.0%**
France	16.0%	38.6%	54.6%
Slovakia	21.3%	26.7%	48.0%
Italy	23.0%	21.8%	44.8%
Czech	29.9%	14.3%	44.2%
Finland	15.7%	26.6%	42.3%
Hungary	18.1%	20.3%	38.4%
Estonia	29.9%	8.2%	38.1%
Spain	20.9%	14.4%	35.3%
Portugal	17.4%	13.9%	31.3%
Ireland	25.0%	4.8%	29.8%
Poland	16.5%	11.3%	27.8%
UK	18.9%	7.4%	26.3%
Slovenia	21.4%	3.3%	24.7%
Latvia	21.6%	1.1%	22.7%
Romania	12.1%	6.5%	18.6%
Lithuania	17.3%	0.0%	17.3%
Bulgaria	12.8%	2.7%	15.5%
Greece	12.1%	0.0%	12.1%
Cyprus	10.7%	0.0%	10.7%
Malta	8.8%	0.0%	8.8%

Source: self study on basis [8]

the equivalent value of 31 MJ/kg for coal [5]. This represents a valuable resource raising the overall calorific value of domestic waste which can then be recovered through controlled combustion and re-used in the form of heat and steam to power electricity generators.

The strategic objective of waste management planning is the handling of waste in accordance with the principles of the waste management hierarchy, i.e. firstly the prevention and minimization of waste generation and to reduce their hazardous properties and, secondly, maximum utilization of material and energy components of the waste, and where waste cannot be subjected to recovery processes, to be neutralised.

5. Conclusion

Plastics make a major contribution to the national economy and a healthy manufacturing sector is vital to a sustainable economy. The plastics industry is a leader in research and development, and innovation. Plastics materials and applications are constantly developed and improved. Plastics products also provide whole life cost savings [5]:

- reduced fuel use in transit due to their lightweight;
- reduced maintained requirements, for example PVC windows do not require painting;
- reduced energy required for heating when plastics insulation is used;
- reduced food and consumer goods wastage due to the unparalleled protective properties of plastics packaging.

Recovery logistics in waste management systems meets the demands of the new Framework Directive of the European Parliament and Council 2008/98/EC of 19 November 2008 on waste (OJ. EU of 22 November 2008 No. L 312 / 3) whose primary task is to develop instruments to promote the idea of a "recycling society", seeking to avoid waste and to use waste as a resource.

Bearing in mind that in the hierarchy of waste management it is essential to prevent its formation, the Member States are supposed to prepare by 2013 national waste prevention programs, which may become an element of waste management plans. Their primary goal is to stop the directly proportional relationship between economic growth and the amount of waste generated. However, the European Commission aims to develop indicators to measure waste prevention and to create a system for exchanging information on best practice in waste prevention.

Moreover, by 2012 the European Commission will prepare a special report on the cycle of waste production and the extent of preventing its occurrence.

In light of the requirements, which introduced a new framework directive on waste is a particular challenge to introduce efficient and effective recovery logistics systems, in spatial, organizational, and information fields. The task of these systems is to direct all waste to designated storage locations, while maintaining the hierarchy of recovery values, which the legislature based on the principle of sustainable development pointed to.

The plastics industry has developed its own long-term vision for waste management. The overriding goal of plastics manufacturers is to reduce the impact of plastics waste on the environment by [7]:

- diverting organic rich waste streams from landfill as much as possible and, thus, conserving primary resources;

- utilizing a mix of recovery options in order to save material or energy resources, taking eco-efficiency into account;
- treating and recovering plastics waste streams under defined environmental quality standards;
- taking a comprehensive approach into account along all stages of the life-cycle so that the largest environmental benefit, which can be achieved during the use phase of the plastic product, would not be impaired by a too detailed regulation of another stage in the life cycle.

Consequently, waste management should strive to develop intelligent solutions for both material recycling and energy recovery of plastic-rich waste streams.

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