

Chapter 7

Reuse and Circulation of Organic Resources and Mixed Residues

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7.1 Introduction

In the history of mankind, the relatively short period of industrialization has determined the cross-effect of our existence toward the global environment and its resources. As a determinative factor, the strive for better standard of living as well as for technological progress have given the face to our modern societies. A quotation from “The Sixth Extinction” by Elizabeth Kolbert (2015): “... Having discovered subterranean reserves of energy, humans begin to change the composition of the atmosphere. This, in turn, alters the climate and chemistry of the oceans...”.

Energy efficiency is designated as the “fifth fuel” (Hallett 2013). Different modern technologies should favor its implementation. In a way, increasingly efficient use of the chemical energies of the various side streams could serve that purpose. In the long term, it could increase the cost-effectiveness and sustainability of societies at the same time.

At present, in order to restructure our way of living during the post-industrial era, it is crucial to put weight on recirculation. This could open up novel technological solutions which will help in balancing the human impact on the global ecosystem.

This novel trend was initiated by the environmental movement some 50 years ago. The reorientation of societies as a whole always starts on the individual level, as the small beginnings and encouraging experiences could set an example for our future collective behavior.

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7.1.1 First Case of Sorting Out the Household Biowaste in Finland 1984

Starting in 1984, the Student Union of Helsinki University funded a suburban scale experiment on household sorting in Finland. The trial was organized for the first time in Finland in the Latokartano complex of student dormitories in Eastern Helsinki, close to Viikki campus for agricultural studies. This student dwelling area has always had a system of local democracy with representatives from each house (houses called “koukku” = “a hook”) which are named after the figures of the Kalevala national epoch to Sampsa, Pellervo, Osmotar, Kaleva, Kaski and Pelto hooks. The meetings are chaired by an “olterman”. This administrative structure was suggested in 1953 by the academician Kustaa Vilkuna, and the area was completed in 1974 (Savolainen 2003).

On the basis of the unique social pattern, the waste sorting experiment became highly successful, and it produced lots of important information for later activities all over the country. Nowadays, 95% of the Finns advocate the sorting of household residual fractions. The Viikki area has grown into a large campus area and is one of the four main campuses of the Helsinki University, as well as a home for over 11,000 citizens (2010). There is also an area where the ecological architecture has been implemented into family houses (Fig. 7.1). Ecological construction has a significant role in Viikki plans and implementation. There is a national housing construction test area. The buildings widely utilize solar energy and energy efficiency solutions. For Eco-Viikki, special criteria were compiled for ecological construction, which directed construction into a more environmental friendly direction. The household waste sorting has been included in the local landscape for many decades in Viikki (Fig. 7.2a, b). Criteria measured ecology of construction projects from five points of view:



Fig. 7.1 Ecological construction in Viikki area (Photograph by Ilari Heitto)



Fig. 7.2 (a) Waste collection shelter, into which the separated wastes are collected; (b) One of the student housing units in the Latokartano dormitory (Photographs by Ilari Heitto)



Fig. 7.3 View on part of the new campus in Viikki area locating the departments for biological studies of the University of Helsinki (Photograph by Ilari Heitto)

- Pollution
- Use of natural resources
- Healthiness of buildings
- Natural biodiversity
- Food production.

Numerous ecological energy and environmental solutions were implemented in the area estates. Most of Viikki's ecological test construction utilized passive and active solar energy opportunities (City of Helsinki 2016). This suburban location is the home of one of the four major campuses of the University of Helsinki in the midst of a lively neighborhood (Fig. 7.3).

7.1.2 Current Household Biowaste Treating in Helsinki and in Stockholm

Helsinki Region Environmental Services Authority HSY is a municipal body, which produces waste management and water services, as well as provides information on the Helsinki Metropolitan Area and environment (Helsinki Region Environmental Services Authority 2016).

In order to rationalize the biowaste processing, it could be possible to get rid of the demanding logistics with the sorted biowaste collection containers from various suburbs and collection centers. Their reception at the HSY waste treatment area near Helsinki, Finland, corresponds to some 200–250 tons daily. Consequently, the automated hall for emptying the containers (Fig. 7.4a), and for pretreatment (Fig. 7.4b), is relatively sizable. Currently, the main product from the biowastes is (1) biogas from which electricity and heat are produced and (2) compost (Fig. 7.4c).

In Stockholm, Sweden, the sorted biowaste has been partially collected for biogas production using household water for its collection. Food waste is washed away with tap water, and the organic wastes are recollected at the site of utilization (Karlberg and Norin 1999).

Estate-specific biowaste collection systems have also been piloted in Stockholm. The installations mean that food waste is put without packaging in the inlet, ground or dispersed, diluted with some water, and stored in a closed tank as slurry. This can be implemented in many technical ways, such as

- Integrated inlet with grinder together with tank,
- Grinder at inlet and suction of slurry to tank and
- Suction of waste from several inlets and one grinder placed with collection tank.

The tanks can sometimes be connected with overflow of excess water to a fat trap, which is connected to the sewage pipes. The city's water company is involved in the development (Stockholm Vatten 2011).

Inlets are placed in the kitchen, to food preparation and dishwasher areas, connected with suction pipes to the central grinder, tank and vacuum pump. The tank room can be placed under street level. Smaller systems can have an integrated work top with inlet to grinder and tank in the same room. Access to water and sewage is necessary both at the point of inlet and in the tank room. Ventilation/outlet to air is necessary for the vacuum pump, as well as for the general ventilation of the tank room.

Based on the experiences from the experiments there are the following limitations:

- Large tough fish skins
- Hard bones and items



Fig. 7.4 (a) The sorted biowaste reception unit automatically handles baskets or containers from all over the cities in the Metropolitan Helsinki area with the daily waste input of around 200–250 tons. (b) Different organic wastes are homogenized and pretreated for a biogas unit. (c) Biogas is one of the main products of the HSY waste treatment plant in Ämmässuo, Espoo, close to the border with Helsinki. (Photographs by Elias Hakalehto)

- Long fibres
- Cutlery

that can cause stoppages. The dry matter (DM) content in the slurry should be around 12–15% and with a “pumpable” viscosity. If the slurry is too thick, it is difficult to empty the tank, and water has to be added to dilute the slurry. Two to three week intervals would be appropriate for emptying the tank.

The heavy vehicle movements can be reduced to at least half if the tank volume is dimensioned to be emptied twice a month. Waste generators with large amounts of food waste normally have collection at least one time per week, often even three to five times per week. A better separation also improves the properties of the remaining waste: it is lighter, drier and can sometimes be compacted. In total, the numbers of heavy lorry movements are reduced significantly at the waste generator. The slurry may contain more water to be transported but on the other hand the practical pay load of the sludge vehicle (10 tonnes) is bigger than for the conventional waste truck (7 tonnes) (Millers-Dalsjö and Lundborg 2012).

Any processing of organic wastes with water would warrant proper hygienic measures. This is especially important if there is a risk for the microbial contamination of the drinking water. It is widely recognized that the microbiological monitoring of clean waters should be improved. Even in developed countries hazardous contaminations of the water pipelines have taken place causing gastroenteric infections for high amounts of people. For enhanced microbiological monitoring of the water hygiene, e.g. a Coliline PMEU version of the Portable Microbe Enrichment Unit has been developed (Hakalehto et al. 2011, 2013). See Fig. 7.5. It could also be



Fig. 7.5 PMEU Coliline™ unit is equipped with Automated Sample Collection System for online monitoring of clean water in water departments and in the distribution system. The unit can be connected directly to the water tubing (See also McCoy 2015). (Photograph by Jouni Pesola)

connected with centralized water quality monitoring processes and with automated sample collection systems of the water departments. Such installation is currently under construction at the water department of the city of Mikkeli, Finland, and it has been tested in several water companies (Hakalehto et al. 2011, 2015).

Also, the quality of the environmental waters could be affected by processing of the organic wastes. The microbiology of the lake water samples, for example, were studied by the PMEU method (Hakalehto and Heitto 2012; Hakalehto et al. 2014). The findings were applied to trace the sources of the wastewaters leading to disturbances of the microbiological balance (Heitto et al. 2006, 2009).

7.2 Role of Microbes in the Circulation

Most organic materials cycle in Nature. This takes place by solar energy, which is bound to the chemical bonds in biological matter.

Equally important with the collection of the exposed light energy is the return of the so formed organics back to the circulation by the actions of various soil microbes. They also facilitate the cycles of carbon in Nature (Hakalehto 2015a). This process relates to the degradation of biomass, which is a big issue for communities, industries and agriculture (Hakalehto et al. 2013; Thorin et al. 2013; Hakalehto 2015b). Such a microbiological process is at the heart of a biorefinery (Hakalehto 2015b). This concept was tested in the ABOWE project during 2012–14 in the Baltic Sea region countries.

