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Αστικά Στερεά Απόβλητα και Ρύπανση του Περιβάλλοντος
Τάσεις στη Διαχείριση των Αστικών Στερεών Αποβλήτων στις Ευρωπαϊκές Χώρες και στην Ελλάδα

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Περίληψη: Η δραματική αύξηση των αστικών στερεών αποβλήτων (ΑΣΑ) τις τελευταίες δεκαετίες είναι αποτέλεσμα της ταχύτατης αστικοποίησης του πληθυσμού, της καταναλωτικής και της τεχνολογικής εξέλιξης των ανθρώπινων κοινωνιών του πλανήτη μας. Τα αστικά στερεά απόβλητα , μαζί με τα υγρά απόβλητα, αποτελούν σήμερα ένα από τα πλέον επείγοντα περιβαλλοντικά προβλήματα σε όλες τις χώρες λόγω της εκτεταμένης ρύπανσης που προκαλούν στο έδαφος και στα υδατικά συστήματα με την διαρροή τοξικών και επικίνδυνων χημικών ρύπων. Επίσης, τα στερεά απόβλητα μπορούν να καταστούν αιτίες πυρκαγιών, μεταφοράς μολυσματικών παραγόντων στα υπόγεια νερά και ρύπανσης καλλιεργειών με βαρέα μέταλλα και άλλες χημικές ουσίες.

Τα στατιστικά δεδομένα πιστοποιούν ότι τα στερεά αστικά απόβλητα αυξήθηκαν δραματικά στον 21^{ο} αιώνα και υπολογίζονται ότι σήμερα παράγονται 1,3 δισεκατομμύρια τόνοι σε παγκόσμια κλίμακα. Σύμφωνα με υπολογισμούς θα αυξηθούν σε 2,2 δισεκ. τόνους το 2025. Τις μεγαλύτερες ποσότητες αποβλήτων παράγουν οι ανεπτυγμένες βιομηχανικές χώρες λόγω του σημαντικού ποσοστού αστικού πληθυσμού τους και τον υπέρμετρα καταναλωτικό τρόπο ζωής. Οι μοντέρνες ανθρώπινες κοινωνίες καταναλώνουν τεράστιες ποσότητες τροφίμων, υλικών συσκευασίας, πλαστικών, και άλλων υλικών μίας χρήσης. Οι 34 ανεπτυγμένες χώρες του ΟΟΣΑ σήμερα παράγουν, περίπου, το 50% των αστικών αποβλήτων, ενώ στην άλλη πλευρά η Κίνα παράγει το 70% των στερεών αποβλήτων των χωρών της ΝΑ Ασίας. Οι ΗΠΑ κατέχουν την πρώτη θέση ως χώρα στην παραγωγή στερεών αποβλήτων με 621.000 τόνους κάθε ημέρα. Στην Ελλάδα παράγονταν 4 εκατομ. τόνοι (1997) αστικών στερεών αποβλήτων (ΑΣΑ) και ξεπέρασαν τα 6 εκατομ. τόνοι ΑΣΑ το 2011. Στην περιφέρεια Αττικής παράγεται, περίπου, το 40% της ετήσιας ποσότητας και εκτιμάται ότι σήμερα η παραγόμενη ποσότητα των αστικών αποβλήτων ξεπερνά τους 6.000 τόνους την ημέρα**.** Το νέο ευρωπαϊκό και εθνικό θεσμικό πλαίσιο για τη διαχείριση των στερεών αποβλήτων θέτει διαρκώς αυστηρότερες προδιαγραφές που πρέπει να εφαρμοσθούν από τις τοπικές κοινωνίες. Η εμπειρία των Ευρωπαϊκών χωρών με ανεπτυγμένα προγράμματα διαχείρισης ΑΣΑ δείχνει ότι μπορεί να επιτευχθεί περιβαλλοντικά καλύτερη διαχείριση με *μείγμα* διαφόρων μεθόδων, ανάλογα με τα ιδιαίτερα γεωγραφικά, δημογραφικά, χωροταξικά και κοινωνικο-οικονομικά χαρακτηριστικά κάθε χώρας. (α) προγράμματα πρόληψης και ελαχιστοποίησης των αποβλήτων (περιορισμό πλαστικών συσκευασιών, κλπ), (β) πρόγραμμα χωριστής διαλογής αποβλήτων στην πηγή και ανακύκλωση χρήσιμων υλικών (χαρτί, μέταλλα, πλαστικά, δοχεία αλουμίνας, γυαλί) (γ) μηχανικής- βιολογικής επεξεργασίας (Mechanical Biological Treatment) του χαμηλότερης καθαρότητας, οργανικού κλάσματος (κομποστοποίηση και διάθεση λιπάσματος στη γεωργία, καθώς και εξουδετέρωση υγρών τοξικών αποβλήτων, συλλογή μεθανίου, κ.λπ) , και (δ) θερμικής επεξεργασίας (καύση, αεριοποίηση, πυρόλυση) των σύμμεικτων στερεών αποβλήτων με αντίστοιχη παραγωγή ενέργειας.

Πλήρες κείμενο της εργασίας στα αγγλικά [36 σελίδες]: αρχείο PDF, 7.6 MB

<Επιστροφή στη λίστα επιστημονικών θεμάτων και ανακοινώσεων>

Municipal Solid Waste and Environmental Pollution
Trends of Municipal Waste Management in European Countries and in Greece

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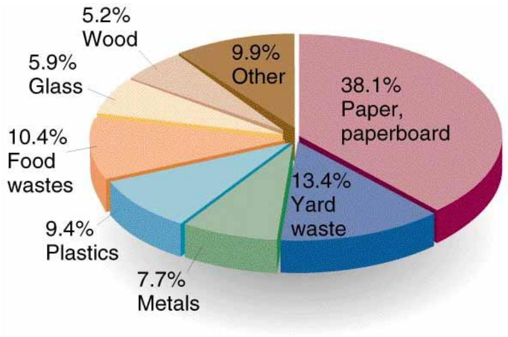
Abstract : The dramatic increase of municipal solid waste (MSW) in the last decades reflects the evolution of urbanization of the Earth's population at an unprecedented rate, as well as excessive consumerism and technological culture of the human societies in all areas of the planet Municipal solid waste represent today one of the most urgent environmental problem for all countries, especially on account of the widespread pollution of soil and aquatic systems. Effective and environmentally acceptable waste management strategies depend on local waste characteristics, which vary with cultural and socioeconomic variables. Studies showed that today the world produces 1.3 billion tones of MSW. Additionally, municipal waste can be the cause of wild fires in forested areas, a source of spreading infectious pathogens to underground waters and pollutants of agricultural soil and farm products by heavy metals and hazardous chemicals.

In recent years statistical data showed that MSW) are increasing at an unprecedented rate to reach 2.2 billion tones by 2025. MSW tends to be generated in much higher quantities in wealthier regions of the world because of the high proportion of urban populations adopting high-consumption lifestyles. Human societies use more and more packaging and plastic materials producing , approximately, 1.2 kg/person/day solid waste (2013) that is expected to increase to 1.42 by 2025. The most advanced industrialized countries of OECD (34 nations) today generate ~ 50% of world's waste, whereas populous China produces 70% of solid waste in the SE Asian region. For comparison, the USA comes first as a country in terms of production of MSW output at some 621,000 tons per day. Greece belongs to the OECD countries and in the last decades the generation of MSW increased substantially, from 4 million tones (1997) to 6 million tones in 2011. It is estimated that MSW will increase to 7,7 million tones in 2025. The region of Attica with its highly urban populated areas produces 40% of MSW. It is estimated that Attica generates 6.000 tones of MSW every day. Every family in EU countries on average throws away around 500 kg of household rubbish every year. Manufacturing, water and energy sectors produces 450 million tones/yr of MSW and construction another 900 million tones/yr. Altogether, the European Union produces up to 3 billion tones of MSW every year. The new European and national legislative framework for effective management of MSW places continuously stricter regulations for all countries. The European experience on environmentally advanced programmes of MSW management showed that a mixture of methods are more effective in dealing with MSW, depending on geographical, and socioeconomic characteristics of every country: a) programmes of waste prevention and minimization (biodegradable materials, less packaging), b) programmes of separation of rubbish at source and recycling (recovery practices, collection of useful and reusable waste materials, paper, metals, glass, aluminum), c) mechanical-biological (Mechanical Biological Treatment, MBT) and landfill management (to contain leachate and reduce methane generation, plant material, food scraps for composting and digestion processes to decompose organic matter and used as mulch or compost for agricultural and landscaping), d) modern waste incineration and energy recovery of mixed solid waste.

Introduction: Trends in Global Municipal Solid Waste Generation

Growing prosperity and urbanization of the world's population (in 2014 54 % of the world's population lived in urban areas and is expected to increase to 66% by 2050) in the last decades increased substantially the generation of municipal solid waste (MSW) as well as other types of waste (liquid waste, agricultural, industrial, toxic chemicals, electrical and electronic waste). Estimates of MSW at a global scale showed that 1.3 billion tones were produced in 2013, expecting to increase to 2.2 billion tones by 2025. Developed industrialized countries, such as the 34 OECD nations (Organization of Economic-Cooperation and Development), generate, approximately, 50% world's waste and China produces 70% of MSW in South East Asia region. Increasing rates of urbanization and consumerism could double the volume of MSW annually by 2025, challenging environmental and public health management in the world's cities Although some of this waste is eventually recycled, the doubling of MSW would bring substantial environmental problems and cause difficulties in management practices.[1-3]

Municipal solid waste (MSW) consists of organic material (food scraps, garden grass, etc), paper, plastic, glass, metals, and other refuse collected by municipal authorities, largely from homes, offices, institutions, and commercial establishments. MSW does it include sewage, industrial waste, or construction and demolition waste generated by cities, and of course does not include rural wastes. Studies in England and Wales with MSW established that the composition was: paper and cardboard 23–25%, kitchen and garden waste 35–38%, plastics 8–10%, glass 6–7%, and metals 3–5%.[4]



(Data from EPA, Office of Solid Waste, "Characterization of Municipal Solid Waste in the United States," 1997 edition.)

Figure 1. Municipal solid wastes (MSW) increase at an unprecedented rate in all countries in the last decades. The USA as a developed industrialized country produces more than 620,000 tones per day. Characterization of MSW in the USA showed that 38% are paper and paperboard, 13% garden waste, 10.4% food waste, 9.4% plastic, and then metals, glass, wood and other types of waste.