7.2.1 *Historical Background and Outcome of the REMOWE and ABOWE Projects*

EU Baltic Sea Region Programme 2007–2013 project REMOWE (Regional Mobilizing of Sustainable Waste-to-Energy Production, 12/2009–12/2012) was established with a new partnership, involving a diverse group of organizations, all with interest to develop forward waste utilization. REMOWE aimed to contribute to a reduction of carbon dioxide emissions by catalyzing utilization of waste from cities, farming and industry for energy purposes (electricity, heat, fuels) in an efficient way in the Baltic Sea region. Project partners from Sweden, Finland, Poland, Lithuania, Estonia and Germany represented both far developed regions in the field as well as regions in which the level of energy utilization of waste was low at that time. For example, Germany's experiences of producing biogas were shared and transferred through the project to other regions (Mälardalen University 2016).

The REMOWE project described the current status of waste management, waste policies and waste-to-energy technologies in five countries. Further, a study of State-of-Art in Waste-to-Energy production was compiled (Thorin et al. 2011). A novel biorefinery concept, innovated by Adj. Prof. Elias Hakalehto as well as dry

digestion is identified in this report. In REMOWE, Ostfalia University of Applied Sciences under the leadership of Prof. Thorsten Ahrens performed biogas potential tests in laboratory on different wastes from the partner regions following the principle of wet digestion. Based on the results another principle (dry digestion) was reported as a potential future system for biogas production from household waste in partner regions. Moreover, within REMOWE, special regional innovation processes were conducted in five Baltic Sea Region countries to find new ideas for mobilizing waste-to-energy production. The novel biorefinery concept was evaluated to possess the highest innovativeness and sustainability among the ideas presented in Finland and Estonia; it also ranked high in Poland. The dry digestion technology was also ranked high in REMOWE evaluations (Löönik et al. 2012). A regional model was piloted in Finland by the University of Eastern Finland, efficiently calculating regional waste-to-energy potentials and related climatic and economic impacts based on regional data (Huopana et al. 2012).

The ABOWE project (Implementing Advanced Concepts for Biological Utilization of Waste, 12/2012–12/2014) was an extension stage of the REMOWE project within the Baltic Sea Region Programme 2007–2013. In ABOWE, these two technologies were piloted and tested in semi-industrial mobile pilot plants. These pilots are Pilot A Novel Biorefinery based on the concept from Adj. Prof. Elias Hakalehto, Finland (Fig. 7.6) and Pilot B (based on a German Dry Fermentation process). Pilot A was tested in Finland, Poland and Sweden and Pilot B was tested in Lithuania, Estonia and Sweden. Based on the testing periods, business models were drafted and introductory seminars were organized in each region. Also the feedstock potentials and climatic impacts of the new processes from the regions'



Fig. 7.6 Pilot A Novel Biorefinery arriving at its Polish testing site at ZGO Gać Ltd's waste management centre in Lower Silesia. Industrial levels of microbial metabolites, such as organic acids, alcohols and hydrogen, were obtained from the carboxylate wastes of food industries, as well as sorted biowaste. For a survey of the results, see den Boer et al. (2016a, b; Hakalehto et al. 2017a) or www.abowe.eu (Photograph by Mika Ruotsalainen)

perspective were evaluated with the regional model developed in REMOWE. The desired outcome from ABOWE was implementer- or investor-driven continuation projects targeting full scale plant investments of the two technologies (Savonia University of Applied Sciences 2016).

During the ABOWE project testing periods with the mobile novel biorefinery pilot plant, it was possible to give a proof of concept in Finland, Poland and Sweden with various biomass waste materials that Pilot A biorefinery could operate as an upstream biorefinery for all kinds of organic wastes. The products are biofuels, bioenergy, organic platform chemicals and organic fertilizers. These are to be produced in an economically feasible way, with the help of microorganisms. Pilot B (dry digestion), on the other hand, provided proof of concept in Lithuania, Estonia and Sweden (Freidank et al. 2014). The ABOWE piloting revealed the potential of total planning in biotechnical waste utilization and bioprocess design. For example, the Pilot A type of biorefinery's residues could be effectively utilized as raw materials in the Pilot B type of dry digestion biogas production unit. This was confirmed by the results from the Swedish test runs (Dahlquist 2016; Hakalehto et al. 2016a; Schwede et al. 2017). Depending on the type of the particular fractions, any solid fractions could then be used as organic fertilizer, composted or combusted. Gaseous emissions could be at least partially redirected into the biorefinery, which enable the recollection of their thermal and chemical energies. For example the carbon oxides and some volatile nitrogen compounds could then be bound into the biomass in the Pilot A type of biorefinery (Hakalehto et al. 2016b).

The ABOWE project was chosen as the winner among the projects of all Finnish universities of applied sciences in the series Soveltava tutkimustieto ja innovaatiot (Applied Research Knowledge and Innovations) in the national KÄRJET 2013 ("SPEARHEADS") competition (Savonia University of Applied Sciences 2016).

7.2.2 What Is Biorefinery Technology? – Theoretical and Practical Considerations

In a broader sense, every action that upgrades the technological or economic value of a biomass, could be considered as "biorefining". Moreover, any improvement in the environmental quality of a biomass waste or side stream could also be tagged as a biorefinery function. In today's world, even any activity that facilitates the circulation of carbon in the industries, biosphere or environment, belongs to that discipline.

On the basis of the considerations above, "biorefining" is actually an "umbrella" for all processes or activities, where carbon is recycled effectively in a useful way. The opposite of conceptual definition is a situation, in which carbon is naturally liberated or deliberately allowed to go, or disappear, or left unexploited.

Consequently, any combustion should be designated as a non-biorefinery. However, there are processes where the incineration gases are directed into a bioprocess for the microbes to assimilate it (Hakalehto and Ojala 2016). This very

principle of carbon assimilation was taken up in 1939 by famous Dutch microbiologist Kluver in his lecture in Helsinki (Kluver and van Niel 1956). A quotation of the book and the chapter by Prof. Kluver of “Evidence for Life’s Unity”:

The carbon dioxide consumption established in 1936 by Wood and Werkman in the fermentation of glycerol by a propionic acid bacterium offered a most striking example. Indications that this phenomenon would be of a much more general occurrence were present, but in a lecture read in 1939 in Helsinki I thought it safe to express myself on this subject in the following cautious terms: “For the moment a lecturer will still meet with energetic protest if he pronounces that the cattle in the pasture, or even his audience, assimilates carbon dioxide. And yet the temptation to make such a statement is already there.” In the next 2 years the introduction of either radioactive or stable carbon isotopes in metabolic studies irrefutably established that, indeed, in the cells of very diverse heterotrophic microbes, as well as in those of animals, the carbon dioxide molecule also lacked the high degree of biochemical invulnerability which had so long been attributed to it.

This situation above implies to the fact that microbes are an integral part of any biorefining function, and any circulation process whether it is a naturally occurring, or an industrial one. This relates to the ways, by which the microbes handle organic substances. In the agricultural fields these activities take place in soil. Therefore, the soil could be compared to a natural biorefinery. In both cases, the gaseous compounds play an important role in the circulation events (Hakalehto et al. 2017b).

7.2.3 *Special Features of the Circulation Phenomena*

In fact, soil is a poor environment, where the optimal nutrition, or functional nutrition for any microorganism is scarce. On the other hand, microbes manage to handle this “scattered ecosystem condition” almost as well as they can manage in the “enhanced ecosystem” of the intestinal tract of man or animals (Hakalehto 2012). This relates to their wide metabolic capabilities as a community.

Circulation would be most eloquent if the organic substances were used for plant or other photosynthetic organisms. Then the wastes would return to the food chains from the bottom level by the soil microbiota. However, a major portion of biowaste is refined directly to biofuels. Then the problem with the replacement of the food or feed use by the conversion into energy becomes an issue. The International Energy Agency states the following about the net energy balance of corn-to-ethanol process (IEA 2004).

There has been considerable discussion recently regarding the net energy gain from producing ethanol from grains. Some research has suggested that it may take more fossil energy to produce a litre of ethanol (i.e. to grow, harvest and transport the grain and convert it to ethanol) than the energy contained in the litre. This would suggest that conversion losses wipe out the benefit of the renewable energy (i.e. sunlight) used to grow the crops. The non-solar energy used in the different stages of the process is primarily natural gas and coal. Only about one-sixth of the fossil energy used to produce grain ethanol in the US is estimated to be petroleum.

On the basis of the considerations above, the most effective overall solution ecologically would be the return of organic residues to the fields, forests and greenhouses after their economically utilizable compounds have been recovered.

This collection and reuse should be accomplished according to the ecological principles. In soil, the focus has to be on the sustainability. There the microbiome essentially determines the elementary cycles in a healthy situation.

7.2.4 Biogas

Biogas contains 40–70% methane, 30–60% carbon dioxide and depending on the variety of the material used for the digestion (e.g. waste) also H₂S and NH₃ as well as traces of chlorine and fluorine can occur. It is produced using microorganisms that transform the raw material into methane and carbon dioxide in an anaerobic digestion process. In Nature methane is formed, e.g. in landfills, wetlands, animal intestines and bottom layers of surface waters. As raw material for biogas, e.g. bio-wastes, animal manure, waste water treatment sludges and plants can be used. Biogas offers a renewable traffic fuel option whose emissions are only 10% of those of gasoline and diesel (Kivimäki 2007; Ahrens 2007). Conventional utilization of biogas is heat and electricity production which improves energy self-sufficiency of farms, waste water treatment units, factories, etc.

In 2008 Gasrec Ltd., Veolia Environmental Services and Iveco began a commercial trial of a CBM (compressed biomethane) -powered street cleansing vehicle in Camden, UK. At the same time, Gasrec and The London Borough of Camden announced Gasrec's installation of London's first biogas fueling station at the Borough Council's York Way Depot to support the trial. The facility was capable of providing the trial Iveco Daily vehicle with fuel for its 60 mile per day route for an initial period of 6 months. Gasrec was supported in the project by their fuel logistics partner the Hardstaff Group and by technology consultant Igas.

This step allowed for more convenient refueling for the trial vehicle and highlighted the suitability of CBM for back-to-base operations. It also widened the scope of the trial to allow evaluation of a complete, scalable solution, and provided the opportunity for the Borough Council to fuel vehicles in its own fleet from the York Way Depot.

This step helped underscore the potential for further commercial fleets, both within additional London Boroughs and other key UK locations. The solution aimed to be beneficial both in terms of environment and costs. It is important for the UK to minimize the imports of vehicle fuel from abroad and this step aimed to pave the way for using fuel sources that are home grown and also carbon neutral, to the benefit of society as a whole. Camden Council aimed to fuel part of Camden Council's own fleet, helping to protect the environment and save money (Energy Tech 2008).

In 2015 the UK Government approved the Biogas Strategy and Action Plan. The objective is that biogas production will reach 20 TWh in 2020 and 40 TWh in 2030. The Chinese government's objective is to double the number of biogas plants in

China from over 40 million plants (year 2010) to over 80 million plants. Small household scale plants form the majority of this objective and the number of middle-sized farm scale plants or large industrial plants is 16,000 plants (Suomen Biokaasuyhdistys 2012).

7.2.5 Fuel Cell Cars

Nissan Motor Co. is developing a system that will power vehicles with electricity generated from bio-ethanol. The carmaker plans to introduce the powertrain for fleet sales by 2020. The ethanol-powered vehicle will have a driving range of more than 600 km, similar to gasoline-engine cars. Unlike conventional fuel-cell vehicles that use a special tank for hydrogen, Nissan's system will utilize liquid fuel and a conventional tank, and will generate hydrogen through reformation of pure ethanol or ethanol-blended water. It then uses a solid oxide fuel-cell system to generate power from hydrogen and air. According to Nissan its bio-ethanol fuels, including those derived from sugarcane and corn, are widely available in countries in Asia, North and South America, and the vehicles will have running costs that will be on par with electric vehicles (IndustryWeek 2016).

In March 2016, Honda began selling the 2017 Honda Clarity Fuel Cell in Japan. The Clarity Fuel Cell is Honda's latest offering regarding fuel cell vehicles (FCEV) and is the first car that houses its entire drivetrain system and fuel cell stack under the hood. Hence, it can offer a full five-seating system.

Hyundai has planned 1000 Tucson FCEV's to be produced by 2017, and after that the company will look towards mass production. Uncertainty, naturally, is the availability of refuelling stations in different countries.

The Hyundai Tucson FCEV has a 365 mile range, and comparable power to a gasoline engine. The model can achieve a top speed of 100 miles per hour and it takes 12.5 s to accelerate from zero to 62 mph.

Hyundai has contracts for municipal fleet leases in Sweden and Denmark, and after 2015, their goal is to produce 10,000 vehicles. The technology used is proprietary, with hydrogen converted in fuel cell stacks to electricity for the Lithium Polymer batteries that power the motors.

The company expects that world governments will continue further regulation of reduction in carbon output, and independence from fossil fuels (Hydrogen Cars Now 2016a).

The Toyota Mirai is the first production vehicle from Toyota to be powered by the hydrogen fuel cell. The Mirai was first officially revealed in 2014. "Mirai" means "future" in Japanese and expresses Toyota's belief of the future car engine technology. The Mirai was expected to sell for roughly \$57,500 in summer 2015 when it was first released in the US. The UK, Denmark and Germany were to start receiving the vehicles in September 2015 and other countries in 2017. Advances in fuel cell technology have greatly reduced the cost of the engine which is just 5% of the cost of the 2008 Toyota FCHV vehicle. The FCV also includes an electric motor

which is charged by the power of the fuel cell and acts in the support of the engine when in operation.

Toyota has plans to market the vehicle to the general public as soon as there are hydrogen refuelling stations available in the country. The vehicle was introduced in spring 2015 in Japan (Hydrogen Cars Now [2016b](#)). Biohydrogen could form a future source of traffic fuel.

7.2.6 Circulation of Agricultural Wastes

Microbiota orchestrate any network of reactions that process natural organic substances, their degradation and reuse in soil. Consequently, agricultural production in the long term is dependent on the functionality and “healthiness” of the soil microbial population. Its activity can be monitored in real-time by analysing the soil gas emission, (Fig. 7.7).

Corresponding to the plant kingdom where newly found varieties could constitute a novel basis for food and feed production, key microbial strains have the

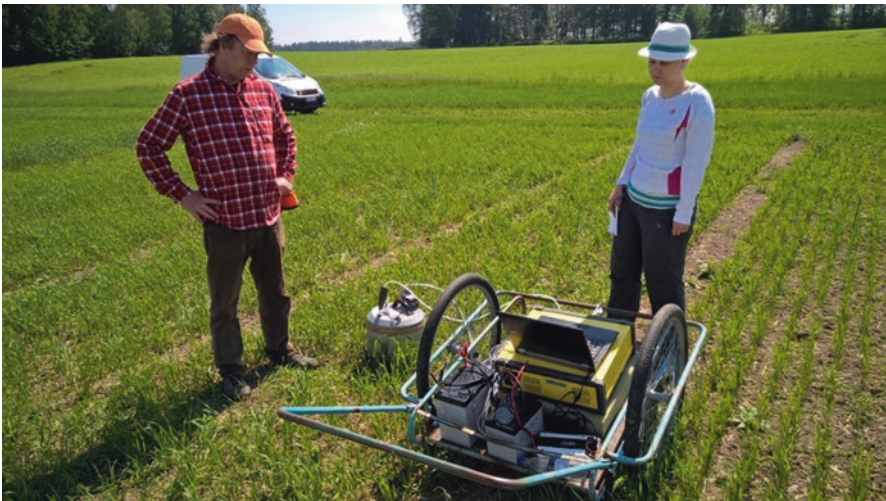
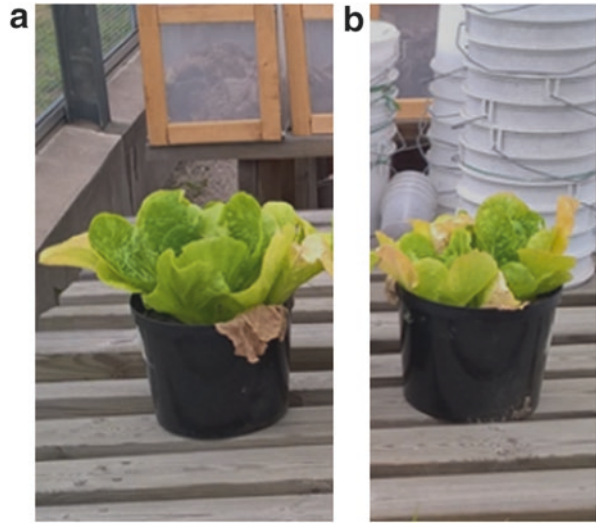


Fig. 7.7 Gas emissions by soil bacteria can be measured by an analyzer that recognizes around 50 of the volatile components. One measurement takes about 4 min. In the picture researchers from the University of Helsinki, Jukka Kivelä (*left*) and Sari Kinnula (*right*) screen the gaseous components emitted from a cereal field which has been fertilized with organic, fibrous substances. Those wastes or side streams derive from the food processing industries, and their effects in restoring the soil functions and microbiota as well as the potential in circulation can be studied by gas emissions. The CO₂ and other gases produced by various microorganisms in soil is then boosting their activity in a positive circle of effects (Hakalehto and Hänninen [2012](#)) (Photograph by Elias Hakalehto)

Fig. 7.8 Greenhouse testing of the microbiological supplementation Aurobion® of the Chinese cabbage by a patented process using *Clostridium pasteurianum* strain for boosting the plant growth (a). The control without “soil probiotics” on the right (b). For further explanation, see the text (Photographs by Elias Hakalehto)



potential for restructuring the soil microbiome (Hakalehto 2016). Such an example is the nitrogen fixing *Clostridium pasteurianum* which has significantly upgraded the crop of Chinese cabbage up to approximately 50%, (Fig. 7.8a, b)

7.2.7 Combined Incineration with Circulation Means

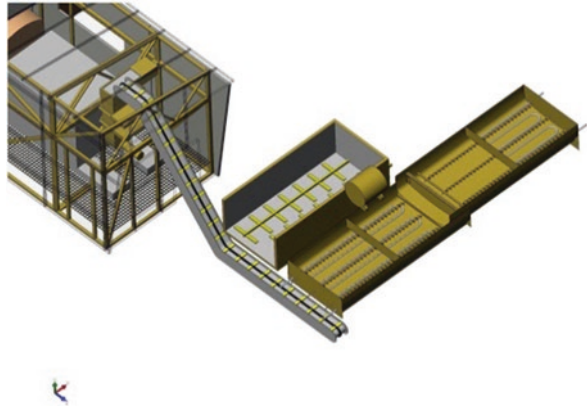
As a classic means for waste disposal and disintegration, controlled combustion has been always a major means for getting rid of unwanted materials.