China is a typical example of a country with rapid rates of urbanisation and increasing tendencies of high rate of consumerism. The total MSW amount in China increased from 31.3 million tones in 1980 to 212 million tones in 2006, that is 7 times in 25 years because of the massive move of population from villages to cities. Currently, waste composition in China is dominated by a high organic and moisture content of kitchen waste in urban areas. In 2007, 91.4% of MSW in China was landfilled, 6.4% was incinerated and only 2.2% was composted. In the last decade China's MSW is growing fastest in paper, plastics and multi-laminates which is generally believed to be a sign of urbanisation and rapid economic development..[5]

The urban population of the Earth in 2014 accounted for 54% of the total global population, up from 34% in 1960, and continues to grow. It is estimated that by 2017, even in less developed countries more than 50% of the population will be living in urban areas. As the world hurtles toward its urban future, the amount of MSW, representing excessive lifestyle consumerism, will grow even faster than the rate of urbanization. Today, more than 3 billion urban residents on Earth generate 1.2 kg per person per day (which accounts for the1.3 billion tones MSW per year). By 2025 it is estimated that this will likely increase to 4.3 billion urban residents generating about 2.2 billion tones MSW per year.[6]

Municipal solid waste (MSW) and a variety of collection practices are everyday experience in every country. MSV consists of everyday items such as packaging material, furniture, clothing, plastic items, aluminum cans, glass bottles, food scraps, newspapers, appliances, paint, tyres (or tires), batteries, wooden items, etc. Although the initial waste management policies and technologies were very different in the various industrialized countries, providing a variety of environmental benefits, nowadays there are key strategic practices and processes that integrate waste minimization, separation at source, recycling, composting, advanced incineration methods for energy generation and minimal landfilling. Key waste management challenges include integrating the informal waste sector in developing cities, increasing and standardizing the collection and analysis of solid waste data, and effectively managing increasingly complex waste while protecting people and the environment.[7]

Municipal Solid Waste in Developed Countries

Municipal Solid Waste in the United States of America (USA)

The USA is the third most populous country on Earth with a total resident population of 319 million (2014) and the most advanced industrialized country with 81% of population residing in cities and suburbs, whereas the worldwide urban rate is 54%. The excessive consumer-related lifestyle of the American population, results in the generation of, approximately, 621,000 tons of MSW per day (the highest in the world). The solid waste, more commonly known in the USA as trash or garbage, consists of paper, plastics, grass, clothing, glass, aluminum cans, food scraps, appliances, paint, batteries, etc.[8]

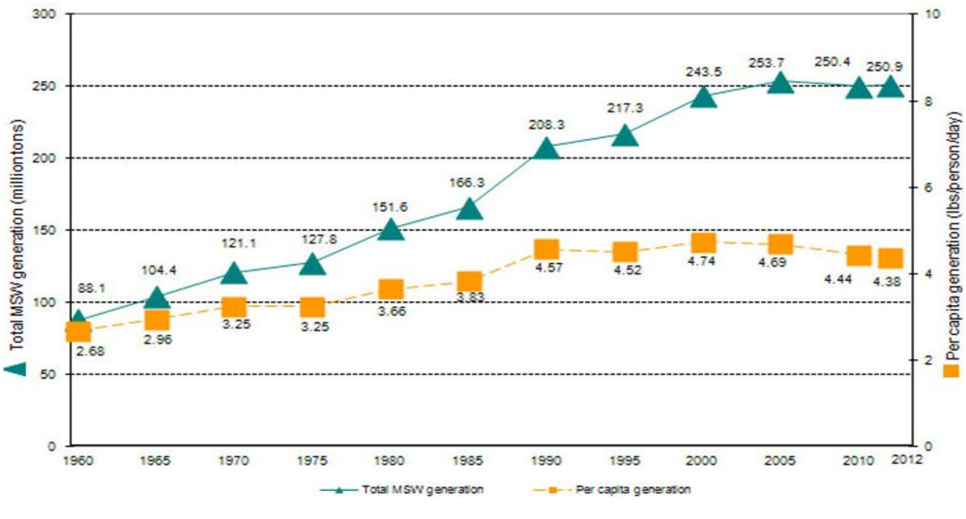


Figure 2. Trends in municipal Solid Waste (MSW) in the USA for the period 1960-2012 (in lb). Total MSW generation increased from 88 million tones (1960) to 250 million tones (2012). The per capita generation of MSW in the same period was 2.68 lb or 1.2 kg/person/day (1960) to 4.38 lb or 1.97 kg/person/day (2012).

Total annual MSW generation in the U.S. has increased by 65% since 1980, to the current level of 250 million tones. Per capita MSW generation increased by 20% over the same time period, from 1.6 kg to 2 kg per person each day. For comparison, MSW generation rates (kg/person/day) are 1.26 kg in Sweden, 1.6 in Germany, and 1.4 kg in the United Kingdom. Packaging, containers, and nondurable goods (including papers and plastics lasting ~3 years) made up over 50% of MSW generation in 2012. Most of the remainder is split between durable goods, yard trimmings, and food waste. In 2012, 34.5% of MSW generated in the U.S. was recovered for recycling or composting, diverting 87 million tons of material from landfills and incinerators—more than double the amount diverted in 1990.[9]

Municipal solid waste in European countries

The European Union of 28 member states (and 6 as candidates) has a combined population of over 507 million inhabitants (2014) or 7.3% of the world population. As an economic superpower the EU in 2014 generated a nominal gross domestic product (GDP) of 18.124 trillion in US dollars, constituting approximately 23% of global nominal GDP, representing 35.849 US$ per capita. All countries in the EU are considered advanced industrialised nations with similar to a certain degree consumer customs and environmental issues for MSW management. In 21 of the countries, the amount of MSW generated per capita increased between 1995 and 2012, rising fairly steadily in 10 of these countries. The highest average annual growth rates were recorded for Greece (3.1 %). The highest average annual growth rates were observed in Austria, Ireland and Sweden, before the amounts stabilised or fell slightly between 2003 and 2012. Even though more waste is being generated in the EU-28 countries, the total amount of MSW landfilled has gone down due to new legislation. Countries in the EU would face tougher recycling targets, while burying recyclable waste in landfill would be banned, under plans put forward by the European Commission (2014). The proposals, which form part of the Commission's **Waste Targets Review**, include updated targets to recycle 70% of household waste and 80% of packaging waste by 2030. The proposed landfill ban would apply from 2025. Achieving the new targets could create up to 580,000 new waste management jobs and make Europe more competitive by reducing demand for costly scarce resources. The total MSW landfilled in the EU-27 fell by 61.7 million tones, from 143 million tones in 1995 to 81.2 million tones in 2012 (annual decline of 3.3 %).[10,11]

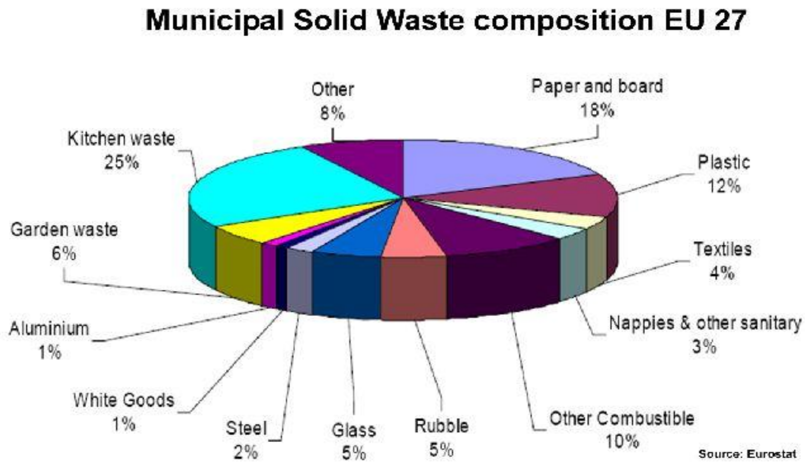


Figure 3. The composition of MSW in the 27 nations of the EU (2012). Organic kitchen waste with 25% comes first, paper and board is second with 18% and third are all types of plastic items with 12% [Source : Eurostat, 2012].

Reduction in MSW landfilling can partly be attributed to the implementation of European legislation (Directive 62/1994 on packaging and packaging waste). By 2001, all Member States had to recover a minimum of 50 % of all packaging put on the market. Furthermore, Directive 31/1999 on landfill stipulated that Member States were obliged to reduce the amount of biodegradable municipal waste going to landfills to 75 % (by 2006), to 50 % (2009) and to 35 % (2016). The Directive has led to countries adopting different strategies to stop sending the organic fraction of municipal waste to landfill, namely composting (including fermentation), incineration and mechanical-biological pre-treatment (including physical stabilisation). As a result, the amount of waste recycled rose from 25.1 million tones in 1995 to 65.9 million tones in 2012. The share of municipal waste recycled overall rose from 11 % to 27 %. The recovery in EU countries of organic material by composting has grown with an annual rate of 5.5 %. Recycling and composting together accounted for 42 % of organic material in 2012. Waste incineration has also grown steadily in the same period. The amount of MSW incinerated in the EU-27 has risen by 25.9 million tones (1995) to 58.1 million tones in 2012.[12-14]

Table 1. Eurostat statistics for Municipal Solid Waste generated in European countries, 2012. The best performing countries in Europe (waste avoidance and recycling are Estonia, Slovenia and Belgium).

	Municipal waste generated,	Total municipal waste treated,	Municipal waste treated, %			Residual waste per person
	kg per person	kg per person	Recycled & composted	Landfilled	Incinerated	kg per person
EU28	**492**	**480**	**42**	**34**	**24**	285,36
Belgium	456	458	57	1	42	196,08
Bulgaria	460	433	27	73	0	335,8
Czech Republic	308	308	24	57	20	234,08
Denmark	668	668	45	3	52	367,4
Germany	611	610	65	0	35	213,85
Estonia	279	220	40	44	16	167,4
Ireland	570	570	45	39	16	313,5
Greece	503	493	18	82	0	412,46
Spain	464	464	27	63	10	338,72
France	534	534	39	28	33	325,74
Croatia	391	381	16	85	0	328,44
Italy	529	523	38	41	20	327,98
Cyprus	663	663	21	79	0	523,77
Latvia	301	301	16	84	0	252,84
Lithuania	469	458	21	79	1	370,51
Luxembourg	662	662	47	18	36	350,86
Hungary	402	402	26	65	9	297,48
Malta	589	559	13	87	0	512,43
Netherlands	551	551	50	2	49	275,5
Austria	552	528	62	3	35	209,76
Poland	314	249	25	75	1	235,5
Portugal	453	453	27	54	20	330,69
Romania	389	313	1	99	0	385,11
Slovenia	362	301	47	51	2	191,86
Slovakia	324	313	13	77	10	281,88
Finland	506	506	34	33	34	333,96
Sweden	462	462	47	1	52	244,86
United Kingdom	472	465	46	37	17	254,88

Source: Eurostat 2012

Trends in municipal waste treatment in the European Union countries

It is estimated that in Europe every person per year throws away 6 of waste. Although the management of waste improves in recent years in the EU, the European economy and lifestyle lose a significant amount of potential 'secondary raw materials' such as metals, wood, glass, paper, plastics as waste. From the 2.5 billion tons of waste a 36% was recycled, with the rest was landfilled or burned.

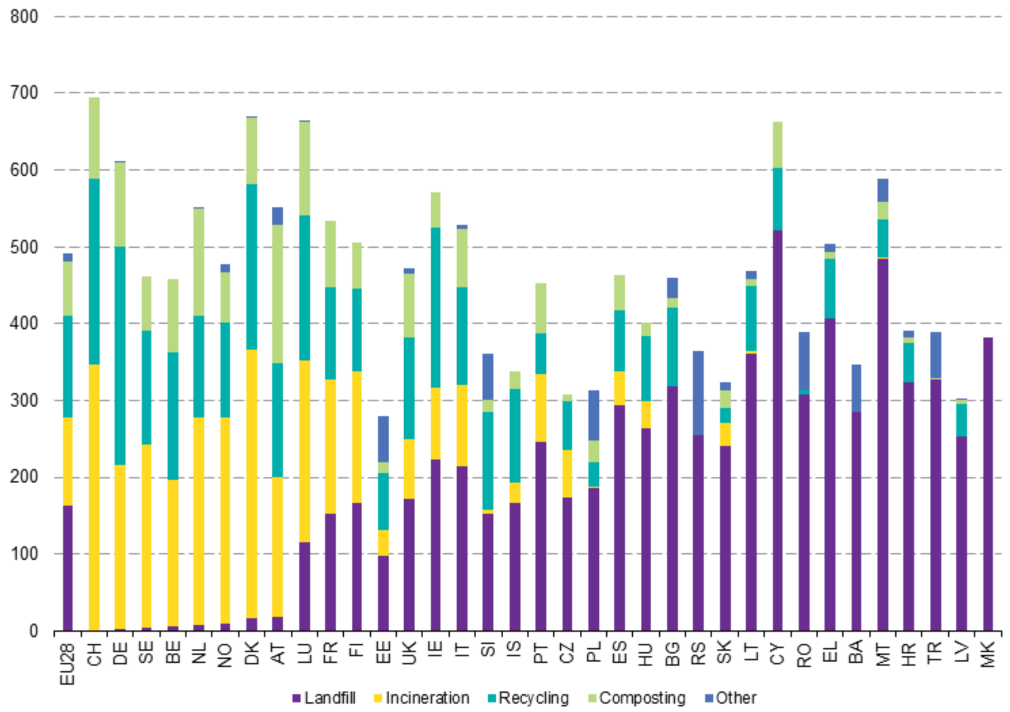


Figure 2. Austria(AT), Belgium (BE), Bulgaria (BG), Croatia(HR),Cyprus (CY), Czech Reb (CZ), Denmark (DK), Estonia (EE), Finland(FI), France (FR), Greece (EL), Hungary (HU),Ireland (IE), Italy (IT), Latvia (LV) Lithuania (LT), Luxembourg (LU), Malta (MT), Netherland (NL), Poland (PL), Portugal (PT), Romania (RO), Slovakia (SK), Slovenia (SI), Spain (ES), Sweden (SE), United Kingdom (UK).
MSW in 28 countries of the EE and the method of treatment in 2012 by country (landfill, incineration, recycling, composting, other) sorted by percentage (%) of landfilling kg per capita (in 2012) [http://epp.eurostat.ec.europa.eu/statitics_explained/index.php/File:Municipal_waste_treated_in_2012_by_country_and_treatment_category_sorted_by_percentage_of_landfilling_kg_per_capita_2012_new.PNG]