However, their incineration has also sparked a lot of adverse environmental consequences throughout the ages. For a truly ecological combustion unit with circulation of solid, (Hakalehto and Ojala 2016) designed a unit with inner recirculation of energy, biomass and carbon. See Fig. 7.9.

7.3 Perspectives from the EU Down to National and Regional Level

The perspective towards waste has changed radically during the past decades. During the 1960s the focus was on landfill waste, during the 1980s on ravaging with mass incineration, whereas in the 2000s the focus turned to recycling, source separation, to waste priority order as well as to producer responsibility. Nowadays, the focus is in recycling economy, closed loop, from consuming to using as well as in new technologies and service models. Also, the focus is on sustainable and smart

Fig. 7.9 The integrated solution for circulating biomass substances and gas emissions in a combustion unit with a bioprocess treatment for improving the incineration or its alternative uses within one waste treatment plant (Hakalehto and Ojala 2016) (Drawing by Nordautomation Oy)



use of limited natural resources. The aim is to get upwards in the waste priority hierarchy (Hannula 2016)

7.3.1 *EU Waste Framework Directive*

EU Directive 2008/98/EC (Waste Framework Directive) sets the basic concepts and definitions related to waste management, such as definitions of waste, recycling and recovery. It explains when waste ceases to be waste and becomes a secondary raw material (so called end-of-waste criteria), and how to distinguish between waste and by-products. The Directive lays down some basic waste management principles: it requires that waste is managed without endangering human health and harming the environment, and in particular without risk to water, air, soil, plants or animals, without causing a nuisance through noise or odours, and without adversely affecting the countryside or places of special interest. Waste legislation and policy of the EU Member States shall apply a priority order in accordance with the waste management hierarchy (Fig. 7.10):

The Directive introduces the terms “polluter pays principle” and the “extended producer responsibility”. It incorporates provisions on hazardous waste and discarded oils, and includes two new recycling and recovery targets to be achieved by 2020:

- 50% preparedness for re-use and recycling of certain waste materials from households and other origins similar to households, and
- 70% preparedness for re-use, recycling and other recovery of construction and demolition waste.

The Directive requires that Member States adopt waste management plans and waste prevention programmes (European Commission 2016a).



Fig. 7.10 EU Waste management hierarchy (EU Commission 2016a). <http://ec.europa.eu/environment/waste/framework/>

An example re-use is a Finnish office furniture retailer Martela Plc that has a Waste Nothing -slogan to express that usable furniture does not belong in a landfill. In their outlets they sell high quality used and reconditioned office furniture in parallel with new ones (Martela 2016).

7.3.2 The EU Circular Economy Package

The European Commission adopted a Circular Economy Package in December, 2015. The package includes revised legislative proposals on waste to stimulate Europe’s transition towards a circular economy which will boost global competitiveness, foster sustainable economic growth and generate new jobs.

The Circular Economy Package contains an EU Action Plan for the Circular Economy with measures covering the whole cycle: from production and consumption to waste management and the market for secondary raw materials. Thus, it will contribute to “closing the loop” of product lifecycles.

The revised legislative proposals on waste set clear targets for reduction of waste and establish a long-term path for waste management and recycling. Key elements include:

- A common EU target for recycling 65% of municipal waste by 2030;
- A common EU target for recycling 75% of packaging waste by 2030;
- A binding landfill target to reduce landfill to maximum of 10% of municipal waste by 2030;
- A ban on landfilling of separately collected waste;
- Promotion of economic instruments to discourage landfilling;
- Simplified and improved definitions and harmonized calculation methods for recycling rates throughout the EU;

- Concrete measures to promote re-use and stimulate industrial symbiosis — turning one industry's by-product into another industry's raw material;
- Economic incentives for producers to put greener products on the market and support recovery and recycling schemes (e.g. for packaging, batteries, electric and electronic equipment, vehicles) (EU Commission 2016b).

The business potential based on resource efficiency and circular economy is huge, as e.g. in the US, up to 90% of raw materials used in production still end up as waste (McDonough and Braungart 2002).

7.3.3 Finnish National Waste Plan

Finnish National Waste Plan until 2022 is one example of implementing EU targets in a Member State. The plan will be implemented in 2017. In Finland, there are challenges with long distances and insufficient resources for official supervision. Moreover, research and experimental activity are desired. The National Waste Plan has set the targets and measures until 2022 and contains a plan for preventing waste generation. The Finnish Government has a target that circular economy will breakthrough. The objectives are:

- Waste management is part of Finnish circular economy,
- Valuable recycling material is also collected in small concentrations, such as E-waste,
- Hazardous substances are safely taken out from the cycle,
- High quality research and experimental activity is performed in the waste sector.

Priorities for objectives and measures are:

1. Construction and demolition waste, including wastes from earth construction,
2. Biodegradable waste and nutrient cycle, including sludges,
3. E-waste,
4. Municipal solid waste (Laaksonen 2016).

7.3.4 Ban for Landfilling of Organic Waste

As an example of one of the above mentioned sectors in waste management, a ban for landfilling of organic waste came in force from the beginning of 2016. Waste cannot be landfilled to a conventional waste landfill if the waste's total organic carbon (TOC) or loss on ignition (LOI) exceeds 10%. This is a very tough ban for the Finnish waste management industry and the first experiences are now being gained regarding coping with it.

This ban does not concern:

- Fly ash and bottom ash from energy production and waste incineration when solubility is low enough,
- Contaminated soil when placed apart from other wastes,
- Dead animals,
- Soda precipitates and deinking sludge,
- Gypsum based wastes and stable inert wastes.

Based on a query to environmental inspectors in Finland (Tukiainen 2016) the wastes that are problematic in terms of the ban are:

- Wastes from sand separation wells,
- Various special wastes from industry,
- Wastes from social and health care services such as tissues and cutting and sticking wastes,
- Wastes from fires,
- Screening wastes from wastewater treatment plants,
- Reinforced plastics and fibres (glass, carbon and aramide),
- PVC (polyvinylchloride),
- Part of construction wools,
- Roofing felt.

If waste has been pretreated and it has been reliably shown that there is no other treatment available, an exception has been possible to be permitted. This exception has been used in many cases (Tukiainen 2016).

7.3.5 A Municipalities' Joint Waste Management Authority

As an example of the organizing waste management authority's task, we used the municipalities' joint waste management authority of Savo-Pielisen jätelautakunta (Waste management board of Savo-Pielinen) that covers a wide area in the Eastern part of Finland and has been described by Pöntinen (2016). It has the same operations regime as the regional waste management company Jätekuikko Ltd., but has different tasks. The city of Kuopio is the largest of that region, and the board is part of Kuopio's administration. Taking care of authority duties, however, is independent from all the other responsibilities of the member municipalities. The costs are covered with waste fees. The tasks of the regional waste management board are:

- Gives binding waste management stipulations which implement the Waste Act in a way that takes into consideration local conditions. Stipulations are prepared in co-operation between municipalities, regional waste management company and environmental protection authorities. During preparation transportation entrepreneurs, citizens and other stakeholders were heard.
- Defines principles for waste transportation and waste fees.
- Monitors the implementation of waste legislation and stipulation.

- Launches own waste political programme.
- Approves the service level of waste management in the region in the form of which services are offered to citizens.

Connecting to the waste management system can be done in various ways (Pöntinen 2016):

- House-specificly,
- Jointly among nearby estates,
- Using regional collection point for single houses and semi-detached houses in suburban areas,
- Through centralized waste collection systems like tube collecting system,
- Through block-specific deep collection system.

7.4 Statistics of Waste Resources Globally and Examples from Finland

7.4.1 *Global Statistics of Waste Amounts*

Large amounts of energy and resources have been consumed following rapid economic growth, urbanization and the widespread improvement in living standards.

The United Nations' Environmental Programme UNEP (2015) compiled a Global Waste Management Outlook in 2015 and here we use some selected data from that piece of work. UNEP reports that providing a global overview of total waste generation with sufficient accuracy is almost impossible to achieve. Existing data generally refer to municipal solid waste (MSW). Wider data on waste from different points in the material and product life-cycle exist especially in OECD countries. Therefore, these pieces of data are used as a "proxy", showing the relative quantities of waste from different sources (Fig. 7.11). All data exclude agricultural and forestry and mining and quarrying wastes. An estimate of waste from a broad range of municipal, commercial and industrial sources is 3.8 billion tonnes per year (UNEP 2015).

In principle, it is possible to attempt the extrapolation from the OECD data in the figure above to estimate total worldwide waste generation. This kind of extrapolation is facilitated by the availability of waste data for Russia and China and some other non-OECD countries. Extrapolating from the database prepared for the GWMO to estimate 2010 worldwide MSW generation results in an estimate of around two billion tonnes per year. On the other hand, the World Bank (2012) reports that the global MSW amounts to 1.3 billion tonnes per year and is estimated to increase up to 2.2 billion tonnes by 2025. In any case, the global annual municipal solid waste amounts are huge and there lies enormous potential for utilization. It is also reported that MSW generation levels are expected to double by 2025. The higher the income level and rate of urbanization, the greater the amount of solid waste produced. OECD countries produce almost half of the world's waste, while Africa and South Asia regions produce the least waste (World Bank 2012).

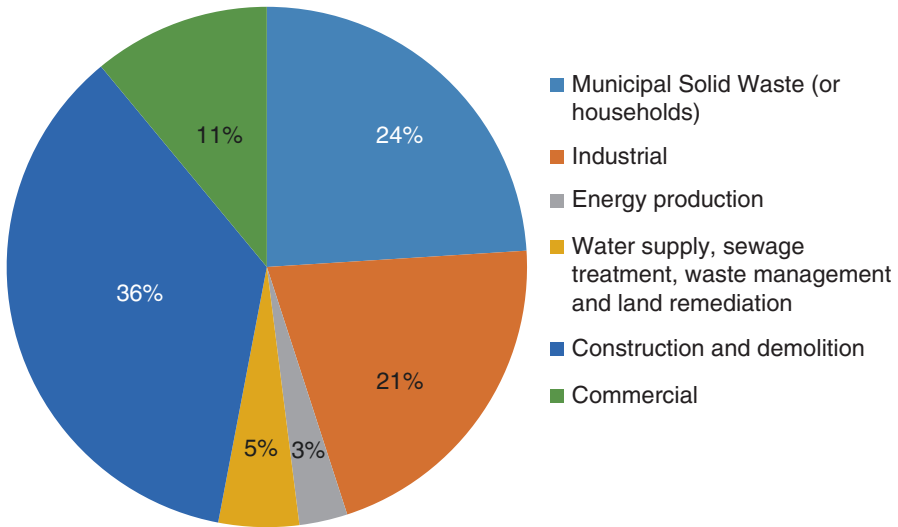


Fig. 7.11 Relative quantities of waste from different sources in the material and product life-cycle (Data from UNEP 2015)

For the other waste streams, extrapolation is even more challenging. Based on the available information, the best ‘order of magnitude’ estimate of total “urban” waste generation worldwide for the municipal, commercial and industrial wastes, including construction and demolition (C&D) waste comparable to the data indicated for the OECD in the figure is in the range of 7–10 billion tonnes per year (UNEP 2015).

Municipal Solid Waste generation rates vary widely within and between countries. The generation rates depend on income levels, socio-cultural patterns and climatic factors. UNEP (2015) has reported a strong positive correlation between waste per capita and income levels per capita. The median generation rates in high-income countries are about six-fold greater than in low-income countries. There can also be considerable variation within countries; in Brazil, for example, the amount ranged from 310 to 590 kg per capita per year in 2012 according to annual reports on Brazilian waste statistics.

Despite the high variability and low reliability of source data, UNEP (2015) reports some interesting patterns between average waste compositions in relation to the countries’ income level:

- A major difference is in organic fractions, which are significantly higher in middle- and low-income countries (averaging 46–53%) than in high-income countries (averaging 34%).
- The percentage of paper waste appears to be proportional to income levels, rising from 6% in low-income countries, through 11–19% in middle-income and 24% in high-income countries.

- Although plastic levels appear generally high, they do not show as much dependence on income level as might be expected, with the averages for all income categories ranging from 7–12%.
- Levels of other ‘dry recyclable’ materials, including metals, glass, and textiles, are all relatively low.
- MSW now increasingly contains relatively small amounts of hazardous substances.

Waste composition affects the physical characteristics of the waste, including density, moisture content and calorific value, which in turn affect waste management and the choice of technology for collection, treatment and the so called 3Rs: reduce, reuse, recycle. For example, the ash content of MSW in high-income countries has decreased over the last 50 years, while the content of paper, plastics and other packaging materials has increased, significantly reducing the bulk density and increasing the calorific value.

In Japan, for example, 48 million tons of MSW were generated in 2008, which represents a gradual decrease from the 55 million tons generated in 2000. This is a consequence of the adoption of the 3R strategy as well as stagnant economic growth (Takaoka et al. 2013).

Overall, waste generation per capita has risen markedly over the last 50 years. Due to the strong correlation with income level one can assume that, unless specific waste prevention measures are taken, per capita waste generation levels in the current low- and middle income countries will increase as their economies continue to develop and gross national income (GNI) levels rise.

Hoornweg et al. (2015) have projected MSW generation in different regions per capita forward to 2100. According to UNEP (2015) any projection beyond 2050 becomes extremely speculative. It should be interpreted rather as a scenario of what might happen under a particular set of assumptions, than a forecast. High income and OECD is projected to develop from c. 880 kg/person/year down to 730. Sub-Saharan Africa, on the other hand, is projected to develop from ~220 kg/person/year up to 510. There would still be a clear gap between these two, but dramatically less than nowadays. All the other country groups in the world are between these extreme figures and a rise is projected for all of them between 2010 and 2100 (Hoornweg et al. 2015).

7.4.2 *Municipal Solid Waste*

Municipal Solid Waste comes from households, commerce and public services. Industry as well as construction and demolition waste is not included in this definition. For example in Finland, MSW generated 2.3 M tonnes in 2014 which totalled 481 kg per capita per year. According to EU Circular Economy Package, 65% of MSW shall be recycled by 2030 and a maximum of 10% can be landfilled in 2030. This means a challenge for Finland as nowadays 33% is recycled, and on the other

hand, a lot of waste incineration capacity in Finland was invested recently. Since waste incineration plants were invested for municipal waste incineration a concern arose among the Finnish waste sector whether there is sufficient incineration capacity available for industrial wastes (UNEP 2015; Laaksonen 2016; EU Commission 2016b; Tukiainen 2016). However, keeping in mind the priority order, waste recycling would be more prioritized than energy recovery.

The Finnish Waste Plan proposed to prioritize source separation enhancement within commercial and public services sectors as well as in urban areas. Preparation for reuse and recycling are the focus in line with the EU priority order. For example packages should be recycled as packages and products as products. Producer responsibility systems are a key tool for this.

An example of waste bin stipulations in Savo-Pielinen area in Finland (Pöntinen 2016):

- Mixed waste bin must be at all estates and from this bin waste is directed to energy recovery. Inert wastes are not allowed in principle.
- Recyclable wastes. Most of these are packages which belong to the so called producer responsibility system. Regional waste management company may complement the collection of these.
- Bins for biowaste and cartonboard must be in estates with at least five apartments. Biowaste bin must also be present if it is generated over 50 liters per week.
- Bins for metal and glass must be in estates with at least 20 apartments.
- Plastic bin must be in estates with at least 40 apartments.
- Paper bin must be in every estate except one-family houses and estates in sparsely-populated areas.
- Energy waste (recovered fuel, REF) must not be collected separately.

Fractions that can be recycled must not be directed to incineration. Other wastes are collected to mixed waste and transported further to incineration.

Uniform and well functioning bin equipment enables efficiency, working safety and better service. Frequent enough emptying is addressed. In some cases emptying intervals are prolonged in order to encourage prevention and separation of waste and to cut unnecessary costs of customers. An example of waste bins in Barcelona is given in Fig. 7.12.

7.4.3 Example of a Producer Responsibility System

Suomen Pakkauskierrätys RINKI (Finnish Packaging Recycle Ring) is a non-profit service company owned by industry and commerce. The company takes care of cartonboard, metals, glass, wood and plastics. Industries and commerce which have annual turnover over 1 M € must belong to the company or they would need to organize about 2000 waste collection points themselves, so all industrial and commercial companies in Finland have joined the company. They have transferred their



Fig. 7.12 Waste bins in Barcelona, Spain (Photograph by Ari Jääskeläinen)

legislation-based responsibility to this producer responsibility community and there are 4200 companies as members. There is also a separate producer responsibility community for waste with deposit in Finland.