The European Commission set important goals for an integrated European environmental policy, especially a roadmap on a resource efficient Europe (EC, 2011) and the EU's Waste Framework Directive (EU, 2008). But national efforts for reduction and efficient management of MSW have been under way for longer, in large part driven by earlier EU legislation such as the Landfill Directive (EU, 1999). Although only a few countries reduced their municipal waste output between 2001 and 2010, there are clear indications of a shift away from landfilling towards preferred waste management approaches. The number of countries that landfill more than 75 % of municipal waste output decreased sharply. In general, there have been substantial increases in the proportion of municipal waste recycled.[11]

The EU countries with the most advanced waste management practices moved away from landfilling into recycling and incineration. In Sweden, the amount landfilled dropped from 42 kg per capita in 2004 to 23 kg per capita in 2005 and right down to 3 kg per capita in 2012 after the introduction of a ban on landfilling organic material in 2005. In Germany, landfilling has been reduced steadily over the last decade, mainly by recycling, mechanical biological treatment and incineration. It dropped sharply due to the ban on landfilling of untreated municipal waste that entered into force on 30 June 2005. Denmark, that is one of EU countries that generates more waste per capita, is world leader in incineration of household waste, burning 60% of it. This means that (after discounting recycling of various types of MSW that can give recycled raw materials) Denmark burns large amounts of waste.[11] All EU countries in the last decade showed a positive indications of a shift away from landfilling MSW towards preferred waste management.[12]

Figure 3. Denmark is the country that generates more waste per capita, is world leader in incineration of household waste, burning more than 60% of it. Demark has at the same time a very active and efficient system of recycling of electrical and electronic waste.

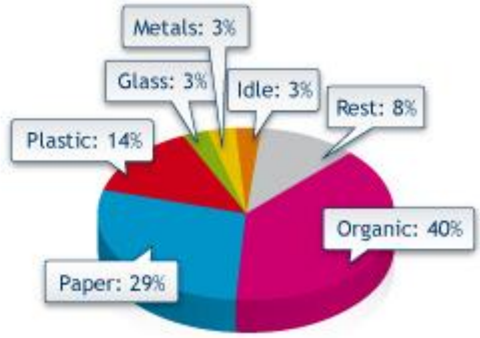
Municipal solid waste in Greece

According to statistical data, Greece produced 4 million tones of MSW in 1997, whereas in 2011 the MSW increased substantially to 6 million tones and is expected to increase further into 7.7 million tones in 2015 with present trends. The most populous area of Attica (estimated to 5 million) produces 40% of MSW per year, whereas the region of central Macedonia (Thessaloniki) produces 16% of MSW. In 2000 the median per capita generation of MSW was 408 kg/person/year and in 2010 increased to 475 kg/person/year. Attica produces 6.000 tones/day. The composition of MSW are very similar to other developed countries: In 2010 : 46-47%were organic kitchen waste, 19-20% paper, 18% plastics, 3-4% glass and 15,5 % other. But in recent years studies showed a substantial increase in plastic waste in the urban areas of Greece.[13,14]

Municipal solid waste (MSW) and toxic industrial waste in Greece are two of the most distressing and urgent environmental problems with many regional points of friction between central environmental authorities and local administration and citizens who do not want landfills in their backyards. Greece in the last decade was paying exorbitant fines to the EU for illegal waste tips, which in 2005 were calculated to be more than 3.000. At the same time toxic and hazardous industrial waste, tar derivatives, tyres, used cars, batteries, engine oils and others were accumulating at increasing rates in various areas of Greece at an alarming rate. Despite the general hygiene problems and water pollution, illegal waste tips caused fires and environmental contamination of soil and wetlands. Despite the numerous past problems and lack of funding, but under the direct pressure of the EU regulatory actions, Greece improved substantially the situation on waste in the last decade. Land disposal of MSW (landfills) is still the predominant method for managing MSW and recycling is catching up (from only 10% in 2005). Until recently (2009) 90% of MWS was disposed without prior treatment and recycling at the source was advancing at very slow pace. Athens and Thessaloniki at present recycle around 20-25% of their MSW by various ways (separate collections, separation in the landfill, etc) but progress is very slow and there are in 2014 some illegal waste tips, some island and towns face difficulties in managing their MSW. As of 2011, there are still 109 illegal dumping sites all over Greece in operation, despite the ruling of the European Court of Justice of 2005 (case c-502/03) which dictated that by the end of 2008 all illegal dumping sites should have been closed and rehabilitated.[15,16,]

In the last few years many state and private operators in Greece started various initiatives for the collection of waste. In 2007 25% of the domestic waste was recycled (mainly package material, glass, plastic, etc) with the help of private contractors. Special storage containers (bleu waste collection containers) helped to promote the recycling effort (some of them sponsored by private companies). In

2007, 50.000 old cars were collected by the local authorities from the streets and recycled, 47.000 tyres, 37.000 tones of oil of internal engines, 450 tones of batteries, 32.000 of capacitors and 30.000 tones of electrical equipment . By 2008, 525,000 tons of packaging material were recycled/recovered from a total production of 1,050,000 tons. A total of 19 centres for sorting and recovery were established in Athens, Thessaloniki, Heraklion, Chania, Kalamata, Patras, Zakynthos, Schimatari, Lamia, Karditsa, Corfu, Katerini, Magnesia, and Ioannina. Also, Greece operates two waste to energy facilities, one in Athens, (Ano Liosia Hygenically Controlled Landfill) and one in Thessaloniki (at the Tagarades Hygenically Controlled Landfill). The Ano Liosia facility produces heat and power from biogas (capacity of 23.5 MW). The Tagarades power plant produces electricity from biogas (capacity of 5 MW), capable of covering the energy needs of 80,000 residents.[17,18]



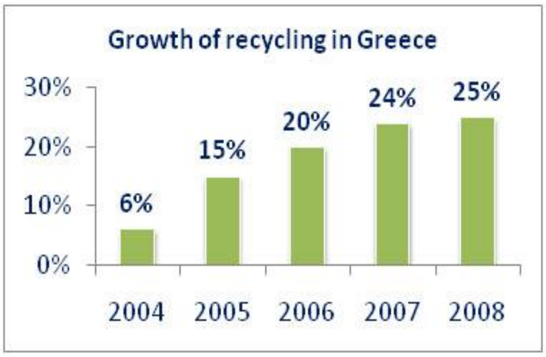


Figure 3. Composition of MSW in Greece (2009) and recycling. In the last decade plastic items and packaging materials have increased substantially. Studies in the Athens area observed that in MSW more than 50% are plastic materials. [Source: Ministry for the Environment, Energy & Climate Change – Hellastat, waste management sector study (2009 & 2010)].

The Ministry for the Environment, Energy and Climatic Change and various organizations promoted various initiatives and conferences on the subject of MSW management and the challenges for Greece towards a Zero Waste Economy, despite the financial difficulties of the last 5 years (2009-2004).[19,20] In the last decade, several initiatives and policy measures have been employed by the Greek government in order to divert MSW from landfilling and disengage the dependency on landfills. One of the direct outcomes of Law 2939/2001 'on packaging and recycling of packaging and other products - Establishment of the National Organization for Recycling of Packaging and other Products' was the establishment of the Hellenic Recovery Recycling Corporation (HERRCO) in the end of 2001, which became fully operational by 2003. Although initially covering less than 40 % of the population, mainly in urban areas, by 2011 around 75 % of the total population of Greece is covered by the collection mechanisms of HERRCO. This operation has significantly boosted the performance of recycling and material recovery, removing a fraction of MSW from landfill .[21,22]

Both composting (to a lesser extent) and recycling in Greece were boosted after the establishment and operation of two large MBT (Mechanical and Biological Treatment) plants in two regions of Greece in 2005-2006. It seems that the MBT output has contributed significantly in providing material recyclables, but not so much compost material. The future EU targets for MSW are going to influence the pace of changes in Greece with the Landfill and the Waste Framework Directives. According to the current trends, Greece is likely to miss the targets of both Directives if it does not accelerate efforts towards recycling and diversion of waste from landfill considerably. Regarding the Landfill Directive, the level of landfilling of biodegradable MSW was estimated to amount in 2010 to around 108 % of the generated amount in 1995. Therefore, besides missing the target for 2010, Greece is likely to experience great difficulties in meeting the targets for 2013 and 2020. Greece will need to make an exceptional effort in order to fulfil the 50 % recycling target of the Waste Framework Directive by 2020. Also, Greece seems to have a strong future strategy regarding treatment of MSW. According to European Investment Bank, a great number of plants are in the planning or construction stage, mainly based on MBT technology, which has the potential to contribute to all Greece's targets by simultaneously diverting the biodegradable fraction from landfills and increasing the material recovery. The introduction of new plants could have the same effect on recycling as the two existing MBT plants which boosted the figures for recycling.[23,24]

International Trends in MSW Management

Management of Municipal Solid Waste (MSW) is not only a serious environmental issue for most countries, but also a sociopolitical problem. Increased MSW generation throughout the world creates more environmental problems in different countries, particularly in developing countries where the cities are not able to manage wastes due to lack of institutional, financial, technical and regulatory issues as well as reduced public participation in the practical aspects of management. The consequences of inadequate disposal of MSW and difficulties in management solutions cause the widespread use of illegal tips, water pollution and environmental degradation. The impact of disposed MSW has significant adverse effect on atmospheric pollution with odorous chemicals, volatile organic compounds (VOC) and methane, contamination of surface and groundwater through leachate, soil contamination, air pollution through burning of wastes and spreading of diseases by different vectors such as birds, insects, and rodents. The final results of MSW are adverse effects on the environment and human health. Proper management for the disposal of MSW is a necessity and an integral part of the healthy urban environment, reduction of degradation of land resources, and planning of the safe urban infrastructure while considering the promotion of sustainable economic growth. In the last decades all developed countries legislated for efficient MSW management practices that so far are in priority order: recycling, digestion and composting, incineration and landfilling as a last resort. In many developed countries emphasis is given to controlled incineration for energy and electricity generation of MSW that is not for landfills, then anaerobic digestion and composting of biodegradable waste (use of compost for fertilizers and the gas for energy), priority for recycling or recovery of useful raw materials (paper, metals, glass, alumina, rubber) or separate valuable materials from the mixed waste (electrical items, electronic , textiles, plastics, car parts, wood, etc) and sell the recovered materials to waste collectors for further use.[25,26]

Increasing population levels, booming economy, rapid urbanization and the rise in community living standards have greatly accelerated the municipal solid waste generation rate in developing countries. Municipalities, usually responsible for waste management in the cities, have the challenge to provide an effective and efficient system to the inhabitants. However, they often face problems beyond the ability of the municipal authority to tackle mainly due to lack of organization, financial resources, complexity and system multi dimensionality.[27,28]

Scientists studied different waste treatment options for MSW in a systems analysis. Different combinations of incineration, materials recycling of separated plastic and cardboard containers, and biological treatment (anaerobic digestion and composting) of biodegradable waste, were studied and compared to landfilling. The study evaluated the use of energy resources, environmental impact and financial and environmental costs. The case studies were performed in three Swedish municipalities.

The study showed that reduced landfilling in favour of increased recycling of energy and materials lead to lower environmental impact, lower consumption of energy resources, and lower economic costs. It was concluded that landfilling of energy-rich waste should be avoided as far as possible (environmental impact and recovery of useful materials). The researchers conclude that when planning for effective waste management, it is important to know that the choice of waste treatment method affects processes outside the waste management system, such as generation of district heating, electricity, vehicle fuel, plastic, cardboard, and fertilisers.[29,30]

Expert opinion envisage great financial opportunities from the appropriate waste management. The waste market (composting, waste-to-energy, recycling) has a very high economic value. It is estimated that OECD countries MSW market has a value of 125 billion ($US). In emerging economies (Brazil, China, India) MSW has a value of 25 billion ($) and there is an increase in global MSW market (2007-11) by 37%. Municipal solid waste can become a material resource through the recovery of materials and energy from waste. It is estimated that MSW can become a world secondary materials market (in million metric tones): fibers 170 mt, ferrous metal 405 (mt), non-ferrous metal 24 mt, plastics 5mt, The total recovery of useful raw materials from waste is estimated at ~ 600 mt/year.[31]

Disposal and Management of MSW through Landfilling

From the 1950s all developed countries started a systematic disposal of municipal and other wastes by landfilling or spreading waste in controlled dumping places. MSW was collected by special vehicles and transported directly to a landfill site as the most appropriate hygienic method. A modern sanitary landfill is not a dump; it is an engineered facility used for disposing of solid wastes on land without creating nuisances or hazards to public health or safety, such as the breeding of insects and the contamination of ground water. Developed countries disposed MSW in a systematic manner in specially constructed dumps, developing countries usually threw out MSW in open dumps in a haphazard way causing environmental pollution and unhygienic conditions.[32]

Figure 4. Controlled landfill is safe stockage of solid waste with confinement in a suitable waterproofed area, minimizing the risks for man and the environment. Anaerobic processes of decomposition of organic materials can be contained with the production of biogas and leachate.

Landfilling can be organized in a proper way through scientific and technological techniques Once the maximum waste volume has been reached, the site is closed and restored, the waste is covered with sealed top layer which is then covered with soil in order to reduce the seepage of the meteoric water (reduction of leachate production) controlled biogas leakage into air and allow the site to be grassed over and trees planted [http://www.mater.polimi.it/mater/en/wmt/landfilling]

Some statistical data of MSW indicate that in 1995, in the developed countries of Western Europe, 67% of waste was landfilled and was reduced to 57% in 1999. But from the turn of the century (2000) landfilling of MSW was decreased in most developed countries. Germany 18% (2004), Japan 13% (2003), France 36% (2005), Italy and USA 54% (2005) and UK 64% (2005). From 57% of MSW in the EU countries landfilled the proportion decreased to 37%, recycling increased to 25%, composted is at 15% and incineration for energy increased to 23% [Euractiv.com : Environment, Landfills continue to rule despite EU recycling target, 5/3/2013].

The member states with the highest share **of** landfilled MSW (2011) were Romania (99%), Bulgaria (94%), Malta (92%). The highest shares of incinerated waste were in Denmark (54%), Sweden (51%), Belgium (42%), Netherlands (both 38%), Germany (37%). Recycling was most common in Germany (45% of waste), Ireland (37%) and Belgium (36%). The highest composting for municipal waste were Austria (34%), the Netherlands (28%), Belgium and Luxembourg (both 20%), Spain and France (both 18%). Recycling and composting of municipal waste together accounted for more than 50% of waste treated in Germany (63%), Austria (62%), the Netherlands (61%) and Belgium (57%). [http://www.euractiv.com/sustainability/landfills-continue-rule-despite-news-518229].

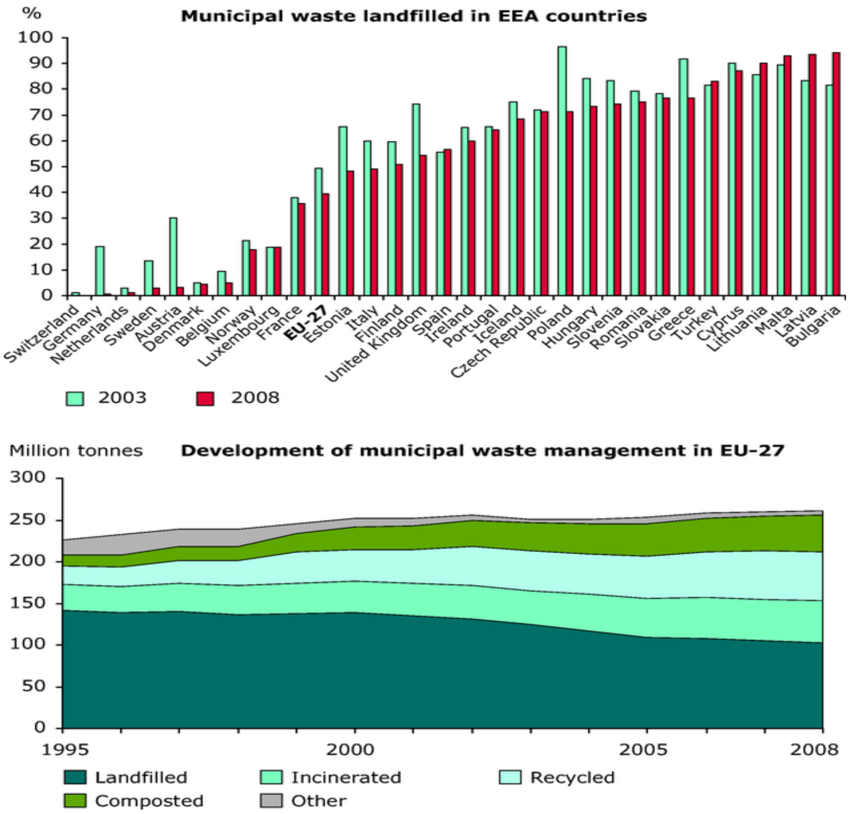


Figure 5. Percentage of municipal waste landfilled in European Environment Agency countries, 2003 and 2008; and development of municipal waste management in EU-27, 1995 to 2008 . [http://www.eea.europa.eu/data-and-maps/figures/percentage-of-municipal-waste-landfilled]

In the last decade the European countries' landfilling rates of MSW were reduced, as most governments introduced a ban on landfilling of waste. Disposal of wastes with landfilling in the USA had decreased from 89% of the total amount generated in 1980 to 54% of MSW in 2007. In the USA over the last few decades, the generation, recycling, composting, and disposal of MSW have changed substantially. MSW generation per person per day peaked in 2000 while the 4.38 lb/person/day is the lowest since the 1980's. The recycling rate has increased–from less than 10% of MSW generated in

1980 to over 34% (2012). Disposal of municipal waste to a landfill has decreased from 89% in 1980 to under 54% percent of MSW in 2012 (EPA, Environmental Protection Agency, Municipal Solid Waste Generation, Recycling, and Disposal in the United States: Facts and Figures for 2012, [http://www.epa.gov/osw/nonhaz/municipal/pubs/2012_msw_fs.pdf].

Landfilling of MSW was used to a great extent in other industrialized countries. In the former USSR landfilling was 96% for the year 1989 (U.S. Census Bureau, 1991). During 2005, around 53 million tons of MSW was managed in Japan, of which 13% was landfilled (MoE Japan, 2006). During the period of 1995–2005, the proportion of MSW landfilled in South Korea decreased from 68% to 41% due to the introduction of a volume-based waste fee system (unit pricing system) in 1995.[33] Presently more than 90% of the MSW in China is disposed in landfills; however, China has recently (2007) closed more than 1,000 landfills because of environmental concerns.[34,35]

Landfilling of MSW is beneficial because ensures that hazardous waste materials receive appropriate storage and treatment in a way that protects the environment and human health, but is has some disadvantages and stops recycling of useful raw materials and energy recovery. Well-designed hazardous waste sites have protective seals to keep hazardous chemicals from escaping into the ground. However, if a leak occurs, hazardous chemicals can contaminate groundwater in the region. Landfills can also emit harmful gases into the atmosphere. Newer landfills have the ability to capture those gases and transform them into energy. Hazardous waste landfill operators seal their facilities with double liners and use other methods to keep hazardous materials from escaping into the environment.

Evaluation of the environmental performance and discounted costs of the incineration and landfilling of MSW have been performed using the life cycle assessment (LCA) methodology in a recent study using data from Toronto , the most populous city in Canada. Two scenarios were assessed. In the first scenario the entire residual waste was landfilled whereas in the second scenario approximately 50% of the residual waste was incinerated while the remainder is landfilled. Electricity was produced in each scenario. Results showed that the waste diversion initiatives were more effective in reducing the organic portion of the waste, in turn, reducing the net electricity production of the landfill while increasing the net electricity production of the incinerator. Therefore, the scenario that incorporated incineration performed better environmentally and contributed overall to a significant reduction in greenhouse gas emissions (displacement of power plant emissions; are at a noticeably higher cost). Although landfilling proves to be the better financial option, it is for the shorter term. The landfill option would require the need of a replacement of landfill much sooner. The highest shares of municipal waste landfilled were recorded in 2012 (Eurostat, News release STAT/14/48, 25.3.2014) were in Romania (99% of waste treated), Malta (87%), Croatia (85%), Latvia (84%) and Greece (82%).[36]

Disposal and Management of MSW through Incineration

In the last 20 years many countries realized that the opportunities for landfilling as a disposal method of MSW are rapidly declining with depleting available cheap land resources and the wasteful nature of disposing useful resources in the landfill operation. Although recycling and composting are the most beneficial and effective ways for some types of municipal waste, there is a high proportion of mixtures of MSW that are difficult to separate and recycle. The favored method became incineration of MSW with heat recovery, from the point of economic benefits and resource recovery in the form of heat and power production. During this period incineration of MSW has seen turbulent times in terms of popularity from environmental groups and scientists alerted by the air pollution problems and the formation of dioxins, furans, airborne particulates, and other toxic substances. But the technology of incineration improved substantially (high temperature, catalytic burning, electrostatic filters) to become an attractive alternative for disposal with significant energy recovery benefits.[37-39]

The most important benefits of MSW incineration are (a) the volume and mass of MSW is reduced to a fraction of its original size (by 85–90% by volume), mass reduction (about 70%), and the possibility of energy recovery; (b) the waste reduction is immediate and not dependent on long biological breakdown reaction times; (c) incineration facilities can be constructed closer to the MSW sources or collection points, reducing transportation costs; (d) using heat recovery technology, the cost of the operation can be offset by energy sales; and (e) air discharges can be controlled to meet environmental legislative limit values. Despite the beneficial effect of incineration, it would not be a suitable option in developing countries due to the extreme moisture content and accordingly a low calorific value, too low for a self-sustaining incineration. Waste combustion is particularly popular in countries such as Japan where land is a scarce resource. Denmark and Sweden have been leaders in using the energy generated from incineration for more than a century, in localized combined heat and power facilities supporting district heating schemes. European countries rely heavily on incineration for handling municipal waste, in particular Luxembourg, Austria, the Netherlands, Germany and France. [40-42]

Vestforbrænding (Denmark), the largest waste-to-energy plant in Denmark handling more than 700,000 tons of waste per year.

Incineration Line 6, a waste-to-energy incinerator/power plant in Roskilde (Denmark)

Figure 6. Denmark is one of EU countries that generates more waste per capita, is world leader in incineration of household waste, burning 60% of it.[file:///C:/Users/User/Pictures/WASTE-TO-ENERGY-DENMARK.pdf].

Environmental and health concerns for MSW incineration

Incineration proved to be controversial method for many environmentalists because of air pollution problems and the health effects from emissions of dioxins, furans and other toxic substances. These concerns were reduced recently by substantial improvement in technology of high temperature incineration, better control of emissions (dioxins, furans, etc) and use of ash residues as a non-hazardous solid for various building materials or can be landfilled.