There are 1.8 M tonnes per year of packages produced in Finland from which 1.1 M tonnes (60%) are reused or recycled by the packaging industry itself. The amount of packaging waste is correspondingly 0.7 M tonnes, from which is directed to:

- Recycle 56%,
- Energy recovery 35%,
- Landfill 7%.

Term Producer Responsibility was invented in Sweden in 1997. In Denmark and Switzerland, for example, there is not a Producer Responsibility Law whereas in Norway the system is voluntary. In Finland, the producers take care of the reverse logistics system and waste management utilities provide the complementary services. Operations are financed with recycling fees. For example, the price of a milk pot contains a recycling fee of 0.5 cents (Koivunen 2016).

The Finnish Government Decree on packaging and packaging waste (2014) stipulates that the collection points must cover the whole country. Cartonboard, glass and metal have to be collected in each suburban area with at least 500 inhabitants. In sparsely populated areas the collection points must be available in line with trade centres, which make up a total of 420 collection points in sparsely populated areas. At least one plastic collection point must be available for a suburban area with over 10,000 inhabitants.

At the moment there are altogether 4400 collection points in Finland, having bins for:

- Fibre in 1850 points,
- Glass in 1850 points,
- Metal in 1850 points,
- Plastics in 500 points and
- Clothes in 2200 points.

In Finland, there are altogether six contractors in collection of producer responsibility waste in RINKI which means that the logistics is very efficient. Various sized bins are scaled to shops with various sizes and they are compatible with the refuse lorries. Intelligent collection equipment enables the functioning logistics. For example, bins send automatic notifications about filling rates (Koivunen 2016).

7.4.4 Metals

Metals are traditionally popular materials to recycle as they maintain their properties much better than many other materials and have economic value in replacing natural resources' consumption. Recycling rates depend both

- On the degree of mixing and
- On the concentration of the target material or element.

In a study of 60 metals (UNEP 2011, see Fig. 7.13), one third have recycling rates greater than 50%. These include aluminium, titanium, chromium, manganese, iron, cobalt, nickel, copper, zinc, rhodium, palladium, silver, platinum and gold. These all are either needed in high concentrations and/or possess a high value. They are very crucial raw materials in nowadays' life.

More than half of the metals have recycling rates of less than 1%. Many of these, such as indium and gallium, are regarded as 'critical materials' or are rare earth metals including lanthanum, cerium, praseodymium, neodymium, gadolinium and dysprosium. These metals are all used in a wide range of electronic products including screens, chips, speakers and microphones as well as in magnets. The concentrations are often very low and the degree of mixing with other elements is very high. These make it very challenging to recycle these critical metals. A major challenge moving forward is to ensure that design for environment (DfE), including dismantling and recyclability is prioritized in these industrial sectors (UNEP 2011).

The periodic table is used above to show 60 metals' global average end-of-life recycling in which the physical and chemical properties that made the material desirable are retained for new use.

Unfilled boxes indicate no data or estimates available or the element was not addressed in the study.

The dynamics of the metal industry is described here with aluminium which is the most used and the fastest growing of the non-ferrous metals. In 2000, China produced 12% of the global aluminium (2.9 million tonnes). By 2011 this rose to 43% (19.4 million tonnes) at the same time that global total grew as much as 80%.

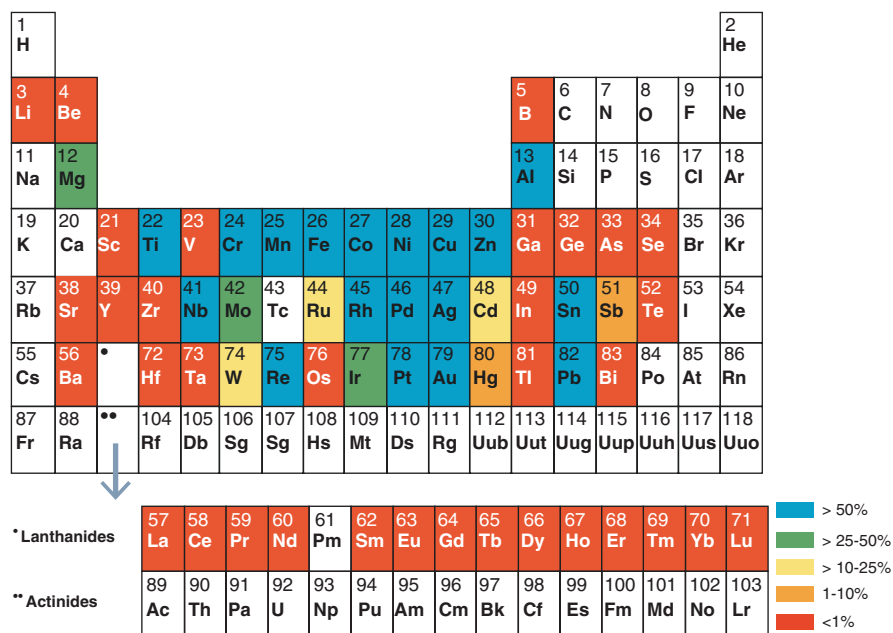


Fig. 7.13 End of life recycling rates for 60 metals (Source: UNEP (2011). Recycling Rates of Metals: A Status Report. http://www.unep.org/resourcepanel/Portals/24102/PDFs/Metals_Recycling_Rates_110412-1.pdf)

During the same period, demand for aluminium scrap increased by 7.4 million tonnes per year. From this increase, China accounts for 85% (6.3 million tonnes). Supply from scrap has not increased at the same pace with the increase in aluminium production. The ratio of scrap used in aluminium production decreased over the period from 31 to 29% (UNEP 2011).

7.4.5 Plastics

Plastics are also very actively used waste material. Global production of plastics increased from 1.5 million tonnes in 1950 to 204 million tonnes in 2002 and 299 million tonnes in 2013. There is a continuing shift of production from the West to Asia, the latter representing more than 40% by weight of world production in 2013. The annual volume of transnationally traded waste plastics (15 million tonnes) represents 5% by weight of new plastics production. There is huge potential to increase the reverse logistics of plastics. Plastic scrap flows from Western countries with established recycling collection systems mainly to China, which receives around 56% weight of global imports. Europe (EU-27) exports almost half of the plastics collected for recycling and 87% of this is directed to China (UNEP 2015).

In Finland, the recycling rate of plastics was 23% in 2013. In the EU Recycling Economy Package the objective for plastics recycling is 55% by 2025 so a major step forward is needed (Laaksonen 2016).

7.4.6 Paper

In Finland, there are long traditions for collecting paper waste. After the Second World War it was common for young boys to earn some money by going round and collecting used newspapers from houses and delivering them to paper waste buyers. Since then, Finland has had a high rate of paper waste recycling.

The total world production of paper and paperboard in 2012 was around 400 million tonnes; 45% was in Asia, 26% in Europe and 21% in North America. Recycled paper and paperboard (known in the industry as ‘recovered paper’ or ‘recovered cellulose fibre’) has always been a major raw material for the paper industry. The proportion of recovered paper of the total pulp used in the European paper industry rose from 40% in 1990 to 53% in 2013. This is a major development as at the same time total production in Europe rose by around 50%. Two hundred and thirty million tonnes of recovered paper was collected and consumed globally in 2012 (UNEP 2015).

7.4.7 Food Waste/Biowaste

According to 2013 estimates of FAO (Food and Agriculture Organization of the United Nations), approximately 1.3 billion tonnes of edible food per year is lost or wasted. This represents one third of all the food produced for human consumption. This amount of food would be sufficient to provide nutrition for more than 2 billion people, which is more than double the undernourished persons in the world, according to the official FAO estimate (UNEP 2015).

Moreover, the production of this lost food has caused both resource use and environmental impacts for climate, land, water and biodiversity in producing this food. The global greenhouse gas (GHG) emissions, for example, related to food waste were estimated at 3.3 G tonnes of CO₂ equivalent in 2007. The financial loss of food waste in terms of producer prices is as much as USD 750 billion. If we counted in terms of supply chain and market values, the sum would be far greater. The further along the supply chain the loss occurs, the worse its environmental impact, and the financial losses, as more handling and resource input is needed. (UNEP 2015)

These losses occur at different places along the supply chain and the places and the reasons vary a lot between developing countries and developed countries (Table 7.1).

Preventing this wasting would naturally have a great positive effect globally on food security. Food waste could be utilized in various ways:

Table 7.1 Food loss comparison between developing countries and developed countries

	Place along supply chain	Reasons
Developing countries	Almost 80% of the losses in farm and in transportation and processing	The unavailability of selling outlets or inadequate packaging and storage
Developed countries	Almost 80% of the losses in retail, catering and at home	Various reasons including extremely stringent cosmetic standards for fruit and vegetables, relatively low prices for consumers, strict adherence to 'use by' and 'best before' dates despite inadequate understanding of the meaning of such labelling, lack of knowledge on food safety and 'use by' dates set earlier than necessary due to fear of litigation

Data from UNEP (2015)

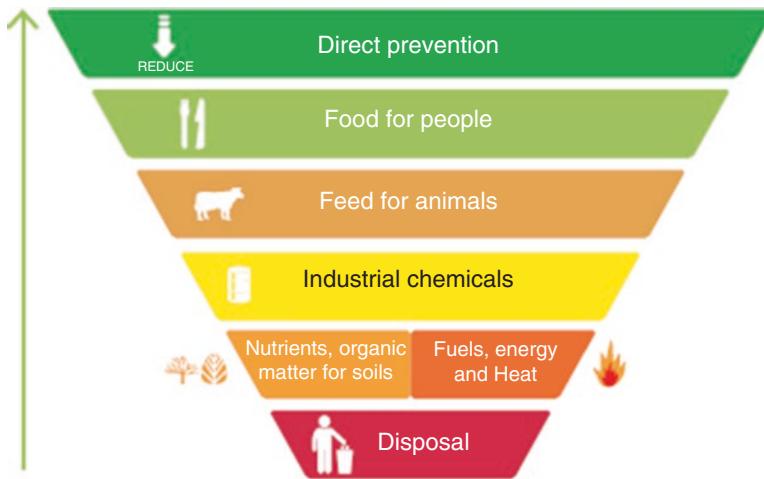


Fig. 7.14 Food waste hierarchy (UNEP 2015)

- Directly,
- Through redistribution to those in need,
- Via conversion to feed for animals,
- Via conversion to industrial chemicals,
- Via conversion to fertilizer or organic matter,
- Via conversion to fuels and energy.

Figure 7.14 illustrates the hierarchy of measures regarding food waste. The following presents a couple of examples regarding food waste abatement.

Food banks were established all around the world, contributing to food and nutrition security by connecting prospective food waste and people in need. One example is the food bank in Belo Horizonte, Brazil who has been a pioneer in urban governance on food security since 1993. The City Food Bank was established in 2003 with the target to prevent food waste while providing healthy food to those in need. Food is collected from partners including street vegetable markets, green groceries and supermarkets, and then goes through a rigorous process of selection, processing, and storage, with sanitary norms strictly observed. The processed food is distributed to over 100 institutions of City Food Bank register, including day-care centres, homes for the elderly, orphanages and shelters, about 15,000 people receive the help (Rocha and Lessa 2009).

In France, 20–30 kilos of food waste is generated per capita per year, totalling circa 1.3–2 M tonnes per year. The value of thrown away food has been estimated as 12–20 billion euros. In spring 2016, the Parliament voted unanimously on a law which bans supermarkets from wasting groceries that were not sold. Instead, they must take action to decrease food waste. Supermarkets must give unsold but edible groceries to charity, animal feed or for composting. Large supermarkets must make a contract with charity organizations about giving groceries to those in need. The French Government wishes to be able to halve the amount of food waste by 2025 (Guardian 2016).

Silvennoinen et al. (2012) studied the Finnish food chain and found the food loss along the supply chain to be as presented in Fig. 7.15.

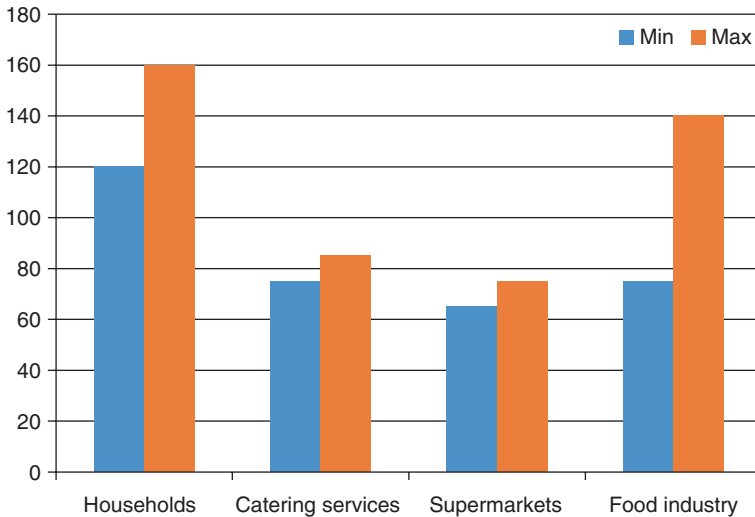


Fig. 7.15 Preventable food waste in the food chain. The total amount is 355,000–460,000 tonnes per annum or 62–86 kilos per capita (Data from Silvennoinen et al. 2012)

In Finland, thanks to the packages, only 2% of food spoils before it reaches the consumers. For example, in Africa this number is over 10% or even tens of percents (Pöntinen 2016).

In the EU separate collection of biowaste will be increased and encouraged. Biowaste will be directed to anaerobic digestion or other treatment systems that promote circular economy. In Finland, the municipal biowastes were treated by (2014):

- Composting 43%,
- Anaerobic digestion 17%,
- Landfill or combustion 40% (Laaksonen 2016).

7.4.8 Example of a Campaign to Enhance Biowaste Separate Collection

In 2003, regional waste management company Jätekuikko Ltd. started to deliver biobags for the year's need. The effect was 10 kg per inhabitant from 37 kg per annum to 47 kg per annum. The delivery is still carried out annually, totalling two million biobags per annum. Baskets for collecting biowaste were also delivered.

Based on separation research the composition of mixed waste is such that there is 30% biowaste which totals 12,000 t per annum. In comparison, from the same region 8000 t biowaste is separately collected annually.

Separation has to be easy and the inhabitant must experience that it is useful. Jätekuikko held a campaign for men below 35 years. Easiness and meaning were selected as focuses. It was illustrated that 2 kg biowastes give 140 h light with a 7 W energy saving lamp.

An advertisement was directly mailed to 40,000 households, in addition web site, social media and regional television were used. The reach of people between 15 and 34 years was 97% (72,000 persons).

Jätekuikko Ltd. tried two different ways to deliver biobags for citizens. One trial was to introduce a rack inside of the waste bin shelter to which the waste lorry driver changes biobag rolls in conjunction with emptying the biowaste bin. The other trial was that citizens could fetch the biobags from supermarket with a special card. For the first trial 92% of respondents used these biobags. The rest of the respondents viewed this as not important or had no room or functionality in their apartment for biowaste separation. Seventy three percent viewed the trial as a functioning one. However, Jätekuikko Ltd. concluded that this is not a recommendable option due to hygienic and other practical reasons. In the second option supermarkets were satisfied.

Regarding the potential for the biowaste yield, Jätekuikko Ltd. estimated that 1.8 kg/person/week would be possible. In practise the yield has been about 0.4 kg/person/week. The campaign that Jätekuikko Ltd. launched in 2015 did not affect to the yield, which shows that it is slow to affect attitudes. Biowaste is regarded as inconvenient so it is crucial to improve the cleanness of the collecting equipment. Jätekuikko Ltd. has also marketed options of joint biowaste bins for single houses, which has increased the amount of these by 24% but still the absolute number is

very low. This would give discounts in a basic annual waste fee as well as in mixed waste emptying fees as the interval gets longer. On the other hand, many single houses have their own composting equipment (Maunula 2016).

7.4.9 *E-waste*

Waste electrical and electronic equipment (WEEE), known as ‘e-waste’, comes from a large variety of electronic products, large equipment (washing machines, air-conditioners, freezers etc.) and small equipment (hairdryers, electric toothbrushes, vacuum cleaners etc.). As a consequence from increased consumer demand, perceived obsolescence, short life cycles of many products, rapid changes in technology and inventions of new electronic devices, WEEE grows fastest among the world waste streams. Many products have not been designed with recycling in mind (Baldé et al. 2015).

According to the estimate of the United Nations University, 41.8 million tonnes (Mt) of e-waste was generated in 2014, a 25% increase from 2010. Waste generation was spread across continents as follows: Asia (16 Mt), Europe (11.6 Mt), North America (7.9 Mt), Latin America and Caribbean (3.8 Mt), Africa (1.9 Mt) and Oceania (0.6 Mt). Europe’s per capita e-waste generation is the highest (15.6 kg/person) and Africa’s the lowest (1.7 kg/person). Annual generation is estimated to increase up to 50 Mt in 2018 (Baldé et al. 2015). Surely the amount will further increase from that.

In Finland, it is estimated that there is 0.9% e-waste in household mixed waste (Helsinki Region Environmental Services Authority 2012). In the service sector Helsinki Region Environmental Services Authority has estimated the corresponding amounts:

- Supermarkets 0.1%,
- Schools 0.3%,
- Restaurants 0.3%,
- Hospitals 1.9%,
- Offices 0.2% (Helsinki Region Environmental Services Authority 2012).