The health effects of emissions of dioxins, furans and other carcinogenic substances was the most serious problem for MSW incinerators. Especially high volumes were produced during start up and shut down of incineration. The problem was resolved by modifying the combustion techniques at very high temperatures, the use of electrostatic and baghouse filters, while the fly and bottom ash residues are collected and reused for materials and cement. The high carcinogenic potential of dioxins forced the Environmental Protection Agency (EPA) to announce in 2012 that the safe limit for human oral consumption is 0.7 picograms (1pg= 10^{-12} g) Toxic Equivalence (TEQ) per kilogram bodyweight per day, which works out to 17 billionths of a gram for a 150 lb (70 kg) person per year.[43-45] In 2005, The Ministry of the Environment of Germany, where there were 66 incinerators at that time, estimated that "...whereas in 1990 1/3 of all dioxin emissions in Germany came from incineration plants, for the year 2000 the figure was less than 1%. Chimneys and tiled stoves in private households alone discharge approximately 20 times more dioxin into the environment than incineration plants.[46]

In Paris, France, the Compagnie Parisienne de Chauffage Urbain supplies several thousand homes with hot water from incinerators located on the outskirts of the French capital

Incinerator MSW, Premnitz, energy from waste [operator EEW, Germany, 2009, cost 70 million euros]

Figure 7. In the capital; city Paris of France the municipal solid waste is incinerated in the outskirts of the French capital. The MSW Incinerator in the town of Premnitz, Germany. Operator EEW Energy, this plant generates environmentally friendly electricity and steam from 250 000 tones of combustible material. Businesses in Premnitz's industrial and commercial park are supplied with generated energy].

Austria, and especially the capital city Vienna, projects its power plants not only for providing clean energy, but are also a part of the city's skyline, with their artistic and innovative design. Tours are offered to let visitors take a peek behind the scenes of this technology and learn more about environmental and climate protection measures. A popular photographic motif in Vienna is the **Spittelau** waste incineration plant**,** whose façade was redesigned and given its present colorful, irregular structures by eco-architect Friedensreich Hundertwasser following a major fire in 1989. Since then, the former utility building has combined the topics of waste, energy and art in a fascinating way. On a tour of the plant, visitors get an insight into Vienna's waste, recycling and disposal system, as well as the environmentally friendly generation of thermal heat and hot water.

Figure 7. *The Spittelau waste incineration plant processes around 250,000 tones of MSW every year. [The incineration plant produces approximately*: *40,000 MWh of electricity, 470,000 MWh of district heating, 6,000 tones of scrap iron, 60,000 tones of clinker, ash and filter cake. The environmentally friendly heating produced at Spittelau is enough to heat 60,000 households in Vienna in a year.*

Technological improvements for MSW incineration and health risk assessment

The incineration methods for MSW and waste from medical facilities have improved substantially. **Fixed grate** is the older and simpler kind of incinerator with a brick-lined cell with a fixed metal grate over a lower ash pit, with one opening in the top or side for loading and another opening in the side for removing incombustible solids. The rotary-kiln incinerator with two chambers is used by municipalities and by large industrial plants consisting of an inclined refractory lined cylindrical tube. In the primary chamber, there is conversion of solid fraction to gases, through volatilization, destructive distillation and partial combustion reactions. The secondary chamber is necessary to complete gas phase combustion reactions. The fluidized bed techniques uses a strong airflow is forced through a sandbed. The air seeps through the sand until a point is reached where the sand particles separate to let the air through and mixing and churning occurs, thus a fluidized bed is created and fuel and waste can now be introduced. The sand with the pre-treated waste and/or fuel is kept suspended on pumped air currents and takes on a fluid-like character. The breakdown of dioxin, furans and other chemicals with aromatic rings substances requires exposure of the molecular ring to a sufficiently high temperature (more than 1,000^{o}C) so as to trigger thermal breakdown of the strong molecular bonds holding it together. Modern municipal incinerator designs include a high-temperature zone, where the flue gas is sustained at a temperature above 850^{o}C (1,560 °F) for at least 2 seconds before it is cooled down. They are equipped with auxiliary heaters to ensure this at all times. These are often fueled by oil or natural gas, and are normally only active for a very small fraction of the time. Further, most modern incinerators utilize fabric filters (often with Teflon membranes to enhance collection of sub-micron particles) which can capture dioxins present in or on solid particles.[47,48]

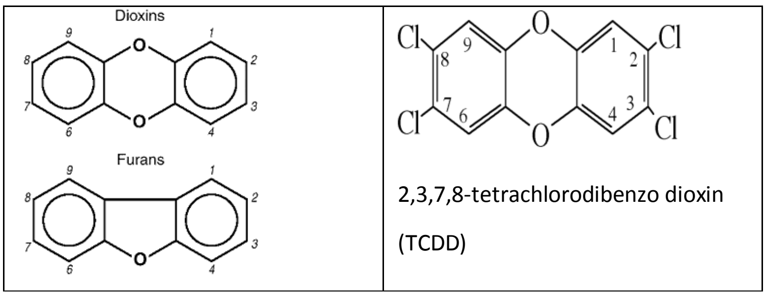


Figure 8. Basic chemical structures of Dioxin and Furans. Chlorination (or bromination) in various positions of the aromatic benzene ring is the characteristics of the Dioxins as a group of chemically-related compounds that are persistent environmental pollutants (POPs). More than 90% of human exposure is through food, mainly meat and dairy products, fish and shellfish.

Health assessments of dioxin emissions from incinerators were carried out for many years in various countries and adverse health effects to people living in areas with incinerators of MSW. A study in Belgium (a country that has many incinerators of MSW) followed young people and children and compared their exposure to a control group. Measurements showed that exposure in 1997 was below the exposure in 1980. Adverse health outcomes from dioxin exposure in the past cannot be excluded. There was no evidence for enhanced exposure to genotoxicants based on a comparison of chromosomal damage to blood cells of children from the study area to those from a control group.[49]

A study in Spain (from 1996-2010) followed a wide surveillance programme to get overall information on the impact of a MSW incinerator in Tarragona (Catalonia, Spain). The concentrations of dioxins (PCDD) and furans have been periodically measured in soil and vegetation samples collected at locations in the incinerator surroundings. Both soil and herbage showed a notable reduction in the PCDD/F concentrations in comparison with the baseline study, with this decrease only being significant for soils. In contrast, PCDD/F values in air remained similar during the whole assessment period. Human exposure to PCDD/Fs was evaluated under different scenarios, and the associated non-carcinogenic and carcinogenic risks were assessed. The hazard quotient was below unity in all cases, while cancer risks were under 10^{-6} (1 case to one million), which is lower than the maximum recommended guidelines. The current results clearly show that the MSWI of Tarragona does not produce additional health risks for the population living nearby.[50]

Incineration of MSW is associated with considerable public concern, which may have a significant harmful effect on the mental, physical and emotional health of local residents, regardless of whether emissions have any direct effect on health. Many public authorities in many industrial countries for the protection of environment and human health have undertaken risk assessment presentations. Resident's concerns were obtained through participation in an open public meeting, correspondence and discussion with local authority officers. In the last 30 years data from several studies suggested that the risk posed by emissions from modern incinerators to populations living near them is very low. Perhaps the most authoritative is that of the US National Research Council, part of the National Academies, which, while acknowledging the need for further study, stated 'when operated properly by well trained employees, modern waste incinerators pose little risk to public health.[51]

'A report by the Institute for European Environmental Policy came to a similar conclusion [Farmer A, Hjerp P. *Municipal Solid Waste* Incineration: Health Effects, Regulation and Public Communication. London: Institute for European Environmental Policy, 2001. http://www.nsca.org.uk] In contrast, Greenpeace concluded 'incinerators are potentially very damaging to health' [*Allsopp M, Costner P, Johnston P. Incineration and Human Health. Greenpeace Research Laboratories, Exeter, UK, 2001*].

The U.K. Health Protection Agency concluded in 2009 that *"….Modern, well managed incinerators make only a small contribution to local concentrations of air pollutants. It is possible that such small additions could have an impact on health but such effects, if they exist, are likely to be very small and not detectable. The HPA published a final report with the epidemiological studies on risk assessment from air pollution from MSW incinerators in 2010…..*".[52,53] A review of the Department of Environment Food and Rural Affairs (DEFRA) included a total of 102 publications and concluded that there is no convincing evidence of a link between incineration and cancer or respiratory problems, and between landfilling and cancer.[54] The existing epidemiological evidence linking waste management and human health was for many years quite controversial. Most studies investigated health impacts of old types of waste management facilities, especially in the case of incinerators. There is very little data on direct human exposure, and most studies resorted to surrogates such as residence information, with most recent studies including data on potential exposure pathways (e.g. pollutant concentration in soil, modeled atmospheric exposure). Confounding factors have not been adequately controlled in many studies, especially social deprivation and exposure to other sources rather than the one investigated.[55]

The construction of incineration facilities for MSW in many countries resulted in environmental protests, especially for the proximity of incineration air pollutants to towns of cities. Public concern about potential health risks associated with incineration has prompted studies to investigate the relationship between incineration and risk of cancer, and more recently, birth outcomes. Scientists conducted a systematic review of epidemiologic studies evaluating the relationship between waste incineration and the risk of adverse birth and neonatal outcomes. A review of 14 studies explored the incineration air pollution and birth outcomes for people living near incineration MSW facilities. All epidemiological studies did not find any associations between exposure to incineration air pollution and all congenital anomalies in neonatals. Associations were reported in some studies for grouped anomalies but limited evidence for other outcomes. The current evidence-base is inconclusive.[56]

The construction of a MSW incinerator in Durham, Ontario, Canada (for 140,000 tones/year), promoted the study of risk assessment for human health effects and ecological risk assessment. Overall, the results of the human health risk assessment indicate that it is not expected that the proposed project (i.e., construction, operation, and eventual decommissioning of a modern Energy –for-Waste, EFW, thermal treatment facility) will result in any adverse health risk to local residents, farmers or other receptors in the Local Risk Assessment Study Area. Although some risk has been identified through the assessment of this risk can be attributed to conservative modeling assumptions that overestimate the actual risk present (e.g., use of method detection limits to represent chemical concentrations and use of child-specific ingestion rates to represent toddler rate of ingestion) and/or pre-existing natural or anthropogenic conditions that correlate to baseline risk. These pre-existing natural or anthropogenic conditions were generally shown not to differ from those of similar urbanized areas in Ontario. In both studies results suggest minimal risks to humans expected at approved operating capacity. The same was the case for ecological risk assessment.[57,58]

Another advantage of incineration of MSW is the electricity and heat generated. Produced heat substitutes power plants powered by other fuels at the regional electric and district heating grid, and steam supply for industrial customers. Incinerators and other waste-to-energy plants generate at least partially biomass-based renewable energy that offsets greenhouse gas pollution from coal-, oil- and gas-fired power plants. The European Union considers energy generated from biogenic waste (waste with biological origin) by incinerators as non-fossil renewable energy under its emissions caps. These greenhouse gas reductions are in addition to those generated by the avoidance of landfill methane (CH_4). The bottom ash residue remaining after combustion has been shown to be a non-hazardous solid waste that can be safely put into landfills or recycled as construction aggregate. Suspended particulate matter (PM) emissions can be efficiently removed from the flue gases with baghouse filters. These technological advances reduced substantially the air pollution of incineration facilities and produced residue ashes which can be used for construction materials, cement and asphalt for roads.[59-61]

The most advanced and only method for infectious medical waste and dried sewage sludge is incineration at high temperatures. Medical waste incineration with the technological progress of the last decade has proved very effective, and finally produces an end product ash that is sterile and non-hazardous.[62] Heavy metals, PAHs, polychlorinated biphenyls and metal leachability in fly and bottom ashes are the main problems of medical waste incineration, but can be regulated by technological means.[,63]

Among the European countries, the highest shares of incinerated MSW for the year 2007 were observed in Denmark (53%), followed by Sweden (46%), France (36%), Luxembourg (35%), Germany (34%), Belgium (33%), the Netherlands (32%), Austria (30%), Portugal (19%), Norway (16%), Czech Republic/Finland/Italy (12%), Spain (10%), Iceland/United Kingdom (9%). However, countries such as Bulgaria, Cyprus, Estonia, Greece, Ireland, Latvia, Lithuania, Malta, Poland, Romania, Slovenia, Switzerland, and Turkey had no incineration at all. What is the explanation for this situation? With the exception of Switzerland all other countries concerned have relatively local populations who distrust expert opinion and have doubts of uncertainty about incineration or distrust expert opinion. Probably, their environmental agencies lack the initiatives to persuade public opinion on the merits of incineration of MSW. It is critically important to involve local people in the discussion leading to a decision at an early stage. This may be due to an intuitive feeling that the experts are wrong. Meetings with the public may be needed in these countries with officials from the Environment Agencies as opportunities to register local concerns and unknown health fears. Accepting that contrary opinions may be expressed is very necessary. Scientists know that doubts about expert opinion are connected with concerns about uncertainty of adverse health outcomes in the future. Expert opinion often includes a discussion of uncertainty. Explaining that many scientific conclusions based on experimental or observational evidence are subject to uncertainty is difficult and cuts across the perception that science should provide sure answers. In some ways this is due to firm assertions made by scientists and in part to the fact that the public in general are personally familiar with only elementary science or elementary expositions when the uncertainties, which certainly exist, are not discussed.[64]

In 2010 there were 406 incinerators of MSW operating in the European Union and 43 plants were planned to be build in the coming years. The total amount of waste incinerated in the EU countries was around 54 million tons per year in 2010. Germany, France and Italy accounted for 63% of all incinerators and 64% of all waste incinerated. However, the countries with higher incineration rates measured in per capita terms are Denmark (365 kg/inhabitant), Luxembourg (240) and Sweden (226). Sweden manages MSW so effectively with incineration and recycling (landfills only 4%) that developed recently a shortage of garbage for its incinerators. Sweden manages to fuel the waste-to-energy incinerator-factories that provide electricity to 250.000 homes and 20% of the entire country's district heating. Sweden is now importing trash from the landfills of other European countries (England, Norway, etc). In fact, those countries are paying Sweden to transfer increasing tones of MSW. At present there is an overcapacity of incineration of MSW in Europe resulting in shipping of municipal waste among various countries, e.g. from UK to Denmark and Sweden. Emissions of green house gases from MSW incinerators depend on the implementation of policies in various countries .[65,66]

Management of Municipal Solid Waste through Composting

In most parts of the world, MSW is largely incinerated, recycled or landfilled, though significant quantities of organic residue in MSW can be used alternatively. In the last decades increased attention has been given to alternative waste management options such as source separation into organic and inorganic fractions followed by either composting or anaerobic digestion with accompanying biogas production.[67,68]

Composting of the organic solid fraction of municipal waste is a controlled bioprocess that has been proposed as an alternative to landfilling and the incineration of MSW. The compost can be used as a land-applied nitrogen material (fertilizer) to optimize crop yield and minimize environmental risk. The land-application of mature compost from MSW has been proved to be an agronomically and environmentally admissible practice.[69]

Composting is a waste management practice that allows transformation of different organic waste (kitchen vegetables, fruit, organic waste, garden feed stocks, crop residues, etc) into a stabilized composting product which can be used as a fertilizer and soil improver. The number of composting facilities and the amount of source-separated and composted MSW has been increasing in many countries of Europe and in the United States. The management of organic matter from MSW is an essential part of sustainable management of resources and all European municipalities. And yet, municipalities may be faced with a number of questions as to how to implement a user-friendly, efficient and economically feasible system. Fortunately, after decades of experiences and with consolidated practices in the field of collection and treatment of organic waste, today it is possible to assess any given situation and design a system to capture most of organic waste present in MSW and ensure high quality output, saving costs to the communities and bringing the nutrients back to the soils.[70,71]

Figure 9. Composting is the controlled breakdown of organic matter by microbes in the presence of air. Composting is most commonly an aerobic process. The main byproducts of the breakdown are carbon dioxide, water and heat & compost. Composting is the efficient management of the biological decomposition of organic matter (garden waste, feed stocks, crop residues and waste from vegetable markets).

In Greece, as in other European countries, there are no many composting and anaerobic digestion facilities for the preparation of different compost materials from olive oil waste and other organic wastes.[72-75] After 2000 there were some initiatives for pilot programmes of compost of household and commercial waste. One of the ambitious project kicked off in Kifissia (north suburb of Athens) with the aim to boost awareness regarding sustainable biowaste management in Greece. Three organizations, the Association of Communities and Municipalities in Athens Region (ACMTR), the National Technical University of Athens (NTU), and EPTA Ltd Environmental Engineers and Consultants-, have teamed up to launch a programme (financed by LIFE) of environmental of composting with municipal solid waste.[76] In June 2014, the NTU, AMAR, EPTA SA and the Municipality of Kifissia organized a *2nd International Conference on Sustainable Solid Waste Management* within the framework of LIFE+Athens-Biowaste project [www.biowaste.gr,www.facebook.com /athensbiowaste] dealing with the separate collection and composting of biowaste in Athens.[77]

The first plant in Greece for composting of MSW started in the city of Kalamata (Peloponnisos) in 1995. It treated mixed MSW with a capacity of 31,500 tones/year. However, due to various problems the plant was closed down (2003) and although there are plans for its refurbishment and operation up to better standards, these have not been realized yet. A new large plant is being built in Athens (2012) and will soon go into operation. It will also treat mixed MSW (mechanically separated) and it will include a rotating drum for size reduction and pretreatment and tunnel composting. Its daily capacity will be 1,200 tons MSW. The plant has not come to full operation yet, so there are no results about the quality and use of its products. A third plant, of similar technology but much smaller (40,000 tons/year capacity), is being constructed in Chania, Crete. Various regional waste management plans foresee the construction of composting MSW plants as the main tool to meet the landfill directive targets, but the proposed plants have still not entered the actual planning phase [available at http://www.compostnetwork.info/greece.html , European Compost Network, Country Report of Greece, accessed February 2015].

The European Union (EU) has initiated a consultative process that will assist in the creation of new policies for waste prevention and recycling. **Composting** and **anaerobic digestion** of MSW are strategies that are likely to be employed to reduce waste generation and to recycle nutrients. All countries of EU increased the rate of composting of MSW from 1995 to 2007 in Belgium (rate increased by 175%), Italy (by 95% in the period 2001-2007), Denmark (by 55%), Germany (by 55%), France (55%) etc. In 2007, composting of municipal waste was most common in Austria (41%), Italy (37%), the Netherlands (23%), Belgium (22%), and Luxembourg (21%), etc. followed by Denmark/Germany/Spain and Switzerland (all are 17% each), France (14%), Sweden and United Kingdom (both 12%), Finland and Portugal (both 10%). The lowest composting percentage of MSW was recorded in Malta and Slovakia (both 5%), Poland (3%), Greece/Ireland/Lithuania (2% each), and Czech Republic/Estonia/Hungary/Latvia (1% each), and not done at all in Bulgaria, Cyprus, Iceland, and Romania. It is obvious from the statistical data that countries with less advanced management system of MSW have very low proportion of composting. Eurostat data from EU countries recorded that of treated municipal solid waste 15% was composted In the 28 member-states in the EU. This municipal waste in the EU (2012) was treated with the basic four different ways: 34% was landfilled, 24% incinerated, 27% recycled and 15% was composted. For the EU4 there has been a significant increase in the share of municipal waste recycled or composted, from 18% in 1995 to 42% in 2012.[78,79]

Figure 10. Composting of MSW on an industrial scale. Facilities and practice to control odors, leachate, and runoff are a critical part of any compost operation. In the EU28 treated MSW into compost reached 15% (2012).

Recycling and Management of Municipal Solid Waste

Recycling is the recovery at source of useful materials, such as paper, glass, plastic, and metals, from the trash to use to make new products, reducing the amount of virgin raw materials needed. Recycling means separating, collecting, processing, marketing, and ultimately using a material that would have been thrown away. For example, newspapers can be recycled for producing paper to be used in newspaper printing or other paper products. Cans and glass bottles can be collected and melted to produce new cans and glass bottles, or crafted for other uses. Recycling of metals can be very important in recovering valuable and expensive metallic elements. Quality products and packaging can be made from recovered materials and effective recycling.[80,81]

Figure 11. Recycling of municipal waste. Source separation is the best way to recover useful raw materials (paper, glass, ferrous and non-ferrous metals and plastics)

Recycling means the waste generated by a source is separated in the source, cleaned and or given away for reuse. Developed countries typically utilize curbside recycling programs to collect and sort wastes for recycling processing. Conversely, developing countries utilize the social sector known as scavengers to handle such activities. Scavengers are citizens with low- to no-income group that collect materials that are dispersed throughout the city or concentrated at dumpsites.

Figure 12. In 2013 Australian Paper began construction of a $90 million paper recycling plant at Maryvale in Victoria, to increase substantially the production of local recycled paper

Municipal waste recycling differs substantially in developed and developing countries. Statistical data from 2012 showed that USA (out of 251 million tons of MSW) recycled 34.5%. Recycling and composting almost 87 million tons of MSW in USA saved more than 1.1 quadrillion Btu of energy. This is the same amount of energy consumed by almost 10 million U.S. households in a year. On average, Americans recycled and composted 1.51 pounds (2.2 pounds= 1kg) out of individual waste generation rate of 4.38 pounds per person per day [http://www.epa.gov/solidwaste/nonhaz/ municipal/pubs/ 2012_msw_fs.pdf]. Recycling in Australia has grown over the past 20 years. It is estimated that recycling in 2002–03 accounted for 30% of MSW, 44% of commercial and industrial waste generated and 57% of construction and demolition waste generated. Waste recovered in Australian municipalities for recycling in 2002–03 was reaching approximately 50%. In the 2008-09 the recycling increased to 50-60% depending for most of paper, glass, aluminum cans, metals.[82,83]

Statistical data for recycling of MSW in developing countries is not very reliable. Recycling statistics focus on paper, plastic, glass and metals. Overall recycling for Brazil of MSW is estimated at 20-49% (for four recyclable materials : paper 30%, plastic 20%, glass 20% and metals 49%), in India recycling of MSW is estimated in the range of 13-20%, China recycling is in the range of 7-10%, Turkey 25-30%, Thailand 14-30%, Phillipines 13%, Vietnam 13-20%.[84]

The overall recycling rate of municipal waste in the 27 member states of EU in 2007 was 18%, but through new legislative pressure from the European Union increased around 36% in 2012. The European Environment Agency (Copenhagen) published a statistical diagram for the total recycling of municipal waste stated in percentage of the generated amount for 2001 and 2010. Total recycling includes material recycling as well as composting and digestion of bio-waste. [http://www.eea.europa.eu/data-and-maps/figures/municipal-waste-recycling-rates-in]. Denmark, Finland, Sweden, Norway and Austria recycled MSW at a rate of 45-50% in 2001. In 2010 recycling increased to 55-60% in Austria, Germany, Belgium, Sweden and Denmark. In some countries such as Greece, Portugal, Cyprus, Poland, etc, recycling of MSW is much lower, at around 20%.

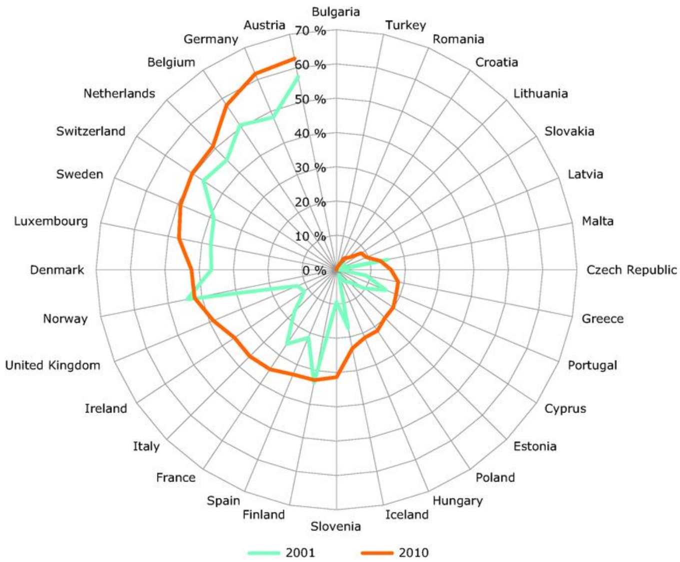


Figure 13. Total recycling (including composting and digestion of bio-waste) of municipal waste in the European countries in 2001 (green line) and 2010 (orange line).