Therefore, attention should be paid specially in source separation of e-waste in hospitals.

The objective is to prolong the life span of electric devices via better reparability. How can repair and lending culture be made more attractive by means of administration? One option would be to introduce lower value added tax for repairing electric devices (Laaksonen 2016). One of the writers witnessed a situation in which a truck load of computer screens in unopened selling packages were directed to a plant in which e-waste is dismantled for recycling of various metals and other components, such that these products were never used anywhere. The reason might be that the products in question were too old to market as high tech, but surely another solution could have been found to get these products in use via charities, etc.

7.4.10 Textile Waste

In the UK, textile waste is a major problem. Every year an estimated *£140 million worth* (around 350,000 tonnes) of used clothing goes to landfill. The Waste and Resources Action Programme (WRAP) is a registered UK Charity and among other activities it leads the Sustainable Clothing Action Plan (SCAP) with the ambition to improve the sustainability of clothing across its lifecycle. The action plan brings together industry, government and the third sector and works across the clothing lifecycle, identifying improvement actions to most reduce the environmental impact, and has agreed to the SCAP 2020 targets (WRAP 2016).

In Finland, textile waste amounts to 54,700 tonnes per year (Laaksonen 2016). On the contrary, in 2015 the Finnish Red Cross sent from its logistics centre over 161 t clothes to Mongolia, Kirgisia, Ukraine, Tadjikistan and Kazakhstan, and in Finland clothes were delivered to over 10,000 asylum seekers in the Red Cross reception centers. There would be huge potential to increase recycling clothes as products for these uses (Finnish Red Cross 2016).

7.4.11 Mixed Waste

Mixed waste is a term widely used in Finland. Typically municipal and commercial wastes, after source separation of recyclables and biowaste, are mixtures of plastics, metals, glass, biodegradable waste including paper and textiles along with other nondescript wastes. Mixed waste was generated in Finland 1.35 M tonnes in 2014. The composition of mixed waste is:

- Plastics 19%,
- Cartonboard and cardboard 10%,
- Textiles and shoes 6%,
- Metal 3%,
- Glass 2%,
- Wood 1%,
- Mixed 15% (Jätelaitosyhdistys 2016).

So in fact, only $0.15 \times 1.4 \text{ M tonnes} = 210,000$ tonnes is truly mixed waste annually. There is clearly room to improve the source separation of recyclables.

According to the Finnish National Waste Plan there should be less than 10% biowaste in the mixed waste. Biowaste lowers the heating value of the mixed waste. On the other hand nutrients will not return to nutrient cycle if biowaste is incinerated. There is nowadays 36% (493,000 tonnes per year) biowaste in the mixed waste. This has been 90 kilos per capita per annum. The objective would be 17.9 kg. According to a regional waste management company Puhas Ltd. from the eastern part of Finland there is even 49% biowaste in the mixed waste during winter time. On the contrary, there is an obligatory separate biowaste collection or composting

in the central part of Finland. That is also the best region in Finland with only 19% biowaste in mixed waste. Still, there is also some room for improvement reflecting the objective (Laaksonen 2016).

7.4.12 Construction and Demolition Waste

Construction and demolition (C&D) waste is generated during the construction, renovation or demolition of buildings, roads, bridges and so on. These activities typically generate large quantities of waste, although often data on C&D waste are not collected as part of the activity or in a consistent way, so most published estimates need to be carefully interpreted. Eight hundred and twenty one million tonnes of C&D waste was estimated to be generated across the EU in 2012, 77 million tonnes in Japan, 33 million tonnes in China and 17 million tonnes in India (all in 2010). From the total waste generated, C&D waste often represents the largest portion. For example, of the all urban waste generated in OECD countries C&D waste represents 34%. The volume of C&D waste is also sharply increasing in line with the trend of infrastructure development all around the world (UNEP 2015).

C&D waste contains a high proportion of inert materials (e.g. concrete, masonry, asphalt), and also wood waste, metal, glass, gypsum and plastics as well as hazardous substances such as treated wood, lead paint and asbestos. Due to the variety of materials, it would be important that the C&D waste is segregated at source, with each stream managed as required. In practice, there is usually a shortage of room at construction sites for containers for different types of wastes. Some waste management companies offer C&D waste separation at their waste management sites as a service for construction companies (UNEP 2015).

Waste management controls were first introduced in the 1970s and at that time the illegal dumping of C&D waste was widespread. In many developing economies illegal dumping is still a problem, or even epidemic, like it is in India for instance (Centre for Science and Environment 2014). The management of C&D waste is a critical part of sound waste management since illegal dumps can be like ‘magnets,’ increasing probability of municipal solid waste or even hazardous waste being dumped, exposing serious health and environment risks (UNEP 2015).

The primary motivation in the construction industry for increasing reuse and recycling is cost control, as these practices will reduce costs through reduced disposal costs, decreased purchasing costs for new materials, and increased revenue earned from the sale of materials (UNEP 2015). Also, working safety is enhanced when the construction site is in order in terms of wastes.

Countries recycle C&D waste with an enormous range. A ‘best estimation’ of the EU average was given for 2008–2009 as 30–60%, with EU countries reporting recycling and recovery rates over 90% on the one end and 10% on the other end (European Commission 2016c).

EU has set an objective of 70% recycling rate by 2020; whereas, nowadays the recycling rate in Finland is 26%. Construction of new buildings yields 16%,

renovation 57% and demolition 27% (Statistics Finland 2016). The trend in new building construction is that the waste amount decreases in relation to the built square meters. Nowadays, the total waste amount from a new building in Finland is 22 kilos per square meter. From this:

- Wood 27–30%,
- Mineral waste 14–26% (concrete and bricks),
- Mixed waste 40–51%.

Overall, over 2 M tonnes C&D waste is generated annually without loose soil; 40% of this is wood and 31% stone and concrete.

Unfortunately, there is no obligation to report C&D waste streams in Finland so the monitoring authority in the location does not receive information about these streams. Part of the stream goes through waste management centres which are monitored and which report the waste amounts they receive. However, it is not known how large proportion goes through them. There has to be a transfer document in place in connection to the batches of C&D waste. For example, it is not allowed to introduce concrete to forest roads. The question is whether companies are ready to pay for C&D waste treatment or not (Koponen 2016).

According to Finnish Waste Law the following C&D fractions must be recycled:

- Concrete, bricks, tiles etc. mineral waste,
- Gypsum containing waste,
- Wood waste (without impregnation),
- Metal,
- Glass,
- Plastics,
- Paper and cartonboard.

Many of them are appropriate to be separated in collection equipment in case there are larger amounts. There would be need for separation instructions for various phases of the construction work as the composition of waste varies a lot regarding the construction phase.

Examples of C&D waste utilization from Finland:

- Roofing felt for asphalt raw material,
- Demolition windows for heat insulation such as foam glass,
- Clean wood and impregnated wood are utilized in energy production,
- Pallets for repair with an automatic, robotized production and inspection line,
- Wood plastic composite production being tested,
- Demolition concrete may be used in earth construction such as roads, storage fields and courtyard construction as well as the same locations as contaminated soil.

Mixed C&D waste can be separated in a waste management plant with a digger as a rough pre-separation for removing metals to recycle. Mechanical separations involve crushing, sieving, wind separators, air classifiers and removal of metals. In Finland, mixed C&D waste is separated in waste management centres. At best 85–90% of C&D waste is obtained for recycling and energy recovery.

A modern option is near infra red (NIR) separation units which use NIR spectrum for separating desired fractions out from the waste stream, such as wood, cardboard, paper and mineral material. NIR cannot separate plastics, and thus another technology is needed.

For construction components their trading occurs through a web-based market place and eco-markets are used, too, but transportation of large items might be a problem. Used building components such as doors have currently poor demand and low price in Finland (Koponen 2016; Hannula 2016).

Tukeva work training foundation's Ekoraksa 2 project (Eco construction site 2) provides help for work-intensive demolition. Persons that are long-term unemployed and in a weak situation regarding the labour market are employed in collection and separation of excess materials from construction, detachment and separation of materials from buildings that will be demolished, renovating construction materials and supplies for reuse as well as for selling recycled supplies. An objective is to create permanent jobs to various phases of recycling of construction materials and supplies as well as to direct these persons to vocational education or open labour markets (Tukeva 2016).

7.5 Conclusion

Human societies and their economic structures consist of overlapping networks, which resemble the food-chains and the interactions of various biological organisms in Nature. Seeing the substrate flow as an ecosystem could essentially help us in tracking the movements of biomasses and other disposed side streams. The goal should be to avoid accumulation of biowastes, or any biodegradable wastes and the replacement of landfills, emissions and leakages by a pattern of reuse and circulation. This effort needs understanding of the microbiological dimensions and microbiomes, since they form the powerhouse of recirculation.

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