The European Commission has adopted proposals to turn Europe into a more circular economy. It hopes to boost the recycling of municipal solid waste to 70% by 2030 and ban the landfilling of recyclable material by 2025. The Target Should be Zero Waste. Waste management in Europe has improved considerably in the last years. Recycling rates for MSW have more than doubled in the area of the EU plus Norway and Switzerland, going from 17 % of municipal waste recycled or composted in 1995 to 38 % in 2010. Recycling already covers a large share of EU consumption of certain materials, especially paper and cardboard, iron and steel, but is below 10% for others such as copper, concrete and plastics. Revenues from recycling are just as substantial and fast-growing. According to a report from the European Environment Agency (EEA), the turnover of seven main categories of recyclables almost doubled to more than €60 billion in the EU from 2004 to 2008.

Figure 14. The Zero Waste movement is an international campaign that has a clear and simple vision: a prosperous and inclusive future without waste and wasteful practices in the consumer society of the 21^{st} century. A future without waste and toxics is a necessity for the sustainable future of our planet [http://www.zerowasteeurope.eu/about/principles-zw-europe/].

European countries produce, approximately, 16 tones of material per person per year of which 6 tones become waste. Although the management of that waste continues to improve in the EU and other countries, recycling of MSW for useful materials is still lacking and the economy loses a significant amount of potential 'secondary raw materials' such as metals, wood, glass, paper and other raw materials which are produced from petroleum, mining products, etc.[85]

The latest statistics showed that 42% of MSW in the 32 member states of EU was recycled or composted in 2012 (data published by the European Commission in 25/3/ 2014). One of the countries with the highest performance in recycling if the United Kingdom, that increased substantially its share of recycling of MSW (not including composting) to 46%, one of the highest rate in the EU. [http://www.letsrecycle.com/news/latest-news/eu-recycled-42-of-municipal-waste-in-2012/].

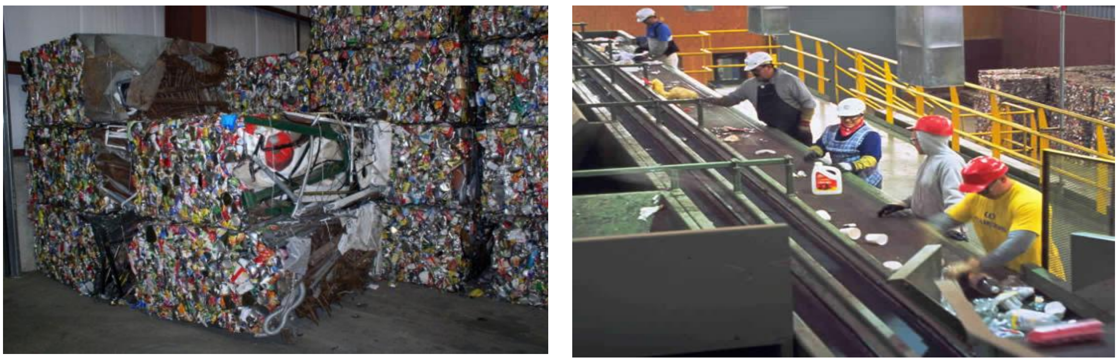


Figure 15. Recycling of municipal solid waste through a "circular economy", by reusing, repairing and recycling old materials, packaging and consumer products is the only way forward for sustainable management. It is estimated that additional 500 million tones of MSW every year can be recycled in the EU countries.

The EU is working towards a "circular economy" in Europe, in which reusing, repairing and recycling materials is the norm - instead of extracting raw materials, using them once and discarding them. It is estimated that more than 500 million tones of MSW and industrial waste that could have been reused or recycled were instead landfilled or burned in Europe. Making the most of our resources could boost EU competitiveness on the global stage and reduce its reliance on increasingly scarce and expensive raw materials. The European Commission in Brussels released a press statement (2/7/2014) that "*Higher recycling targets to drive transition to a Circular Economy with new jobs and sustainable growth*" The Commission adopted proposals to turn Europe into a more circular economy and boost recycling in the Member States. Achieving the new waste targets would create 580,000 new jobs compared to today's performance, while making Europe more competitive and reducing demand for costly scarce resources. The proposals also mean lower environmental impacts and reduced greenhouse gas emissions. The plans ask Europeans to recycle 70 % of municipal waste and 80 % of packaging waste by 2030, and ban burying recyclable waste in landfill as of 2025. The Commission also included a target for reducing **marine litter** along with food waste reduction objectives [http://europa.eu/rapid/press-release_IP-14-763_en.htm].

Recycling of Plastic Solid Waste

Plastic solid waste presents the greatest challenges for recycling but also contains great opportunities for reducing the volume of MSW and provide its sustainable management. A recent review on plastic recycling put special emphasis on waste generated from polyolefinic sources, which makes up a great percentage of our daily single-life cycle plastic products. There are 4 different routes of plastic solid waste treatment for recovery: primary (re-extrusion), secondary (mechanical), tertiary (chemical) and quaternary (energy recovery) schemes and technologies: a) Primary recycling involves the re-introduction of clean scrap of single polymer to the extrusion cycle in order to produce products of the similar material (but rarely applied among recyclers, as recycling materials rarely possess the required quality). b) The various waste products, consisting of and scrap) are the feedstock of secondary techniques, reduced in size to a more desirable shape and form, such as pellets, flakes or powders, c) Tertiary treatment schemes have contributed greatly to the recycling status of plastic solid waste in recent years. Advanced thermo-chemical treatment methods cover a wide range of technologies and produce either fuels or petrochemical feedstock. Non-catalytic thermal cracking (thermolysis) is receiving renewed attention, due to the fact of added value on a crude oil barrel and its very valuable yielded products, d) Energy recovery was found to be an attainable solution to plastic waste in general and municipal solid waste (MSW) in particular. Although primary and secondary recycling schemes are well established and widely applied, it is concluded that many of the plastic solid waste tertiary and quaternary treatment schemes appear to be robust and worthy of additional investigation.[86]

Plastics cracking, is a process developed to recycle plastic wastes into useful petrochemical materials. Under thermal cracking conditions, plastic wastes can be decomposed into three fractions: gas, liquid and solid residue. The liquid products are usually composed of higher boiling point hydrocarbons. By adopting customary fluid cracking catalysts and reforming catalysts, more aromatics and naphthenes in the C_6–C_8 range can be produced, which are valuable gasoline-range hydrocarbons.[87] Pyrolysis of plastic waste can be an alternative for the reclamation of rejected packing and packaging plastic waste. These rejected plastic can be different materials [(e.g., polyethylene (PE), polypropylene (PP), polystyrene (PS), polyvinyl chloride (PVC), polyethylene terephthalate (PET), acrylonitrile butadiene styrene (ABS), aluminum, tetra-brik, and film)], for which an attempt at complete separation is not technically possible or economically viable, and they are typically sent to landfills or incinerators. A study used a simulated plastic mixture and a real waste sample from a sorting plant were pyrolyzed using a non-stirred semi-batch reactor. Red mud, a byproduct of the aluminum industry, was used as a catalyst.[88] Various efficient methods of plastic recycling have been published in the last decade**.**[89] Plastics from waste electrical and electronic equipment have been an important environmental problem because these plastics are PVC and contain toxic halogenated flame retardants which may cause serious environmental pollution (formation of dioxins and furans) during treat processing. Pyrolysis has been proposed as a viable processing route for recycling the organic compounds and turn plastic waste into fuels and chemical feedstock. Dehalogenation procedures are also necessary during treat process, because the oils collected in single pyrolysis process may contain numerous halogenated organic compounds, which would detrimentally impact the reuse of these pyrolysis oils. Zeolite or other type of catalyst can be used in the pyrolysis process for removing organohalogens.[90]

Figure 16. Plastic materials are categorized in numbers 1-7, the number represents the resin identification code associated with the type of plastic used and indicates the item's ability to be recycled

In the 21st century with increasing global resource scarcity, municipal solid waste (MSW), especially plastics, becomes a resource that can be managed globally to offer raw materials. A reverse supply chain network for waste recycling needs to process all the waste with minimum costs and environmental impact. Recycled plastic can be used in industrial manufacturing to partly replace virgin plastics. The basic raw material for plastic is naphta, a distilled fraction from crude oil. Common 'second life' applications for recycled plastic packaging materials include fleece clothing, strapping, sewage pipes, flower pots, bins, pallets, kerbstones, garden furniture, etc. Driven by the huge demand for recycled material in the manufacturing sector in the Far East, much waste is exported there, even under strict restrictions of waste trading from both Europe and Far East countries. The application of recycled plastics instead of virgin plastics makes product manufacturers more competitive and hence, China drives the global waste trade. 200,000 tones of plastic waste from Europe are exported to China each year for recycling. The packaging waste directives 94/62/EU and 2004/12/EU demand that European countries collect and recycle 22.5% of the plastic packages that are placed on their markets. Some developed countries trade all to the Far East, while other countries recycle a part themselves and trade the rest. For example, the Netherlands has a recycling target of 42% in 2012 to 52% in 2022 for plastic packaging waste.[91,92]

Municipal and industrial waste of aluminium (Al) and alumina (Al_2O_3) recycling

Aluminium recycling from MSW is one of the most efficient way to reduce waste and reuse valuable raw material again and again. Products and waste from aluminium can be reused simply by re-melting the metal, which is far less expensive and energy intensive than creating new aluminium through the electrolysis of aluminium oxide (Al_2O_3), which must first be mined from bauxite ore and then refined using the Bayer process. Recycling scrap aluminium requires only 5% of the energy used to make new aluminium. In the USA 30% of all aluminium produced comes from recycled scrap. Used beverage containers (aluminum cans) are the largest component of processed aluminum scrap.

Aluminum is one of the most recycled -- and most recyclable -- materials on the market today. Nearly 75% of all aluminum produced in developed countries (including the USA). is still in use today. Aluminum can be recycled over and over again without any loss to quality. In fact, an aluminum beverage container can be recycled and then can go back on the shelf in 60 days [http://www.aluminum.org/industries/production/recycling]. In the EU27 more than 50% of all the aluminium produced originates from recycled raw materials and used consumer products (cans) and that trend is on the increase.

In 2004, approximately 11.4 million tones of aluminium were used for the production of fabricated goods in the EU. Primary aluminium production in the EU currently amounts to just 3 million tones. This in fact means that, without aluminium recycling, the EU would have to import about 8.4 million tones of primary and recycled aluminium to meet requirements. Primary aluminium production in the rest of Europe yields a further 2.2 million tones. The EU countries despite the Al recycling still depend considerably on aluminium imports. In 2004, the EU produced 4.5 million tonnes of ingots for aluminium castings, wrought aluminium and deoxidation aluminium from aluminium scrap [European Aluminium Association. *Aluminium Recycling in Europe. The Road to High Quality Products,* http://www.alueurope.eu/wp-content/uploads/2011/08/Aluminium-recycling-in-Europe-2007.pdf].

The aluminium industry in developed countries actively is involved in providing collection and recycling of aluminium (Al) and aluminum (Al_2O_3) scrap. In Europe among the municipal waste aluminium waste has one of the highest recycling rates. It is ranging from 63% in beverage cans to more than 90% in building, construction, automotive and transportation materials. The aluminium industry is constantly investing and researching in active collection and sorting improvements of aluminium products for recycling [http://www.alueurope.eu/eu-policies/recycling/].

Figure 17. In the USA every year nearly $1 billion worth of aluminum cans are thrown away. In the EU27 beverage cans are recycled at 63%, more than 90% construction and vehicular products, and more than 50% of aluminium produced in Europe originates from recycled raw aluminium materials.

Automotive recycling industry and end-of-life vehicles

Automotive ownership worldwide exceeded 1 billion units in 2010 (it is estimated to reach 2.4 billion by 2050). The EU and USA have 50% of motorcars (270 and 240 million respectively), China reached 100 million cars in 2012 with a substantial increase in production and ownership in the last years. It is estimated that 15 million motorcars are deregistered every year worldwide and 40 millions reach the end-o-life vehicle (ELV) with recycling rates at 75%-90% in developed countries. Other statistics showed that each year 27 million cars around the world that reach the end of their useful life are recovered for recycling.[93]

The total number of end-of-life vehicles reported in the 27 member-states of EU, from 6.3 million in 2008 increased to 9.0 million in 2009. In the last decade, approximately 14-15 million vehicles reach the end of their use each year in just the United States. In the USA, the automotive recycling industry is the 16th largest industry, estimated to be a $25 billion per year. There are approximately 7,000 vehicle-recycling operations in the USA. Recycling vehicles provides enough steel to produce almost 13 million new automobiles, while generating jobs for 46,000 people [available at : AutoAlliance .Driving Innovation. *Automotive Recycling . You Car's Afterlife. A Look at the Automotive Recycling Industry,* USA, http://www.erie.pa.us/pdf/recycling/FactSheetAutoRecyclingFacts.pdf, accessed 27.2.2015].

Recycling of cars involve a series of collection and transport into specialized yards for dismantling. Once dismantled, the vehicle is compacted and then sent through a shredder where fragments are sorted magnetically into ferrous (steel and iron) and non-ferrous materials (metals include aluminum, magnesium, copper, brass and zinc). The removed metal, roughly 75% of a vehicle, is then mixed with new metal before returning to manufacturers for reuse. In 2004 over 14.5 million tons of steel was recycled and reused from end-of-life vehicles only the USA. The metal removed is reused for such things as a new vehicle's chassis and engine. Auto dismantlers also remove recyclable fluids and materials. Recyclable materials are typically batteries, catalytic converters, tires and plastics. These materials are recycled into a variety of new consumer products. Recycling plastics from an end-of-life vehicle is a growing part of the recycling industry. Salvaged plastic bumpers become new bumper reinforcements in the recycling process for Ford Motor Company. Toyota has recovered and recycled bumpers into new bumpers for new cars [USA, Automotive Recyclers Association, www.a-r-a.org].

Figure 18. Recycling of used motorcars has become a big industry in most developed countries and provides millions of iron, steel, non-ferrous minerals, plastic and other materials for the motor industry.

Recycling of motorcar tyres

It is estimated that more than 1 billion motorcar and other vehicular tyres (or tires) are discarded annually worldwide. More than half of the used tyres are burned for their fuel value. Germany for example burns 55% of tyres for fuel. Tires are not desired waste for landfills due to their large volumes and 75% void space. The most noticeable problem associated with large tyre piles is the fire hazard they present. Once a tyre pile catches fire, it is very hard, if not impossible, to extinguish. In some instances, tyre piles have been Tyres can trap methane gases and its 'bubbling' effect can damage landfill liners that have been installed to help keep landfill contaminants from polluting local surface and ground water. Shredded tyres are now being used in landfills, replacing other construction materials. Tyres can be recycled into hot melt asphalt and as an aggregate in portland cement. Tyres can also be recycled into new tyres. Old tyres can be used as strong constructive materials in "green" buildings. Also, old tyres can be collected and under pyrolysis processes can be transformed into fuel gas, oils, solid residue (char), and low-grade carbon black. Recent developments in devulcanization promise to deal with substantial volumes of rubber tyres and convert them into value-added materials. This new generation of devulcanization compounds produced from processed tyre scrap can be blended with virgin rubber compounds, maintaining performance while substantially reducing the raw material cost.[94]

Environmental Protection Agency (EPA) in the USA, estimated that in 2003, 290 million tyres were generated as solid waste. The same period 80% were of motorcar tyres were recycled or used for fuel, asphalt, etc.: 130 million (44%) were used as fuel, 56 million (19%) were recycled or used in civil engineering projects, 18 million (8%) were converted into ground rubber and recycled into various products, 12 million (4%) were converted into ground rubber and used in rubber-modified asphalt, 9 million (3%) are exported and 6.5 million (2 %) were recycled into cut or stamped products. [http://www.epa.gov/osw/conserve/materials/tires/ basic.htm] and *Rubber Manufacturers Association*, 2004. In the EU member states (2000-2001, statistics from the European Tyre Recycling Association, ETRA) a total of 2.5 million tones of old tyres were used as fuel or recycled : 23% were used for energy generation, 30% for landfilling/stockpiling, 16% for rubber recycling, 7,5% for exports, 8% for civil engineering projects and 15% for miscellaneous uses [http://www.waste-management-world.com/articles/2003/07/scrap-tyre-recycling.html].

Figure 19. Recycling of tyres in developed countries has increased and a high proportion of used tyres are being recycled reducing resource use and the threat to environment. Almost 50% of used tyres are used as fuel for energy production.

A number of EU Directives are expected to significantly impact on the way scrap tyres are disposed of in the coming decade. The three most important legislative changes are discussed briefly below.

Landfill Directive (1999/31/EC). The Landfill Directive will have a significant impact on the manner in which tyres are disposed of in Europe, and new routes of disposal will have to be found for at least 30% of newly generated scrap tyres. In some Southern European countries such as Greece, Portugal and Spain where most (if not all) scrap tyres are currently landfilled, this law will have a dramatic impact.

End-of-Life Vehicle (ELV) Directive (2000/53/EC). Ratified by the EU Member States in 2002. Its objective is to reduce the amount of waste generated by vehicles, and to facilitate reuse and recycling of end-of-life vehicles. By 2006, at least 85% of an ELV by weight has to be reused or recovered, and by 2015 this percentage will increase to 95%.

Waste Incineration Directive (2000/76/EC). The Waste Incineration Directive was adopted into national law in the EU Member States in 2002, with the aim of preventing or limiting emissions from incineration and co-incineration of waste. The Directive sets more stringent emission standards for a number of pollutants including dust, HCl, HF, NOx, dioxins and heavy metals. Since thermal recovery in cement kilns and power plants is one important route for disposal of scrap tyres, the Waste Incineration Directive may compel some current users of tyre-derived fuel to refurbish their emission control systems. Although this Directive is not thought to have a significant impact on the incineration or co-incineration of waste tyres, scrap tyre pyrolysis and gasification operations may not be able to meet the set criteria for minimum operating temperatures and total organic content (TOC) in the bottom ash.

Recycling of electrical and electronic equipments

Although it is very difficult to calculate the total numbers of electrical and electronic items produced every year at a global scale, the amount of electronic and electrical equipment waste projected to be generated globally is estimated at 70 millions of tones of e-waste are disposed worldwide every year. Cell phones and other electronic items contain high amounts of precious metals like gold or silver. Americans dump phones containing over $60 million in gold/silver every year. Only 12.5% of e-waste is currently recycled [https://www.dosomething.org/facts/11-facts-about-e-waste].

In recent years only in the USA 100 million cell phones are thrown away as trash. According to EPA in the USA every year 41 million desktops and laptops are discarded, 20 million television sets. Also, it is estimated that only 13% of electronic waste are recycled every year [EPA data from “Municipal Solid Waste Generation, Recycling and Disposal in the United States, 2012,” Feb 2014, http://www.epa.gov/epawaste/nonhaz/municipal/pubs/2012_msw_dat_tbls.pdf].

Figure 20. 70 million tones of electrical and electronic waste are produced every year at a global scale.

A recent United Nations report suggests that in some countries, production of Waste Electrical and Electronic Equipment (mobile phones, computers, TVs, electrical items) could rise by as much as 500% over the next decade. The report notes that China already produces about 2.3 million tones of e-waste domestically each year, second only to the USA with about 3 million tones, while it remains a major dumping ground for developed countries despite having banned e-waste imports [United Nations (22/2/2010, “As e-waste mountain soar, UN urges smart technologies to protect health, UN-DPI/NMD-UN News Service Section, http://www.un.org/apps/news/story.asp?NewsID=33845&Cr=waste&Cr1#.VPRWv3ysWZ].

Electrical and electronic equipment and smaller items are fridges, cookers, microwaves, washing machines, dishwashers, vacuum cleaners, irons, toasters, clocks, personal computers, printers, copying equipment, telephones and pocket calculators, batteries, drills, smoke detectors, thermostats and heating regulators etc). Millions of tones are discarded every year in the majority of developed and developing countries. It is estimated that 2 million tones of electrical and electronic equipment are discarded by householders and companies in the UK. Recycling of Waste Electrical and Electronic Equipments (WEEE) is a specialist part of the waste and recycling industry.

The Waste Electrical and Electronic Equipment Directive (WEEE Directive) is the European Community directive 2012/19/EU on waste electrical and electronic equipment(WEEE) which, together with the RoHS Directive 2002/95/EC (Restriction of Hazardous Substances in Electrical and Electronic Equipment) became European Law in February 2003. The new RoHS Directive 2011/65/EU (RoHS 2) entered into force on 21 July 2011 and requires Member States to transpose the provisions into their respective national laws by 2 January 2013. The WEEE Directive set collection, recycling and recovery targets for all types of electrical goods, with a minimum rate of 4 kilograms per head of population per annum recovered for recycling by 2009. The RoHS directive puts restriction for toxic substances used in electrical and electronic equipments.

Recycling of municipal solid waste, motorcars, tyres and electronic items in Greece

Recycling of MSW in Greece in the last decade increased very slowly from 10% in 2001 to 20% in 2010 but will need to make an exceptional effort in order to fulfil the 50 % recycling target of the Waste Framework Directive by 2020. Greece at present has 25 centres for recycling of materials and sorting MSW, 5 units for mechanical waste sorting and compost production, 7 units of WEEE recycling.[95,96]

Athens has an organized Blue Recycling Bins system to recycle MSW. More than 4,000 blue recycling bins have been put in place throughout the Athens Municipality. Various types of recyclable packaging items can be placed in these bins (eg aluminum cans, glass, plastic, metals and cardboard boxes). Recycled materials are collected from these bins daily. They are emptied using special vehicles and the materials are taken to the Recycled Item Sorting Centre (Ano Liosia), where they are sorted and forwarded for recycling. *Recycling of electrical appliances and electronic goods* is performed in collaborating with an approved electrical goods recycling operator. It has already begun to recover such goods and forward them for recycling. Citizens can call 1960 and make arrangements to deposit electrical items at a specific time and place, so that municipal staff can then collect them. Appliances Recycling S.A (Συγγρού 196 & Χαροκόπου 2, 17671 Καλλιθέα, www.electrocycle.gr, info@electrocycle.gr). is the official collective system for the Alternative Management of the Waste of Electrical and Electronic Equipment (WEEE) in Greece. The WEEE recycling cost is financed by producers and importers of E/E items based on the product volumes they market in Greece.

Figure 21. Recycling of municipal waste in Greece is at 20% and need to be expanded to 50% by 2020. The system is poor at present as the infrastructure is not in place for regular collection from villages and rural areas. Much needs to be done on encouraging the local population to recycle, but given time and education, there is the potential for good progress.

Paper recycling. Athens provides paper recycling bins for interior spaces of public and private entities, at no cost. Bell-shaped paper and cardboard collection bins. A total of 158 yellow, bell-shaped printed paper and paper packaging collection bins (3.3 m^3 capacity) have been placed throughout the city. It is estimated some 550tonnes of paper will be deposited in them on an annual basis. Recycling ***of*** old vehicles. Athens and the big cities in Greece are cooperating with approved old vehicle recycling operator. Municipalities collect abandoned vehicles for recycling. Recycling of oil products. Athens re covers oil products from its mechanical equipment and forwards them for recycling to an approved operator. Recycling of car tyres**.** Athens municipality collects used motorcar tyres and forwards them for recycling to an approved recycling company.

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